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THESIS

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TOPIC: ASSESSMENT OF INTEGRATED WATER RESOURCES MANAGEMENT PRACTICE IN YATTA CANAL, MACHAKOS DISTRICT, KENYA.

By

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CONFIRMATION

This is to confirm that this thesis was initiated and compiled by myself as original work and that it has not been submitted to any other university for examination.

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Abstract

Yatta Canal is situated in Yatta division, Machakos district about 100 km from Nairobi along Thika- Garissa road. It is about 60 Km long and supplies water for domestic, livestock and irrigation use. The water supply is unreliable especially during dry season and this has been the cause of conflicts between upstream and downstream consumers. Sometimes the Government is forced to intervene to restore order. This study aimed at assessing the use of Yatta canal, based on the principles of Integrated Water Resources Management(IWRM) which stipulates efficient use of water and involvement of all stakeholders in decision making for sustainability.

Based on this concept, it was established that the current water demand outstrips supply and that there is inefficient water use especially for irrigation. Water allocation process favours landowners and stakeholders are not fully involved in planning, management and development. Further, women's participation in decision-making is minimal. There is no environmental voice during water allocation and thus the reserve/ base flow in the canal has not been maintained. This means that IWRM concept has not been practiced and this has resulted to conflict among various water users.

As Yatta canal gets water from Thika river, there is need to establish Thika river basin water users association where stakeholders can influence decisions on water allocation and management. This will create a forum to discuss efficient water use at all levels and promote internal policing to ensure fair allocation, thus minimizing conflicts and promoting the IWRM concept.

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ABBREVIATIONS

AFC	-	Agricultural Finance Corporation
ALDEV	-	African Land Development Board
ASCE	-	American Society of Civil Engineers
AWSB	-	Athi Water Services Board
BOD_5	-	5 day Biochemical Oxygen Demand
BTC	-	Belgian Technical Cooperation
Cap-Net	-	International Network for Capacity building in IWRM
CBOs	-	Community Based Organizations
CBS	-	Central Bureau of Statistics
COD	-	Chemical Oxygen Demand
DAEO	-	Divisional Agricultural Extension Officer
DCSS	-	Department of Culture and Social Services
DFEO	-	Divisional Forest Extension Officer
DWD	-	Director of Water Development
EMCA	-	Environmental Management and Coordination Act
ERSWEC	-	Economic Recovery Strategy for Wealth and Employment Creation
FA	-	Forest Act
FAO	-	Food and Agriculture Organisation
GOK	-	Government of Kenya
GTT	-	Government of Trinidad and Tobago
GWP	-	Global Water Partnership
Ha	-	Hectares
ICRAF	-	International Centre of Agroforestry
IWMI	-	International Water Management Institute
IWRM	-	Integrated Water Resources Management

JICA	-	Japanese International Cooperation Agency
KMD	-	Kenya Meteorological Department
Kshs	-	Kenya shillings
KWAL	-	Kenya Wine Agencies Ltd
l/d	-	Litres per day
lts	-	Litres
m^3	-	Cubic metres
MAAW	-	Ministry of agriculture, Animal husbandry and Water Resources
MCM	-	Million Cubic Metre
MENR	-	Ministry of Environment and Natural Resources
MLS	-	Ministry of Lands and Settlement
mm	-	Milimetres
MOA	-	Ministry of Agriculture
MOLFD	-	Ministry of Livestock and Fisheries Developent
MPND	-	Ministry of Planning and National Development
MTC	-	Matuu Town Council
MTEF	-	Medium Term Expenditure Framework
MWD	-	Ministry of Water Development
MWI	-	Ministry of Water and Irrigation
MWR	-	Ministry of Water resources
MWRMD	-	Ministry of Water Resources Management and Development
MWSO	-	Matuu Water Supply Office
NCA	-	Noelink Consulting associates
NDP	-	National Development Plan 2002-2008
NEMA	-	National Environment Management Authority
NGOs	-	Non Governmental Organizations
NIR	-	Net Irrigation Requirement
NPEP	-	National Poverty Eradication Plan 1999-2015
NWP	-	National Water Policy (on Water Resources Management and Development)
NWRMS	-	First National Water Resources Management Strategy

NWSS	-	National Water Services Strategy
NYS	-	National Youth Service
O&M	-	Operation and Maintenance
RE	-	Resident Engineer
RGS	-	River Gauging Station
SACCO	-	Savings and Credit Cooperative Society
SDC	-	Strategic Design Consultants
SIDA	-	Swedish International Development Agency
SPSS	-	Statistical Program for Social Science
TAC	-	Technical Advisory Committee
TEC	-	Technical Committee
UFW	-	Unaccounted for water
UN	-	United Nations
UNCED	-	United Nations Commission on Environment and Development
US	-	United States
WA	-	Water Act 2002
WA&A	-	Wara and Associates Advocates
WB	-	World Bank
WCD	-	World Commission on Dams
WHO	-	World Health Organization
WRMA	-	Water Resources Management Authority
WRUA	-	Water Resources Users Association
WSB	-	Water Service Board
WSP		Water Service Provider
WSRB	-	Water Services Regulatory Board
WSRS	-	Water Sector Reform Secretariat
YCFU	-	Yatta Canal Field Unit
YCWA	-	Yatta Canal Water Association
YCWUA	-	Yatta Canal Water Users Association

1. INTRODUCTION

Yatta Canal is situated in Yatta division, Machakos district about 100 km from Nairobi along Thika – Garissa road. Its source of water is Thika river and it drains into Mwita Syano river in Kitui District. The canal is within Tana River Basin (MWD, 1989).

1.1 Historical Background

Mr. F. J. Jordan who was a farmer in Thika District suggested construction of the canal in 1936. Later the Department of Agriculture carried out soil survey and established there were some 4,000 acres that were favourable for irrigation in Yatta area (MAAW, 1962). Excavation of the canal began from the proposed intake in December 1953 using the Mau Mau detainees (MWD, 1984). Work progressed on well until December 1957 when the detainee camp was closed as a result of reduced number of detainees because of their rehabilitation and repatriation.

African Land Development Board (ALDEV), which was the authority in charge of construction of the canal, decided to continue constructing the canal using paid labour and machinery. Main excavations were completed in August 1958. The canal works costed Kshs 6,499,680 (£324,982) and was officially opened on 18th September 1959 (MAAW, 1962). Figure 1.1 is a map of Kenya showing location of Yatta canal within Machakos district.

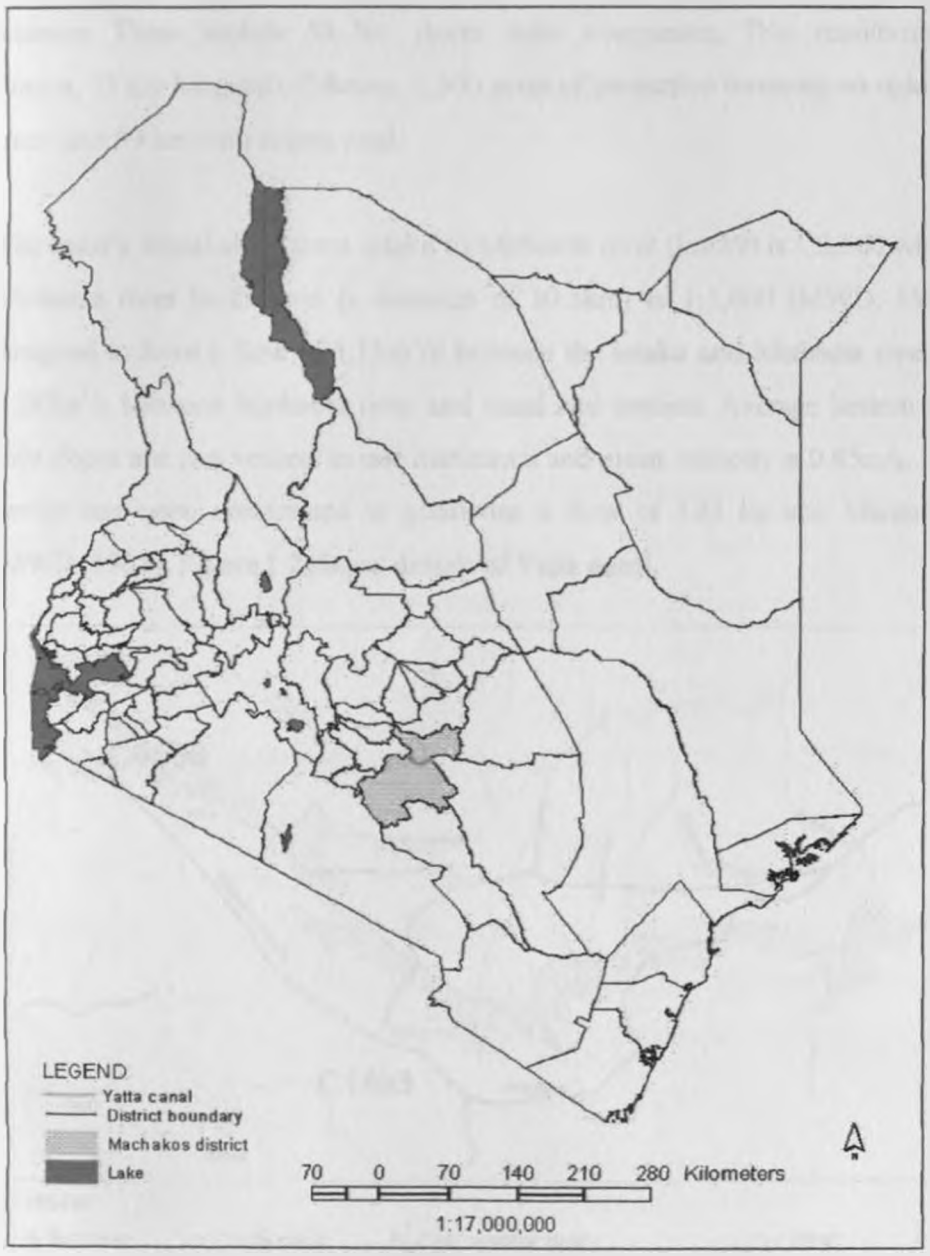

Figure1.1: Map of Kenya showing location of Yatta Canal in Machakos District

1.2 Canal Technical Data

The canal is unlined except for the first 80m up to the washout gate and another 130 m at Mathauta river Bifurcation point. Its length is divided into sections of one kilometer each and named by these distances (the intake is termed kilometer zero- Km 0, canal length at kilometer ten is termed Km 10 while the canal end is termed Km 60) (MWD, 1984). It

has auxiliary structures that ensure continuous flow and protect it from excessive siltation. These include 53 No. storm water overpasses, 7No. road/bridges, 27 No. flumes, 53 km long cut off drains, 1,300 acres of protective terracing on uphill side of the canal and 59 km long access road.

The canal's initial slope from intake to Mathauta river (km49) is 1:2,500 while that from Mathauta river to the end (a distance of 10.5km) is 1:1,000 (MWD, 1989). It was designed to have a flow of 1.13m^3/s between the intake and Mathauta river section and 0.283m^3/s between Mathauta river and canal end section. Average bottom width is 2m, side slopes are two vertical to one horizontal and mean velocity is 0.45m/s. A controlling device has been constructed to guarantee a flow of 143 l/s into Mwita Syano river (MWD, 1984). Figure 1.2 shows details of Yatta canal.

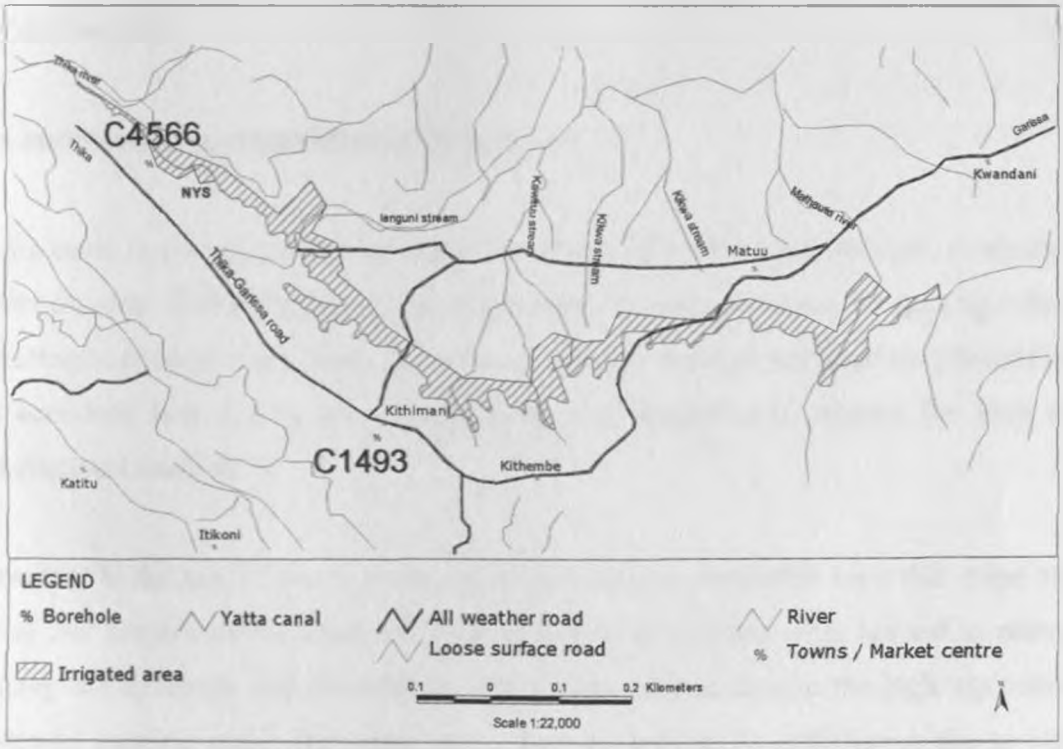

Figure 1.2: Details of Yatta Canal

The canal is used to supply water for domestic, irrigation and livestock use (MWD, 1984). It is the main source of livelihood for inhabitants and those along Mwitasyano river. Because of its multipurpose use and growing demand of water, there is need to use water efficiently to maximize on the benefits. Efficient water use requires that good

water governance is practiced by having unbiased water allocations, stakeholders effectively involved in decision making process and management decentralized to the lowest level possible for sustainability. Issues like water rights, quality, use, environmental flows, natural resources use in the catchment/river basin have to be discussed transparently and agreed upon. This concept is based on integrated water resources management (IWRM).

1.3 Major Constraints in the Canal

Over the years, there has been reduced water flow in the canal especially during dry seasons. This has forced the farmers to move upstream of the canal intake to restrict water abstractions by irrigators along Thika River. Sometimes the flow has been so low that the Director of Water Development (DWD) is forced to impose total ban on irrigation. Matuu town (whose source of water is the canal) has gone without water for several months.

1.4 Justification and Significance of the Study

Yatta canal is the only source of water for Matuu, Kithimani and Ndalani locations of Yatta division. Before the canal was constructed, the area was used for grazing with no meaningful economic activities. Since its completion, the area has been transformed into an economic hub due to commercial farming of horticultural produce for local and international markets.

However in the last 15 years, water supply has become unreliable such that crops have dried and sometimes the canal has dried in the lower reaches. This has led to mistrust among the upstream and downstream water users. Hence despite the high agricultural potential existing within the supply area, there is threat to its exploitation due to water scarcity. The solution to these problems can be addressed by efficient use of water and involving stakeholders in decision-making process-this is the IWRM practice.

1.5 Purpose of the Study

The study aimed at assessing the level of water use efficiency and the supply deficit. It also established the level of stakeholder participation in the management of water resources among the users. This is in line with the principles of IWRM.

1.6 Objectives of the Study

There are four objectives of the study:

i) Establish the current practices of water resources use and their effectiveness along the canal

ii) Determine the level of stakeholder participation and awareness in water resources management along the canal

iii) Identify the integrated water resources management approaches suitable for effective and efficient water use along the canal including supply to Matuu town.

iv) Establish whether or not the water source is adequate to meet the ultimate demand.

1.7 Limitations and Assumptions

Due to financial constraints, the study was limited to a corridor of about 1 Km on either side of the canal though the population size stretches to 20 km in some areas. It however covered Matuu town. It was also assumed that the period of research between December 2005 and April 2006 represented the actual situation during the normal canal flow periods.

2. LITERATURE REVIEW

2.1 Integrated Water Resources Management Concept

2.1.1 Definition

Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and other resources, inorder to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystem (GWP, 2000). IWRM means all the different uses of water are interdependent and involves participatory decision-making process such that different user groups can influence strategies on water resources planning, development and management (Cap-Net, 2002).

IWRM discourages sectoral approach to water resources issues as is currently practiced in most countries (UNCED, 1992). It is no longer possible to consider energy, tourism, irrigation, water supply and sanitation, navigation etc, independently when planning for their development as each will affect the other and might bring conflicts threatening the project's sustainability. Fora for discussing proposed projects have to be created by the governments while strategies for reviewing existing projects have to be developed in order to allocate water resources in a sustainable manner.

2.1.2. Background

2.1.2.1 Water Resources Availability

Of the water resources in the world, 97 percent is sea water and 3 per cent freshwater. 87 per cent of the fresh water is not accessible (hence only 13 percent is accessible i.e. 0.4 per cent of total water)(Cap Net,2002).

World Commission on Water estimates that water use will increase by 50 per cent in the next 30 years. An estimated 4 billion people -one half of the world's population – will live under conditions of severe water stress in 2025, with conditions particularly severe in Africa, the Middle East and South Asia (WB, 2004). 263 river basins are shared by two or more nations (Cap Net, 2002). The world population has increased by a factor of about three during the 20th century whereas water withdrawals have increased by a factor of

about seven. The increase in population and economic growth together with improved standards of living has led to increase in competition for and conflicts of limited freshwater resources. Water resources catchment areas have been highly degraded due to human settlements and activities. The increasing water demand against decreasing freshwater availability requires that water is used efficiently and that there is fair allocation amongst various uses. This can be achieved by practicing IWRM concept as it advocates for involvement of all stakeholders in management of water resources, thus efficient water use (GWP, 2000).

2.1.2.2 Water Resources Management and Quality

In most countries, water issues are handled at sectoral level; planning of a hydropower project does not consider the effect of changed stream flow regime downstream to ecosystem and other consumers, planning for a dam construction for an urban water supply far away does not consider sharing benefits with other stakeholders, design of an irrigation scheme with potential to pollute the river from the return flows containing pesticides/fertilizers does not take into consideration those downstream. IWRM promotes integrated approach to planning, development and management as it ensures all water uses are considered during allocation to maximize on the benefits accruing from the project (GWP, 2000).

In international waters, there has been conflict among riparian countries on water use. As Al Kags (2005) states: 'In 1980, Egypt threatened war with Ethiopia after the latter opposed attempts by the former to divert Nile river water to Sinai desert'. Such conflict can be solved by openly discussing about water use among stakeholders and agreeing on the allocation criteria as advocated for in IWRM approach.

Freshwater resources are limited but their quality is threatened by increased point and non-point pollution sources. Due to increased industrialization and poor or no wastewater treatment, water quality has continued to degrade, reducing freshwater available, creating a potential source of conflict and thus negating IWRM practice (Cap Net, 2002).

2.1.3 Principles of Integrated Water Resources Management.

The decreasing freshwater availability combined with increased demand and biased allocations with disregard to environmental issues require a vibrant water resources management for sustainable development.

Realizing the need to have an integrated approach to water resources management, the United Nations organized an international conference on water and environment, which was held on January 1992 in Dublin, Ireland. The meeting came up with four principles which aim to promote changes in concepts and practices considered fundamental to improved water resources management. The principles have received universal support amongst the international community as the guiding principles under-pinning IWRM (GWP, 2000).

The four principles are:

I **Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.**

The principle recognizes that water is a finite and vulnerable resource since the hydrological cycle on average yields a fixed quantity of water per time period which can not be altered significantly by human actions (GWP, 2000). Water resources management therefore requires holistic approach to achieve its optimal utilization as there is need to recognize all characteristics of the hydrological cycle and its interaction with other natural responses and ecosystems. Holistic approach also involves coordination between the range of human activities that create demand for water, determine land uses and generate water-borne waste products. It also recognizes that water is required for many different purposes and therefore involves demand placed on the resource and the threats to it.

II **Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.**

Water is a subject on which everyone is a stakeholder (GWP, 2000). It is therefore necessary to raise awareness about importance of water planning, supply, management and use among policy – makers, opinion leaders and the general public. Participation

requires that stakeholders at all levels of the social structure have an impact on decisions at different levels of water management. It involves taking responsibility, recognizing the effect of sectoral actions on other water uses and allowing the sustainable development of the resource (Cap Net, 2002). Raising water issues to national level has been a big challenge to most developing countries.

Participation will not always achieve consensus, but arbitration process or other conflict resolution mechanisms will also need to be put in place. Governments have a responsibility for making participation possible especially for women, the poor and marginalized members of the society (GWP, 2000). This does not only involve awareness raising, confidence building and education, but also provision of the economic resources needed to facilitate participation and establishment of good transparent sources of information.

III **Women play a central part in the provision, management and safeguarding of water.**

Women have continued to be responsible for provision of water at household level. In some communities, there exists a culture that ignores or impedes women's participation in water management (GWP, 2000).

Women play a key role in the collection and safeguarding of water for domestic and agricultural use but have a much less influential role than men in management, problem analysis and decision making process (UNCED, 1992). Though there exists social and cultural circumstances that vary between societies, there is need to explore different mechanisms for increasing women's access to decision-making and widening the spectrum of activities through which women can participate in IWRM. Consideration has to be given to the way different societies assign particular social, economic and cultural roles to men and women (Cap-Net, 2002).

There is need to ensure that the water sector as a whole is gender aware, a process which should begin by implementation of training programmes for water professionals and community or grassroots' mobilizers (GWP,2000).

IV **Water has an economic value in all its competing uses and should be recognized as an economic good.**

Water has an economic value as well as being a social good. Everybody has a basic right to access potable water and sanitation at an affordable price. Past failures in water resources management are due to the fact that water has been viewed as a free good, or at least that full value of water has not been recognized (Cap-Net, 2002). In a situation of competition for scarce water resources such a notion may lead to water being allocated low value uses and provides no incentives to treat water as a limited asset.

Water use should be paid for (GWP, 2000). Charging for water is applying an economic instrument to effect behaviour change towards conservation and efficient water usage, provide incentives for demand management, ensure cost recovery and signal consumers' willingness to pay for additional investment in water services.

Though it is necessary to have full cost recovery of water uses, there is need to subsidize the cost so that water becomes affordable to those who can not meet the full cost and give incentives to those practicing good water use management. It is the best practice to have targeted subsidies that consists of adequate taxation or general revenue collection system, mechanisms to identify the target groups and the capacity to monitor and follow up on utilization.

These principles have assisted in implementing IWRM. Over time, research has led to improving on IWRM practices and most of the countries are in the process of implementing them. For the IWRM to be successful, it has to get full support from top policy makers who can easily implement it though it is also good to have advocacy from civil society and communities to force policy makers to accept the change. It will be noted that there has been a lot of resistance from policy makers and water managers to change to IWRM because of fear of loosing power and professionalism.

Countries have adopted different strategies to implement IWRM practice. In most cases the practice is adopted to solve an economic crisis due to unsustainable water use. For example, Yemen's move towards IWRM was part of a series of economic reforms designed to bring the country's economy back from the brink of collapse. In the first half

of the 1990's, Yemen was suffering from high unemployment, inflation and budget deficits. Severe groundwater mining for irrigation in many basins was costing the country an estimated US$ 0.5 billion per year.

An IWRM approach helped policy makers address the groundwater problem by reducing subsidies on diesel fuel and eliminating subsidies on pumping equipment. This strategy transferred water out of agriculture- that uses 85-90 % of the water but contributes only 15% to Gross Domestic Product- to higher value uses(GWP, 2004).

In northern France when cities and industries found their water supply endangered by rapidly dropping water tables due to over abstraction of groundwater, they proposed supply- side solutions- either building a dam on a river 30 miles away and piping water in, or building a desalination plant. The cost was equivalent to US$ 1billion for the French taxpayer. But policy makers chose a demand- side solution instead: they imposed a small tax on each cubic meter of water pumped from the aquifer. Confronted with this tax, industry operators and cities found that they could after all reduce their water consumption, and as a result groundwater use in the area is now sustainable (GWP, 2004).

2.2 Water Resources Situation in Kenya

Kenya has a territorial area of 582,646 Km^2, which consists of 11,230 Km^2 water area and 571,416 Km^2 land area. Of the land area, more than 85% is classified as arid and semi-arid lands (ASAL). The medium to high potential land (less than 15% of land area) which is approximately 81,000Km^2 sustains more than 75% of the nation's population and contributes a substantial portion of Gross Domestic Product (GDP) (NWRMS, 2003).

2.2.1 Challenges facing Water Resources Management

Kenya faces a complex water resources crisis because of having an extremely limited per capita endowment of freshwater resources and high hydrological variability. The country receives a renewable supply of freshwater of less than 650 m^3 per capita, making it be among the water scarce countries in the world (WB, 2003). A country is categorized as

water scarce if its renewable freshwater supplies are less than 1000 m^3 per capita and water stressed if its renewable supplies are less than 1,700 m^3 per capita. By 2025, Kenya is projected to have a renewable fresh water supply of 235 m^3 per capita. In comparison, Uganda and Tanzania have renewable freshwater supplies of 2,940 and 2,696 m^3 per capita respectively (NWRMS, 2003).

The country experiences wide variations in climate spatially and temporaly. Most parts of the country receive two rainy seasons: March to April (long rains) and October to November (short rains). The spatial variability of annual rainfall is considerable, varying from 200mm in the ASAL area to 1800mm in the western region. While the average annual rainfall in the country is 630mm (NWRMS, 2003), about 66 percent of the country receives less than 500mm of rainfall annually (WB, 2003). Droughts are frequent and have become endemic in some parts of the country. The ASAL areas, the poorest regions in the country, are the areas most affected by droughts. During 1998-2000 la nina, the drought damage was estimated at Kshs.191.9 billion ($2.5 billion)(WB, 2003). Areas of Kano plains in Nyanza Province, Budalang'i in Western Province and the lower reaches of the Tana River are susceptible to floods. In ASAL areas flash floods are experienced when it rains (NWRMS, 2004). During El Nino rains, flood damage was estimated at Kshs.70.1 billion ($ 950 million)

The country's water resources have been mismanaged through unsustainable water and land use policies, laws and institutions, and weak water allocation practices, increasing pollution and degradation of rivers, lakes, wetlands and aquifers and their catchments. The solution to unsustainable use is by promoting IWRM practice, as decisions on water use and allocation are based on participatory and integrated approach (WB, 2003).

2.2.2 Water Resources Coverage and Abstraction

According to the National Water Master Plan 1992, the average annual renewal water resources available is 20.3 billion cubic meters (BCM) of which 19.691 BCM is from surface water while 0.61 BCM is from ground water. The main source of surface water is the five water towers namely Mt. Elgon, Mt. Kenya, Mau Complex, Aberdares and Cherangani Hills (NWRMS, 2004). This water is distributed in five drainage areas of

Lake Victoria, Rift Valley, Athi River, Tana River and Ewaso Ng'iro North. The country also shares some surface and ground water resources with neighbouring countries. It lies along the Nile river basin and supports the Nile Basin Initiative.

The potential safe abstraction volume of the ground water is estimated at 610.5 x $10^6 m^3/yr$ consisting of 184.5 x $10^6 m^3/yr$ by boreholes and 426 x $10^6 m^3/yr$ by shallow wells. In 1998 the volume of groundwater abstracted was estimated to be 57.2 x 10^6 m^3/yr, which is 9% of the potential. Groundwater constitutes a large development potential as a source of drinking water in ASAL areas (NWRMS, 2003). The national surface water abstraction volume in 1998 was estimated at 1.0x 10^8 M^3/year. This is about 5.4% of the potential volume reflecting quite a low level of water development. Table 2.1 gives the analysis of each basin's annual water abstraction as at 1998.

Table 2.1: Average annual water availability and abstraction by basin in Kenya in million cubic metres per year (MCM/yr).

NO.	Source	Volume (MCM/yr)	% Water Abstracted
1.	Lake Victoria Basin	11,672	2.2
2.	Rift Valley basin	2,784	1.7
3.	Athi River Basin	1,152	11.6
4.	Tana River basin	3,744	15.9
5.	Ewaso Ng'iro North Basin	339	12.4
6.	Ground Water	600	9.1
	Total	20,291	5.4

Source: The After Care Study on the National Water Master Plan, July 1998

2.2.3 National Development Priorities

IWRM requires change of business as usual approach to water resources management and support is needed from policy makers for it to succeed. The current National Development Plan 2002-2008 recognizes that some of the country's major development challenges are fighting poverty and inadequate infrastructure. Water fights poverty by reducing water borne disease prevalence, agriculture and industrial development and ecosystem sustenance.

To stimulate development and management of water supplies and sanitation, the government is committed to preserve and conserve available water resources and its allocation in a sustainable, rational and economical way due to its uneven distribution, which is essentially IWRM practice (NDP, 2002).

Thus the government realized the need for sustainable management of water resources and environmental protection. The top policy makers are therefore sensitized on the need to have efficient management of water resources, a process embraced by implementation of IWRM. The challenge is to ensure they support it.

During the Participatory Poverty Assessment (PPA) of 1995, poverty and lack of water were often linked together. When respondents were asked to define who a poor person is, some said it is someone lacking access to water (NPEP, 1999). It is appreciated that Kenyans identified a strong link between poverty and lack of access to improved water supply and sanitation and that adequate quantity and quality of water is a basic requirement for Kenya's economic growth. Therefore the people appreciate that water is necessary for economic development, thus policies aimed at improving water availability can be easily supported. IWRM promotes fair allocation among water users and uses for sustainability and poverty reduction, and hence support economic development.

2.2.4 Integrated Water Resources Management Process in Kenya

Kenya embarked on legal and institutional IWRM reforms after the international conference on water and environment in 1992 at Dublin, Ireland. These reforms are aimed at improving service delivery and ensuring sustainable water resources management, and are based on IWRM concept. The rolling out of reforms to stakeholders at grassroots level is in the formative stage.

However water sector reforms in Kenya started in 1974 and have been going on since then. Reforms in mid 1970's to early 1980's aimed at centralizing planning, development and management of water resources but the Ministry of Water Development later realized this was not sustainable. From mid 1980's onwards the reforms are aimed at

decentralizing development and management of water resources by empowering stakeholders for sustainability, and thus supporting IWRM concept. The following is the chronological water sector reforms in the country.

2.2.5 Water Sector Reforms in Kenya

2.2.5.1 Background

After independence, the Government realized that provision of water was going to be a major factor in promoting development in all sectors of economy. To achieve this, a fully fledged Ministry of Water Development was established in 1974 whose mandate was to develop water supplies. People joined hands in the spirit of pulling together and initiated a number of self-help water projects. Most of these projects were designed and implemented without due consideration of water resources potential and were based on sectoral approach.

An ambitious strategy was adopted by the Ministry of taking over the water supplies formerly managed by County Councils and local communities with the objective of managing them more efficiently (NWP, 1999). This resulted in destroying the local initiative and increasing the ministry's financial burden for operation and maintenance.

The Ministry could not cope with the demand of the sector and in 1976 and 1981, it initiated nation-wide studies (funded by SIDA) aimed at identifying how the sector can be financed and managed sustainably. The National Water Master Plan carried out between 1990 and 1992 funded by JICA later updated these studies. The studies identified major constraints in the sector as; institutional weaknesses, inadequate funding, poor sector coordination, limited water resource availability, poor choice of technology, lack of interlinkages with other related sectors (NWP, 1999).

Faced with low water and sanitation service level due to dilapidated infrastructure, inadequate financial resources, uncoordinated sector development and mismanaged water resources, resulting from highly centralized management system, the country initiated reforms in the water sector immediately after the international conference of United Nations Commission on Environment and Development (UNCED) in 1992.

2.2.5.2 National Policy on Water Resources Management and Development

Policy preparation started in 1992 and was completed in 1999 after being passed by parliament on 29th April 1999 as Sessional Paper No. 1 of 1999. It came up with four objectives to be addressed in order to improve the performance of the sector in the country. These are:

- Preserve, conserve and protect available water resources and allocate it in a sustainable, rational and economical way.
- Supply water of good quality and in sufficient quantities to meet various water needs, including poverty alleviation, while ensuring safe disposal of wastewater and environmental protection.
- Establish an efficient and effective institutional framework to achieve a systematic development and management of the water sector.
- Develop a sound and sustainable financing system for effective water resources management, water supply and sanitation development.

In order to achieve these objectives, the Water Act Cap 372 was repealed after stakeholder consultation and was passed by parliament in 2002 as Water Act 2002. The Act is based on the principles of IWRM in that it has proposed separation of water resources management and water services and sewerage functions for effective management. It has also proposed decentralization of water resources management and involvement of stakeholders in decision-making. The Ministry in charge of water affairs will be responsible for financing, policy direction and sector coordination. New institutions created by the Act include the Water Services Regulatory Board (WSRB), which is the regulator of water and sanitation sub-sector, while the Water Service Boards (WSBs) will be incharge of development and management of water and sewerage services. WSBs will contract provision of services to Water Service Providers (WSPs) like companies, NGOs or CBOs. WSB will only be allowed to provide services direct where there is no suitable WSP (WA, 2002).

Water Resources Management Authority (WRMA) will regulate, manage, develop and monitor water resources management sub-sector. It will establish regional offices and appoint Catchment Area Advisory Committees (CAAC) to advise officers of the Authority at regional offices on water resources conservation, use, apportionment and

permit management. Inorder to assist in conflict resolution and enhance co-operation in management of water resources at catchment level, the authority will encourage and facilitate establishment of Water Resources Users Associations (WRUAs) (WA, 2002). The new institutions in the water Act 2002 and their responsibilities are shown in table 2.2.

Table 2.2: Responsibilities of Water Act 2002 institutions

Institution	Core responsibilities
Water Resources Management Authority	Implementation of policies and strategies relating to management of water resources Development of catchment level management strategies, including appointment of Catchment Area Advisory Committees and their facilitation.
Water Services Regulatory Board	Overseeing the implementation of policies and strategies relating to provision of water services. Regulating the provision of water supply and sanitation services. Licensing Water Service Boards and approving their appointed Water Service Providers. Monitoring the performance of Water Service Boards and Water Service Providers.
Water Service Boards	Planning for improvement in provision of water supply and sanitation services. Appointment and contracting Water Service Providers. Asset holder of central government facilities.
Water Services Trust Fund (WSTF)	Assist in financing of provision of water supplies in areas that are inadequately provided for.
Water Appeals Board (WAB)	Adjudicating disputes within the sector.

Source: WSRS, 2004

2.2.3.3Water Services and Sanitation Sub sector

Inorder to roll out the responsibilities to the new institutions, a roadmap was prepared by the Ministry of Water and Irrigation (MWI). The roadmap shows that the new institutions were to be fully operational by 30th June 2006. By now the MWI has established WSRB and WSBs. The Board of Directors and Chief Executive Officers (CEOs) for these institutions have been appointed and some skeleton staff deployed to them from MWI. The WSPs are being contracted to provide water services in the agreed supply areas. The country has been divided into seven WSBs as shown in table 2.3.

2.2.3.4 Water Resources Management Sub sector

WRMA was established through gazette notice No. 8140 of 14th November 2003 (Rural Focus Ltd. et al. 2005). Todate the Authority has established six regional offices and nineteen sub regional offices as shown in table 2.4. The regional managers and CAACs have been appointed and some skeleton staff has been deployed from MWI. The Authority has started operating in the regions and sub regions and it is expected that the MWI will prepare a road map for transfer plan of management and operation of water resources management to the Authority.

Table 2.3: Gazetted WSBs

Name of WSB	No. of Districts	Area Km^2	1999 Population
Coast	7	82,816	2,487,000
Nairobi (Athi)	6	40,130	5,617,000
Central (Tana)	13	52,777	5,032,000
Rift Valley	8	113,771	2,999,000
Northern	9	244,864	1,703,000
Lake Victoria North	11	16,977	5,135,000
Lake Victoria South	16	20,340	5,730,000
Total	70	571,675	28,7.3,000

Source: WSRS, 2004

Table 2.4: WRMA Regions

Region	Regional Headquarters	Sub Regional Headquarters
Lake Victoria North	Kakamega	Kitale, Eldoret
Lake Victoria South	Kisumu	Kisii, Kericho
Rift Valley	Nakuru	Narok, Naivasha, Kabarnet, Lodwar
Athi	Machakos	Kilifi, Kibwezi, Kiambu
Tana	Embu	Kitui, Murang'a, Meru, Garissa
Ewaso Nyiro	Nanyuki	Nyahururu, Rumuruti, Marsabit Wajir

Source: Rural Focus Ltd et al, 2005

In conclusion, it can be seen that the country has made progress in implementing IWRM especially on legal and institutional reforms. More effort is needed especially in

involving stakeholders (by strengthening WRUA) and intersectoral coordination. The rate of implemetion of IWRM can be improved by communicating effectively the gains made so far, for example, the enhanced efficiency in management of water supply and sewerage services due to appointment of autonomous companies as WSPs in Nairobi, Eldoret, Nyeri and Nakuru towns.

3. RESEARCH METHODOLOGY

The research aimed at assessing water use efficiency along Yatta canal and Matuu water supply. It involved assessment of water use, quantity, quality and rights, stakeholder awareness and their involvement in decision-making, reliability of the water supply, management and problems associated with water use, and recommendations made thereof.

3.1 Data Collection

The overall objective of assessing IWRM is to establish whether water is used efficiently and stakeholders are involved in planning, development and management for sustainability inorder to achieve socio- economic development. To achieve this, data was collected in the following areas:

i) Climatic and general information of study area
ii) Current condition of Yatta canal and Matuu water supply
iii) Socio-economic issues
iv) Hydrological data for river gauging station (RGS) No.4CC3 situated at Yatta canal intake
v) Human and livestock population
vi) Types of crops grown and irrigation methods used
vii) Water use
viii) Water management practices
ix) Water quality
x) Water demand management
xi) Integrated approach to water resources planning and development
xii) Coordination among water and related sectors
xiii)Participatory approach to planning, development and management of water resources and types of stakeholders
xiv) Water conflict management
xv) Capacity building

3.1.1 Data Collection Instruments

Data was collected through discussion with key stakeholders, compiling of past record of monthly rainfall, evaporation rate and canal mean monthly flow from RGS 4CC3, observation in the study area, laboratory tests of water samples and use of semi-structured questionnaire. Other climatic data like mean daily temperature was obtained from past records.

3.1.1.1 Discussions with Key Stakeholders

Stakeholders like Ministry of Agriculture (MOA), Ministry of Lands and Settlement (MLS), Ministry of Environment and Natural Resources (MENR), Ministry of Health (MOH), Yatta Canal Water Users Association (YCWUA), Matuu Town Council (MTC), Ministry of Livestock and Fisheries Development (MOLFD), Ministry of Planning and National Development (MPND), and MWI, were interviewed to obtain baseline information. Views on water and related sector coordination, advocacy for efficient water use and participation in decision-making at Yatta canal and Matuu water supply were sought.

3.1.1.2 Observation in the study area

This included assessing water use practice, irrigation methods, outflow drainage from the farms, current condition of canal and water supply infrastructure, water use in feeder streams, flood water draining at Matuu town and other sources of water within the study area (like boreholes and pans).

3.1.1.3 Use of semi-structured questionnaire

A draft questionnaire was developed based on the objectives of the study and requirements of practicing IWRM concept. Consultation was made to various stakeholders like MOH, MWI, YCWUA, MTC, MOA, MOLFD, Department of Culture and Social Services (DCSS), water users and these were incorporated in the draft. It was then pre-tested to three respondents and necessary changes made before actual survey was carried out. The pre-testing aimed at assessing the relevance and easy understanding of the questionnaire. The questionnaire is attached as appendix I.

Population and Sample.

The canal supply area, as defined by past studies and MWI was identified and the population served estimated from past population census. This formed the population of the study area. The sample of the population was picked at random among the water users along the canal (the area bounded within 1Km on either side of canal was adopted due to financial constrains) and at Matuu water supply scheme. Sampling was done randomly by selecting 86 respondents along the canal and 30 respondents within the limit of supply of Matuu water supply scheme. The sample size was based on the length of the canal, type of water use and user and distance of the respondent from upper and lower side of the canal (maximum was 1 km either side). Since most of water uses are common along the canal (i.e. irrigation, domestic and livestock), a sample size of 116 persons was assumed to be adequate.

The interview

Six enumerators, who were supposed to fill the questionnaires when interviewing the respondents, were hired locally and trained on the questionnaire content, methods of administering it, expectations and daily targets. Most of the enumerators were university graduates and had been recently hired by World Vision International to administer questionnaires in the same area. The interviews were conducted from 19th to 21st February, 2006 and the target of 116 questionnaires was achieved.

3.2 Data Analysis

3.2.1 Climatic and general information of study area

Geographical data i.e. mean rainfall, temperature, administrative and political location, etc was collected and compiled for the general understanding of the study area.

3.2.2 Current condition of Yatta canal and Matuu Water Supply

The current state of infrastructure like water conveyance system, flumes, overpasses, treatment plant, storage tanks, access road etc and trends in water flow were established through field observation and interview with MWI, MOA, MTC, YCWUA and other

stakeholders. This helped in assessing effectiveness of operation and maintenance programme and efficiency in water use.

3.2.3 Socio-economic Issues

The level of poverty and income was compared with United Nations standards for defining poverty index, ability by the water users to pay more if services are improved, availability of markets and credit, stakeholders' cohesiveness and access by the poor and marginalized to water for various uses was analysed from the questionnaire.

3.2.4 Water Use

Various water uses like irrigation, domestic, livestock etc and their sources were identified in the study area. Comparison of use within the locations was made to ascertain whether there is unfair water allocation.

3.2.5 Hydrological Analysis

Monthly evaporation rate for 11 years, monthly rainfall for 24 years and mean monthly canal flow for 45 years were obtained from Ministry of Water and Irrigation for gauging station No. 4CC3 (at Yatta canal intake) and analysed. Using Gumbels statistical distribution (due to extreme values in the data), the optimum evaporation rate was obtained to estimate crop water requirement, while dependable monthly rainfall was obtained to estimate effective rainfall and mean monthly canal flow calculated to determine the available supply.

Water is lost through evaporation and seepage. Seepage along the canal was estimated from MWI data while evaporation was estimated from monthly evaporation rate for RGS 4CC3. Net water available was obtained by subtracting water loss from analysis of monthly rainfall and mean monthly canal flows.

3.2.6 Water Demand

Water demand was calculated from the commercial, domestic, livestock and irrigation water requirements.

Domestic and livestock water demand

Based on commercial, human and livestock population projections for both Yatta and Matuu water supply and their daily per capita consumption from MWI Practice Manual and field survey, the present, future and ultimate daily water demand was calculated.

Irrigation water requirements

Based on type of crops grown and their estimated acreage and the crop consumptive water use for each crop (calculated using evaporation pan method), the daily and monthly water requirements were estimated. Summing up commercial, domestic, livestock and irrigation water requirements, total water demand was obtained.

3.2.7 Water Source Adequacy Analysis

Net water available and water demand was compared to determine whether the demand outstrips the supply or vice versa.

3.2.8 Water Quality

Water samples (both surface and ground water) were analyzed in the MWI and MENR laboratories from nine sampling points along the canal and Matuu water supply. Concentration of various parameters like Ecoli, pH, Colour, Turbidity, Conductivity, elements etc were determined and compared with World Health Organization (WHO) standards to assess whether water quality is within the acceptable level for domestic use. Water quality analysis reports are attached as Appendix II.

3.2.9 Water Demand Management

This was assessed at farm and household levels for both Yatta canal and Matuu water supply through field observation and use of questionnaire. Opinion of respondents on

common water demand management practices like efficient water application techniques, minimizing run off losses, soil and water conservation at the farm level, ensuring good soil structures, combining cropping and animal husbandry, timely planting and removal of weeds, was sought and analysed.

3.2.10 Water Management

Through past records and direct interview of MWI staff, information on past, present and future management structures and composition was obtained e.g. the role of MWI, composition of Yatta Canal Water Users Association (YCWUA) etc. Using the questionnaire, the respondents gave their views on the effectiveness of the existing management. It was also established how the water rights are issued.

3.2.11 Integrated Approach to Water Resources Planning and Development

Through direct interview with MWI officials, other stakeholders and literature on Yatta Canal and Matuu water supply, it was established whether integrated approach has been applied in development or rehabilitation of the canal and water supply in the past.

3.2.12 Coordination among Water and Related Sectors

Water related sectors are agriculture, forest, land and environment. During the study, sectoral coordination was analyzed both at the local and national level. National Water Policy was checked to find out whether it has provided for it. Recommendations were made on how it can be improved.

3.2.13 Participatory Approach

From the past records and interview of MWI staff and other stakeholders, it was to be established whether stakeholders especially women have been involved in planning, development and management of Yatta canal and Matuu water supply.

3.2.14 Water Conflict Management

Causes of water conflict and existing mechanisms used to solve them were identified and recommendations made on how to minimize them.

3.2.15 Capacity Building

Assessment was done of existing capacity in terms of personnel, vehicles, plant and equipment to implement IWRM. This was done by checking the current staffing level and operation tools in Yatta Canal and Matuu water supply.

3.2.16 Questionnaire Data Analysis

All data was entered into a SPSS (Statistical Programme for Social Science) for Windows Release 11.5 packages. A spreadsheet was developed to ensure that all information could be entered. Responses to open ended questions were postcoded for this purpose. Each question that had more than one answer was allocated as many variables as necessary in the spreadsheet to ensure that relevant information was not omitted. Answers to questions with more than one variable were not recorded in order of preference but in order of respondent response. Upon completion of all the questionnaires and data entry, the entire spreadsheet was rechecked, to ensure that all the data variables were correctly coded and entered. Analysis of selected data and production of results was carried out using SPSS and many of its statistical options, including frequency tables. Excel spreadsheet was also used for other complementary analysis.

4. RESULTS AND DISCUSSION

4.1 Water Resources Planning

Understanding water resources availability and needs is an important component of IWRM as this helps in planning for various water uses (GWP, 2004). During the planning process, collection of physiographic, hydrologic and socio-economic data is done. This helps stakeholders to make correct decisions during water allocation (GWP, 2000).

4.1.1 Current Condition Of Yatta Canal And Matuu Water Supply

4.1.1.1 Current Condition Of Yatta Canal

The latest major rehabilitation of the canal was carried out from 11th November 2003 to 15th April 2004 (MWRMD, 2004). The works were contracted by the Ministry of Water Resources Management and Development to National Youth Service at a total cost of Kshs.22 million. Works carried out included:

i) desilting and bush clearing of the whole canal

ii) fencing canal intake

iii) construction of 4 No. cattle troughs and 4no. bathing areas

iv)grading of 60 Km access road and construction of two bridges at Kauthulini and Mathauta bifurcation point.

v) stone pitching at canal bends and eroded areas of embankment

vi) general repair of overpasses e.g. placing of gabions on eroded parts and stone pitching at canal crossings (MWRMD,2003(1)).

Currently (i.e. one and half years after rehabilitation) the canal's embankment has been breached as people and livestock try to access water as shown in plate 4.1.

Field survey established that the canal has been desilted twice by the water users after the rehabilitation in 2004. However there was evidence of silt deposition and neglect from Km 40 (Kithendu) to the end. This is because the water users in this area do not get regular supply and this has discouraged them from participating in maintenance activities. Water users need to be motivated to participate in canal maintenance as advocated in IWRM practice (Cap net, 2002).

Plate 4.1. Breached canal embankment at Km 11

Plate 4.2: End of water flow in Yatta canal at Km 45 on 6/2/06

The silt deposition, ineffective water rationing programme and low flows in Thika river due to prolonged drought has reduced canal flows such that some lower sections have had no flow between January and March 2006. Plate 4.2 shows end of flow at the canal as at 6th February 2006.

This situation can be improved by practicing IWRM as all water users will agree on effective rationing programme which ensures reliable supply, thus motivating them to participate in canal maintenance.

However concrete structures like flumes and overpasses are in good condition although access road and cut-off drains need grading in some areas like Km 20, Km 50 to Km 60.

4.1.1.2. Current Condition Of Matuu Water Supply

Matuu water supply started as a community water project sometimes before 1980 under a management committee. The committee faced various problems, which included mismanagement and lack of capacity. Because of policy change in the Ministry of Water Development of supplying water to all by the year 2000, the management was taken over by DWD, after gazettment as the water undertaker through legal notice No. 392 of 14th September 1990 (MWR, 1998). Since then the MWI has been incharge of management of the water supply. The main constraint in the water supply scheme is lack of reliable source, inadequate storage and distribution network. Plate 4.3 shows dry intake of the water supply along Yatta canal which is the main source. The two water pans of 18,000

m^3 total capacity constructed to supplement the canal are not adequate because of their small capacity, evaporation and seepage losses. The pans have been supplying water for only three weeks during the dry season.

Plate 4.3: Intake of Matuu water supply at the canal. (Picture taken on 6/2/06)

Lack of flow in the canal disrupts operation of the water supply making users to seek alternative water sources of suspect quality. Table 4.1 shows the period between 1995 and 2005 when the water supply was not operational due to inadequate flow in the canal. This negates IWRM practice, as there should be fair distribution of available water among the users (Cap Net, 2002).

Table 4.1: Period When Matuu Water Supply Was Not Operational

Year	Period when not operational
1995	None
1996	None
1997	12th –16th Feb; 18th March-1st April
1998	2nd July-8th August
1999	30th March-18th April; 4th –August-14th August
2000	21st –28th January; 21st –27th March; 4th –14th June; 9th –24th August
2001	7th –15th December
2002	19th Feb-4th March; 18th July –10th August
2003	15th Feb-24th Feb; 12th July-4th August
2004	None
2005	16th -28th March; 17th –26th July

Source: Matuu Water Supply Office, 2006

4.1.2 Climate

The climate can be defined as semi-arid with average temperature ranging from 12° C to 25°C, the hottest months being March –October and the coldest being July-August (MWI et al, 2005). There are two distinct rainy seasons. The long rains fall between March and May and the short rains fall between October and December (MPND, 2002) with mean annual rainfall being 650mm (MWI et al, 2005).

4.1.3 Soils

There are three major soil types. These are

- Moderately well drained, deep soils ranging from sandy clay loams to sandy loams.
- Well-drained, deep, red to dark reddish brown clays.
- Deep, poorly drained, firm clays with a tendency to crack on drying (black cotton soils).

Soils in the area have moderate fertility, and inorder to sustain reasonable yields, fertilizer application is essential. Topsoils are mildly acidic (MWD, 1989).

4.1.4 Vegetation

This is characterized by open grassland with scattered acacia trees towards the end of the canal. The upper part contains moderate indigenous forest cover with portions of exotic trees like eucalyptus and mango. However most of the land along the canal is under intense horticultural and food crop farming.

4.1.5 Transport and Communication

The area is generally well connected with road network with Matuu, Kithimani and Ndalani towns joined by tarmac road. Other areas are served by well-maintained murram roads making it possible to access markets for horticulture products.

Landline telephone services are available at Kithimani, Sofia, Matuu and Ndalani shopping centres. Both Safaricom and Celtel mobile telephone services cover the study area well with network. Postal services are available in Kithimani and Matuu towns.

4.1.6 Administration

Yatta canal traverses Ndalani, Kithimani and Matuu locations of Yatta division. However some parts of Kitheuni and Kyasioni sub locations of Ikombe location, (Katangi Division) get water for domestic / livestock use from the canal.

In terms of local authorities, the area is under both Matuu Town Council (Kithimani and Matuu locations) and Masaku County Council (Ndalani and Ikombe Locations). It lies within Yatta constituency, one of the six constituencies of Machakos district (SDC, 2005).

4.1.7 Socio Economic Issues

4.1.7.1 Poverty

Yatta division has a poverty rate of 67.5%, which is higher than average rate for the district (66.2%). This high poverty rate in the division is due to lack of water (MNDP 2002).

From the survey, the mean monthly income per household is shs.15, 337 while the average number of people in a household is seven. This means that each person lives on Kshs 73 per day, which is less than a US dollar (Kshs. 75) and hence below poverty line (United Nations standards classifies those living below a dollar per day as below poverty line).

IWMI, 2005 gives alternative definition of IWRM as involving the promotion of human welfare, especially the reduction of poverty, encouragement of better livelihoods and balanced economic growth through effective democratic development and management of water and other natural resources in an integrated multi-level framework that is as equitable, sustainable and transparent as possible, and conserves vital ecosystem. Also, as one of the millennium development goals is halving the proportion of the world's

population living in extreme poverty by 2015(GWP, 2003(2)), there is need to introduce poverty reduction strategies in Yatta canal which promote equity in water use and hence practice IWRM. These include prioritization of water resources development programmes to populations at water risk (those more vulnerable to drought and water scarcity) (GWP, 2003(2)) especially around Matuu town and those living towards the end of the canal. There is need to protect traditional and customary water rights enjoyed by the poor like the shallow wells and feeder stream flows, which are recharged by the canal (Cap Net, 2002).

4.1.7.2. Main Sources of Income

Main sources of income include farming, employment and business. The bar chart in Figure 4.1 shows the main sources of income against the respective percentage of respondents. This shows that the main source of income for the residents is farming. Being an ASAL area, farming is practiced mainly through irrigation along the canal. This confirms that the canal is the main source of livelihood for Yatta people.

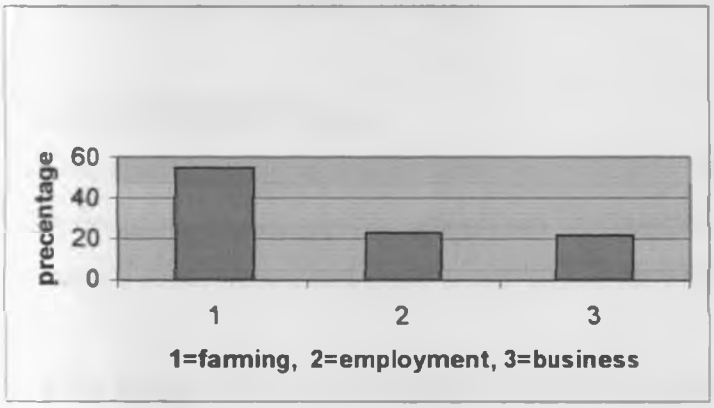

Figure 4.1: Sources of income

Source: Survey, 2006

4.1.7.3. Ability to Pay More for Water

Although 78% of respondents said they are willing to pay more if services are improved, the average amount they are willing to pay is less than what they are paying now as shown in Table 4.2. The reason for the respondents not proposing to pay more is either because of the high poverty rate prevalence and/or they do not trust services can be improved after a long period of poor service.

Table 4.2: Comparison of payment of water if services are improved

Water source	Period/ Unit	Current average bill/cost Kshs.	Bill/cost to pay if services are improved Kshs.
Yatta canal	Year	1734	1687
Matuu water supply	Month	1138	926
20litres jerican	One	9	9

Source: Survey, 2006

Past failure to recognize the economic value of water has led to wasteful uses of the resource and misuse of its infrastructure because of poor maintenance and lack of upgrading. It is no longer possible for the government alone to fund all development and management of water projects due to limited funds against other competing needs (WB, 2004). Water users have to meet the cost of managing water projects and if possible part of the capital investment required for rehabilitating the system. But mechanisms should be put in place to ensure that those who cannot pay for water services like the poor and marginalized are served (GWP, 2003(2)).

4.1.7.4 Social Welfare Groups

One of the challenges facing implementation of IWRM is lack of entry point and support of its principles. Social welfare groups are forums that can be used to assess the community's cohesiveness and promote entry point for IWRM approach (GWP, 2004).

During the survey, 73% of respondents said they are members of at least one self-help group. Most of them were in general self help groups, goat rearing, spiritual nourishment, helping each other in case of a problem, assisting in burials, tree planting and dowry payment. This shows that the community is cohesive enough to implement IWRM.

4.1.7.5 Gender Issues

Women and children suffer most when there is water scarcity (Cap-Net, 2002). IWRM principles provides positive policies which address women's specific needs and equip and empower them to participate at all levels of water resources programmes, including decision-making and implementation (GWP, 2000). These include right to land tenure,

water rights, effective representation in management committees, participation in awareness campaigns etc. Though women are very active in self help groups (90% of respondents said women engage in leadership of self help groups), they do not participate in planning for the rehabilitation of the canal or Matuu water supply. There is only one woman Trustee out of sixteen Trustees in the Board of Trustees (BOT) of Yatta Canal Water Users Association (YCWA) Trust.

4.1.7.6 Availability of Credit and Markets

The main factor which farmers, particularly small-scale ones, point out as causing low productivity in agriculture is inadequate credit to finance inputs and capital investments (MOA and MOLFD, 2004). 11% of the respondents said they get credit for produce and livestock from SACCO, AFC or Exporters. This means that most of them do not have access to credit. 36 % said they market their produce through brokers or exporters. These modes of marketing have frustrated farmers as the prices offered are sometimes below the cost of production. The farmers need to be cushioned against this unreliable market to encourage them plant crops of high value thereby optimizing water use in line with IWRM.

4.1.8 Integrated Approach

IWRM approach in designing and managing infrastructure makes it possible to capitalize on potential synergies, for example, developing water supply schemes that provide people with water for domestic and productive uses (GWP, 2004). Yatta Canal was constructed with the aim of providing water for multiple uses i.e. irrigation, domestic and livestock thus planning and development was based on integrated approach (MWD, 1984). Over the years, water use in the canal has not changed and so planning for rehabilitation has been based on the same water uses. However there is need to consider environmental water for supporting aquatic life and agro industries as they are likely to be established in future as a result of the intense commercial farming going on within the supply area.

4.1.9 Water Resources Assessment

Availability of accurate and reliable water resources data, to be used by decision makers, is an important management instrument for practicing IWRM (GWP, 2004). In the study area, water is available from canal flow and rainfall and is used for irrigation, livestock and domestic (MWD, 1989). Water is lost through evaporation and deep percolation. Daily rainfall, evaporation and mean canal flow data were analyzed from gauging station No. 4CC3 at the canal intake. Water available from other sources was also considered during analysis. Analysis for present, future and ultimate water demand based on various water uses was estimated using data on irrigated area, human and livestock population projections.

4.1.9.1 Water Resources Potential

Though Yatta canal is the main source of water within the study area, there are other sources that supplement it. These are water pans, boreholes and shallow wells. There are several boreholes drilled in the past. Currently only borehole No. C4566 (at NYS farm) and C1493 (near Kithimani shopping center) are in use and supply water for domestic purposes. The other boreholes have been abandoned because of poor maintenance, high fluoride content, hardness and low yields (tested yield for most of those abandoned range from 0.24 m^3/h to 2.82 m^3/h).

Shallow wells are common along the feeder streams towards the canal end and some are lined while others are not. Majority of those living far from the canal and those on the lower end of the canal (areas like Kateki and Kaluluini) depend on them for domestic, livestock and even irrigation. Plate 4.4 shows a lined shallow well near Kateki shopping center at the canal end.

Plate 4.4: Lined shallow well near Kateki shopping center

4.1.9.2 Water Demand Assessment in Yatta Canal supply area

The canal is the source of water for Kithimani, Ndalani and Matuu locations. It also serves Kitheuni and Kyasioni sub locations of Ikombe location, Katangi division. Table 4.3 and 4.4 show the human and livestock population served.

Table 4.3: Human population in the study area.

Division	Location	Sub-location	Population		
			1999	2005	2006
Yatta	Kithimani	Kithimani	5,411	6,401	6,510
		Kithendu	10,163	12,022	12,226
	Ndalani	Ndalani	5,139	6,079	6,182
		Mamba	6,846	8,098	8,236
	Matuu	Matuu	7,749	9,166	9,322
		Katalani	3,527	4,172	4,243
		Kahihuni	5,920	7,003	7,122
		Kakumini	5,651	6,685	6,799
Katangi	Ikombe	Kitheuni	4,263	5,043	5,129
		Kyasioni	3,075	3,637	3,699
Urban					9,322
Rural					60,146
Total					69,468

Source: District Statistics Office, Machakos, 2005.

Table 4.4: Livestock Population in the study area

ck	Population									
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
attle	2,700	2,700	2,500	1,500	1,550	2,000	1,800	1,800	700	800
ttle	-	53,000	50,000	32,000	30,000	23,000	19,000	19,000	13,000	14,000
	70,000	70,000	60,000	20,000	18,000	14,000	14,000	14,000	12,000	15,000
	28,500	28,500	27,000	10,000	8,000	5,000	5,000	5,000	4,000	5,000
ys	460	417	420	200	300	500	500	500	200	700
	130	250	270	110	200	300	300	300	300	250
s	560	1,000	900	500	300	500	500	500	500	500
	-	115,000	120,000	30,000	20,000	19,000	19,000	19,000	30,000	18,000
	-	10,000	20,000	14,900	14,000	17,000	17,000	17,000	2,000	2,225

*Layers, broilers, turkeys and ducks

Source: Divisional Livestock Extension Office, Yatta Division, 2005

From Practice Manual for Water Supply Services in Kenya 2005, the livestock types are equivalent to the following livestock units:

1 grade cow = 1 Livestock Unit (LU)

3 indigenous cow = 1 Livestock Unit (LU)

15 sheep or Goats = 1 Livestock Unit (LU)

5 donkeys = 1 Livestock Unit (LU)

In the conversion of livestock numbers to livestock units, rabbits and pigs have been assumed to be the same as sheep or goats and poultry have been ignored (as the Practice Manual recommends).

Also according to the Divisional Livestock Extension Officer, Yatta Division, about 75% of the livestock in Table 4.4 get their water from Yatta canal. The remaining 25% are watered from other sources like Athi and Thika rivers.

Table 4.5: Conversion of Livestock population to livestock units

ck	Equivalent Livestock Units										
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2006*
attle	2,700	2,700	2,500	1,500	1,550	2,000	1,800	1,800	700	800	816
ttle	-	17,667	16,667	10,667	10,000	7,667	6,333	6,333	4,333	4,667	4,780
	4,667	4,667	4,000	1,333	1,200	933	933	933	800	1,000	1,024
	1,900	1,900	1,800	667	533	333	333	333	267	333	340
ys	92	83	84	40	60	100	100	100	40	140	143
	9	17	18	7	13	20	20	20	20	17	17
s	37	67	60	33	20	33	33	33	33	33	34
	9,405	27,101	25,129	14,247	13,376	11,086	9,592	9,552	6,193	6,990	7,157
L.U.	7054	20,326	18,847	10,685	10,032	8,315	7,164	7,164	4,645	5,243	5,368
ling											
Yatta											
(75%											
total											

Year 2006 figures are projected

Schools, Institutions and commercial water users.

Data on these users was obtained from various institutions and government offices during field survey. Table 4.6 shows the number of users within the study area.

Table 4.6: Schools, Institutions and Commercial water users in the study area.

CATEGORY	NUMBER
Day primary school pupils	18,247
Day secondary school students	2,304
Day college/polytechnic students	652
Boarding secondary school students	2,655
Hospitals (Matuu Sub-district Hospital, Matuu Nursing Home). Hospital beds	122
Health Centres (Kithimani & Ndalani Health Centre)	2
Dispensaries/Private Clinics	9
Churches	42
Commercial Centres	
Hotels	53
Shops	230
Bars/Restaurants/Lodgings	46
Butcheries	18
Petrol stations	5
Bakeries	1

Source: Matuu Town Council Business Register, Divisional Education Office, Yatta Division and Field Survey, 2005.

Projected Population

Table 4.7 shows the projected population of human, livestock and other consumers served in the study area. The study adopted annual growth rate of 1.7% and 1.2% respectively for human and livestock population from Machakos District Development Plan 2002-2008, and 5.5% for business / commercial growth rate as estimated by Matuu Town Council (NCA et al, 2005). Churches, Institutions, Schools, Hospitals and Dispensaries have been assumed to grow at the same rate as human population. The initial year has been taken as 2007.

Table 4.7: Projected population in study area.

No.	Category	Population Projections			
		Present Year 2006	Initial Year 2007	Future Year 2017	Ultimate Year 2027
1.	Human Population				
	- Urban	9,322	9480	11,221	13,281
	- Rural	60,146	60,989	74,400	85,694
2.	Livestock units	5,368	5,432	6,120	6,895
3.	Day primary school pupils	18,247	18,557	21,964	25,997
4.	Day secondary school students	2,304	2,343	2,773	3,282
5.	Day college/polytechnic students	652	663	785	929
6.	Boarding secondary schools students	2,655	2,700	3,196	3,783
7.	Hospital beds (Matuu Sub- District hospital & Matuu Nursing Home)	122	124	146	173
8.	Health Centres	2	2	2	3
9.	Dispensaries/Clinics	9	9	11	13
10.	Churches	42	43	50	59
11.	Commercial centres				
	- Hotels	53	56	96	164
	- Shops	230	243	415	709
	- Bars/restaurants/lodgings	46	48	82	140
	- Butcheries	18	19	32	55
	- Petrol stations	5	5	9	15
	- Bakeries	1	1	2	3

Domestic Water Demand Projections

From the survey, the average volume of water needed per day per household is 123lts. The average number of people per household is 7 people. Therefore the average volume of water needed per person per day is 17 lts. This per capita consumption is adopted when computing water demand for the rural population as that given in the Practice Manual of 15 lts (MWI, 2005) is low considering the proximity of most of the consumers to the canal.

For urban consumption, it was found from the survey that the average number of people in the household is 7 and the average daily water consumption is 170lts. This gives a per capita consumption per day of 24 lts. Given that this will increase when services are

improved especially in Matuu water supply, a figure of 40 lts given in the Practice Manual for individual connections in low potential areas has been adopted.

The other per capita consumption have been adopted as per the Practice Manual. Per capita consumption for petrol stations and bakeries are based on interview with employees. Table 4.8 shows the projected water demand based on the survey and Practice Manual, obtained by using the population projections given in table 4.7 and the per capita consumption.

Table 4.8: Water Demand Projections within Yatta canal.

ory	Per capita consumption l/d	Projected water demand m^3/day Present 2006	Initial 2007	Future 2017	Ultimate 2027
n population					
- Urban	40	372.9	379.2	448.8	531.2
- Rural	17	1,022.5	1,036.8	1,264.8	1,456.8
tock Units	50	268.4	271.6	306.0	344.8
rimary school pupils	5	91.2	92.8	109.8	130.0
econdary school students	5	11.5	11.7	13.9	16.4
ollege / polytechnic students	5	3.3	3.3	3.9	4.6
ling secondary school students	50	132.8	135.0	159.8	189.2
ital beds (Matuu sub-district ital and Matuu Nursing Home)	100	12.2	12.4	14.6	17.3
h Centres	5,000	10.0	10.0	10.0	15.0
nsaries/clinics	5,000	45.0	45.0	55.0	65.0
ches	500	21.0	21.5	25.0	29.5
nercial Centres					
Hotels	500	26.5	28.0	48.0	82.0
Shops	100	23.0	24.3	41.5	70.9
restaurants/lodgings	500	23.0	24.0	41.0	70.0
Butcheries	500	9.0	9.5	16.0	27.5
Petrol stations	1,500	7.5	7.5	13.5	22.5
Bakeries	5,000	5.0	5.0	10.0	15.0
		2,088.4	2,117.6	2,581.6	3,087.7

Crop Water Requirement

The kind of crops grown under irrigation and their mean acreage for the last three years within the canal supply area was obtained from the field survey. Assuming a cropping intensity of 100% and the acreage under irrigation as estimated by MWI to be 800 ha (MWRMD, 2003(1)), table 4.9 gives the irrigated area per crop.

Table 4.9: Type of crops grown under irrigation and their mean acreage.

Crop Type	Mean Acreage for the last three years (acres)	% mean acreage	Irrigated area (ha)
Sukuma wiki (kales)	0.22	2	16
French beans	0.39	4	32
Bananas	0.16	2	16
Cassava	0.55	5	40
Tomato	0.35	5	40
Maize	0.75	7	56
Mangoes	1.9	18	144
Sugar cane	0.16	2	16
Beans	0.5	5	40
Potatoes	0.5	5	40
Pepper	0.22	2	16
Oranges	2.75	26	208
Spinach	0.1	1	8
Karera	0.58	6	48
Onion	0.24	5	40
Dudhi	0.5	5	40
			800

Source: Survey, 2006.

Evapotranspiration, ET crops

For each type of crop, $E T_{crop} = E To * Kc$ –(1) (MWI, 2005)

where

ETo = reference evapotranspiration

Kc = crop coefficient/ factor.

Using pan evaporation rate for RGS 4CC3 (Yatta canal Intake)

ETo = Eo*Kp. – (2)

Where Eo = evaporation from free water surface

Kp = Pan coefficient.

In Kenya Kp = 0.8 for hot and dry low areas (like in the study area) (MWI, 2005).

Hence ETo = 0.8 Eo. – (3)

i) Evaporation from free water surface, Eo from RGS 4CC3 (Yatta Canal Intake)

Data for daily evaporation rate for 11yrs was obtained from MWI. The Pan broke down in 1984, 1991-2003 and therefore there was no data for this period. This was ignored during analysis. However any missing data for the period of record was estimated using least squares method in the regression analysis for the time series. For daily data estimates, monthly data values were considered as data range and 95% confidence level of t- test distribution was adopted. For monthly data estimates, the data range was taken as the number of years the data was recorded for that month and the same confidence level adopted. SPSS was used to estimate the missing data. Monthly evaporation rate data is shown in Appendix III

The data was analysed using Gumbel's statistical distribution (to take care of extreme values) to obtain the mean, 20% exceedence and 80% exceedence probability for monthly evaporation rate. The following Gumbel's statistical distribution equation was used:

$P=1-e^{-e-b}$

$b= \frac{1}{0.778S} (X-m+0.45S)$

Where

P=exceedece probability

b=reduced variate

S=standard variation

m=arithmetic mean of data

X=monthly evaporation rate at P exceedece probability

(Wurbs and James, 2002)

Table 4.10 shows analysed monthly evaporation rate, Eo, at various probabilities of exceedence for each month.

Table 4.10 Analysed monthly evaporation rate, mm.

Evaporation rate	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20% exceedence	169.8	179.4	218	236.6	145.8	118.9	106.8	127.3	153.3	184.9	169.5	150
Mean	156.7	164 4	199 3	204.6	128.4	111.3	101 4	114.3	148	171.7	149.8	139.1
80% exceedence	141.8	147.3	178	168.2	108.6	102.7	95.3	99.5	142	156.6	127.3	126.7

The 20% exceedence has been adopted as the optimum monthly evaporation rate whose trend is shown in figure 4.2.

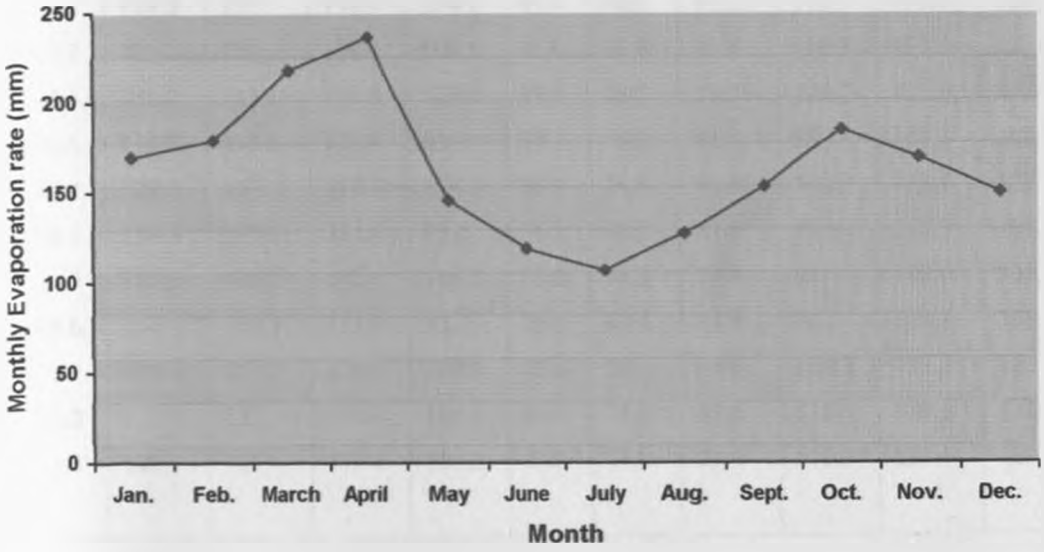

Figure 4.2: Optimum monthly evaporation rate, mm for the period January 1981 to December 1990 and January 2004 to December 2005

Using optimum monthly evaporation rate and equation (3), ETo is obtained as shown in table 4.11.

Table 4.11: Reference monthly evapotranspiration, ETo in mm.

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
ETo (mm)	135.8	143.5	174.4	189.3	116.4	95.1	85.4	101.8	122.6	147.9	135.6	120.0

Using equation (1), the monthly reference evapotranspiration in table 4.11 and the crop factor in Appendix IV, monthly crop water requirement was obtained as shown in table 4.12.

Table 4.12: Monthly crop water requirements ETcrop, mm

rop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
kuma iki (Kales)	108.6	114.8	139.5	151.4	93.1	76.1	68.3	81.4	98.1	118.3	108.5	96
ench beans	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
nanas	129	136.3	165.7	179.8	110.6	90.3	81.1	96.7	116.5	140.5	128.8	114
ssava	115.4	122	148.2	160.9	98.9	80.8	72.6	86.5	104.2	125.7	115.3	102
mato	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
laize	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
langoes	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
gar cane	142.6	150.7	183.1	198.8	122.2	99.9	89.7	106.9	128.7	155.3	142.4	126
eans	108.6	114.8	139.5	151.4	93.1	76.1	68.3	81.4	98.1	118.3	108.5	96
tatoes	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
epper	108.6	114.8	139.5	151.4	93.1	76.1	68.3	81.4	98.1	118.3	108.5	96
ranges	101.9	107.6	130.8	142	106.5	71.3	64.1	76.4	92	110.9	101.7	90
pinach	108.6	114.8	139.5	151.4	93.1	76.1	68.3	81.4	98.1	118.3	108.5	96
arrera	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
nion	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108
udhi	122.2	129.2	157	170.4	104.8	85.6	76.9	91.6	110.3	133.1	122	108

Net Irrigation Requirement, NIR

$NIR = ET_{crop} - P_e - G_e$ –(4) (MWI, 2005)

Where P_e = Effective rainfall (mm)

G_e = Ground water contribution (mm)

The ground water potential in the study area is low and hence G_e has been neglected.

Effective rainfall, P_e:

This is obtained by analyzing monthly rainfall (mm) using Gumbel's distribution to obtain 80% exceedence probability. This is then compared with ETcrop and P_e is obtained from tables. From daily rainfall data obtained from RGS 4CC3 (Yatta canal

intake) the data was analyzed and missing data estimated using least squares method of regression analysis same as that of evaporation. Monthly rainfall data is shown in Appendix III. Table 4.13 shows the analysed monthly rainfall data.

Table 4.13: Analysed monthly rainfall (mm) for RGS 4CC3(Yatta canal Intake)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
20% exceedence	123.4	57.8	176.6	278.7	145.2	19.6	3.2	4.6	10	112.9	286	145.7
Mean	60	30.1	114.2	200.8	80.9	6.8	1.5	2.3	4.7	65.9	212.1	102.8
80% exceedence	0	0	43.1	112.1	7.8	0	0	0	0	12.4	12.8	53.9

The 80% exceedence monthly rainfall was adopted as the dependable rainfall and its trend is shown in figure 4.3.

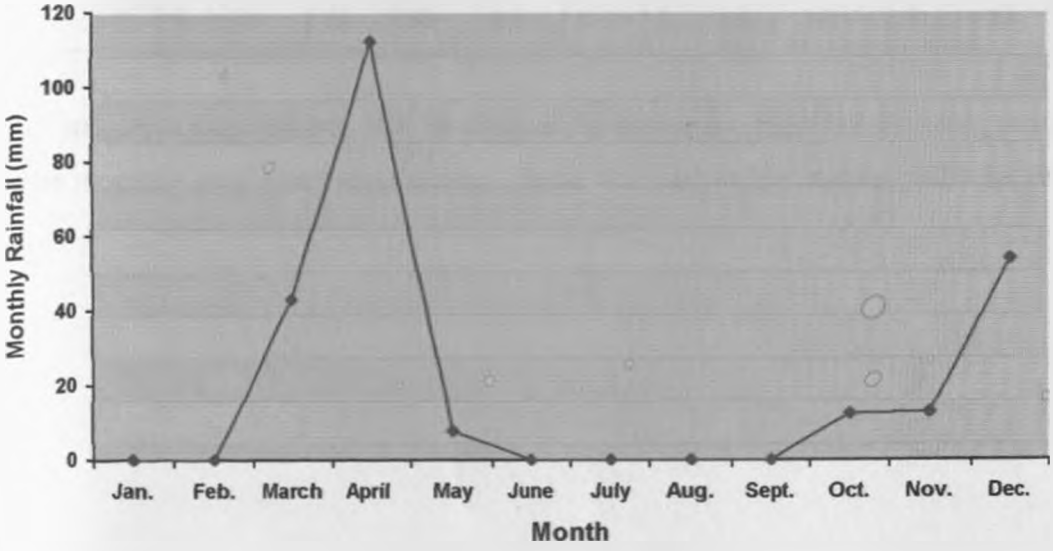

Figure 4.3: Dependable monthly rainfall in mm for the period January 1982 to December 2005

Values of effective rainfall for each month and crop are then obtained from Appendix IV table IV.2 using table 4.12 and dependable monthly rainfall. Effective rainfall is shown in table 4.14 for each crop and month.

Table 4.14: Monthly effective rainfall Pe, mm

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sukuma Wiki	0	0	32	76	4	0	0	0	0	9	75	33
French beans	0	0	34	80	4.5	0	0	0	0	9	80	34
Bananas	0	0	35	82	4.5	0	0	0	0	10	80	34
Cassava	0	0	33	78	4	0	0	0	0	9	80	34
Tomato	0	0	34	80	4.5	0	0	0	0	9	80	34
Maize	0	0	34	80	4.5	0	0	0	0	9	80	34
Mangoes	0	0	34	80	4.5	0	0	0	0	9	80	34
Sugar cane	0	0	37	86	4.5	0	0	0	0	10	83	35
Beans	0	0	32	76	4	0	0	0	0	9	75	33
Potatoes	0	0	34	80	4.5	0	0	0	0	9	80	34
Pepper	0	0	32	76	4	0	0	0	0	9	75	33
Oranges	0	0	31	74	4.5	0	0	0	0	9	74	33
Spinach	0	0	32	76	4	0	0	0	0	9	75	33
Karrera	0	0	34	80	4.5	0	0	0	0	9	80	34
Onion	0	0	34	80	4.5	0	0	0	0	9	80	34
Dudhi	0	0	34	80	4.5	0	0	0	0	9	80	34

The net irrigation requirement, NIR is obtained by deducting monthly effective rainfall from the monthly crop water requirement. Table 4.15 shows the monthly NIR for each crop.

Table 4.15: Monthly Net Irrigation Requirement, NIR, mm

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sukuma wiki (kales)	108.6	114.8	106.5	75.4	89.1	76.1	68.3	81.4	98.1	109.3	33.5	63
French beans	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Bananas	129	136.3	130.7	97.8	106.1	90.3	81.1	96.7	116.5	130.5	48.8	80
Cassava	115.4	122	115.2	82.9	94.9	80.8	72.6	86.5	104.2	116.7	35.3	68
Tomato	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Maize	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Mangoes	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Sugarcane	142.6	150.7	146.1	112.8	117.7	99.9	89.7	106.9	128.7	145.3	59.4	91
Beans	108.6	114.8	106.5	75.4	89.1	76.1	68.3	81.4	98.1	109.3	33.5	63
Potatoes	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Pepper	108.6	114.8	106.5	75.4	89.1	76.1	68.3	81.4	98.1	109.3	33.5	63
Oranges	101.9	107.6	99.8	68	102	71.3	64.1	76.4	92	101.9	27.7	57
Spinach	108.6	114.8	106.5	75.4	89.1	76.1	68.3	81.4	98.1	109.3	33.5	63
Karrera	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Onion	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74
Dudhi	122.2	129.2	123	90.4	100.3	85.6	76.9	91.6	110.3	124.1	42	74

The monthly net irrigation water requirements for the irrigated area of 800 ha has been computed by multiplying NIR in table 4.15 with irrigated area per crop in table 4.9 and is shown in table 4.16.

Table 4.16: Monthly net irrigation water requirements, $x10^3$ m^3

Crop	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Sukuma wiki kales)	17.4	18.4	17	0	14.3	12.2	10.9	13.0	15.7	16.0	0	4.8
French beans	39.1	41.3	39.4	3.3	32.1	27.4	24.6	29.3	35.3	36.8	0	12.8
Bananas	20.6	21.8	20.9	2.5	16.9	14.4	13	15.5	18.6	19.3	0	7.4
Cassava	46.2	48.8	46.1	2.8	38	32.1	29	34.6	41.7	43.1	0	13.6
Tomato	48.9	51.7	49.2	4.2	40.1	34.2	30.8	36.6	44.2	46	0	16
Maize	68.4	72.3	68.9	5.8	56.2	47.9	43.1	51.3	61.8	64.4	0	22.4
Mangoes	176	186.0	177.1	15.0	144.4	122.4	110.7	131.9	158.8	165.7	0	57.6
Sugarcane	22.8	24.1	23.4	4.3	18.8	16	14.4	17.1	20.6	21.6	0	9
Beans	43.4	45.9	42.6	0	35.6	30.4	27.3	32.6	39.2	40.1	0	12
Potatoes	48.9	51.7	49.2	4.2	40.1	34.2	30.8	36.6	44.1	46	0	16
Pepper	17.4	18.4	17	0	14.3	12.2	10.9	13.0	15.7	16	0	4.8
Oranges	212	223.8	207.6	0	212.2	148.3	133.3	158.9	191.4	193.2	0	49.9
Spinach	8.7	9.2	8.5	0	7.1	6.1	5.5	6.5	7.9	8	0	2.4
Karrera	58.7	62.0	59.0	5	48.1	41.1	36.9	44	52.9	55.2	0	19.2
Onion	48.9	51.7	49.2	4.2	40.1	34.2	30.8	36.6	44.1	46	0	16
Dudhi	48.9	51.7	49.2	4.2	40.1	34.2	30.8	36.6	44.1	46	0	16
TOTAL	926.5	978.8	924.3	55.5	798.4	647.3	582.8	694.1	836	863.4	0	279.9

From table 4.16, the net irrigation water demand can be summarized as shown in table 4.17. It is assumed that irrigation period is 8hrs per day.

Table 4.17: Net Irrigation Water Demand

onth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
IR($x10^3m^3$)	926.5	978.8	924.3	55.5	798.4	647.3	582.8	694.1	836	863.4	0	279.9
IR Water mand (m^3/s)	1.04	1.21	1.04	0.06	0.89	0.75	0.65	0.78	0.97	0.97	0	0.31

The highest net irrigation water demand (NIWD) occurs in February (i.e. $1.21m^3/s$). This is taken as the Net Irrigation Requirement NIR, for present water demand. Assuming the size of irrigated land will not increase (because of inadequate water supply) and that the water demand for domestic use is supplied 8hrs per day, the water demand projections for domestic, livestock and irrigation are as shown in table 4.18. This has been determined using tables 4.8 and 4.17.

Table 4.18: Domestic, Livestock and Irrigation water demand projections.

Category	Projected Water Demand m^3/s			
	Present Year 2006	Initial Year 2007	Future Year 2017	Ultimate Year 2027
Domestic and livestock	0.07	0.07	0.09	0.11
Irrigation	1.21	1.21	1.21	1.21
Total	1.28	1.28	1.3	1.32

4.1.9.3 Water Availability Assessment

I. Yatta Canal

Data for canal flow was obtained from MWI records for RGS 4CC3. The missing daily mean flows were estimated using least squares method for time series in regression analysis with the month as the data range. A 95% confidence level was maintained and SPSS programme was used for analysis.

In estimating missing mean monthly flow, data for the month's period of record was used as data range and regression analysis used as for daily mean flows. The mean monthly canal flow data is shown in Appendix III. Mean monthly flow was analysed using Gumbel's statistical distribution and the mean, 20% and 80% exceedence monthly flow values obtained for each month for the period of record. Table 4.19 shows the analyzed monthly canal flow in m^3/s.

Table 4.19: Analyzed mean monthly canal flow at RGS 4CC3 (Yatta Canal Intake) m^3/s.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20% exceedence	1.2	1.18	1.15	1.2	1.23	1.26	1.3	1.28	1.2	1.17	1.2	1.2
Mean	0.98	0.96	0.93	0.92	0.93	0.99	1.06	1.04	0.98	0.96	0.94	0.95
80% exceedence	0.73	0.71	0.68	0.6	0.59	0.68	0.78	0.77	0.73	0.72	0.64	0.66

The 80% exceedence mean monthly canal flow was adopted as the dependable canal flow and is shown in figure 4.4.

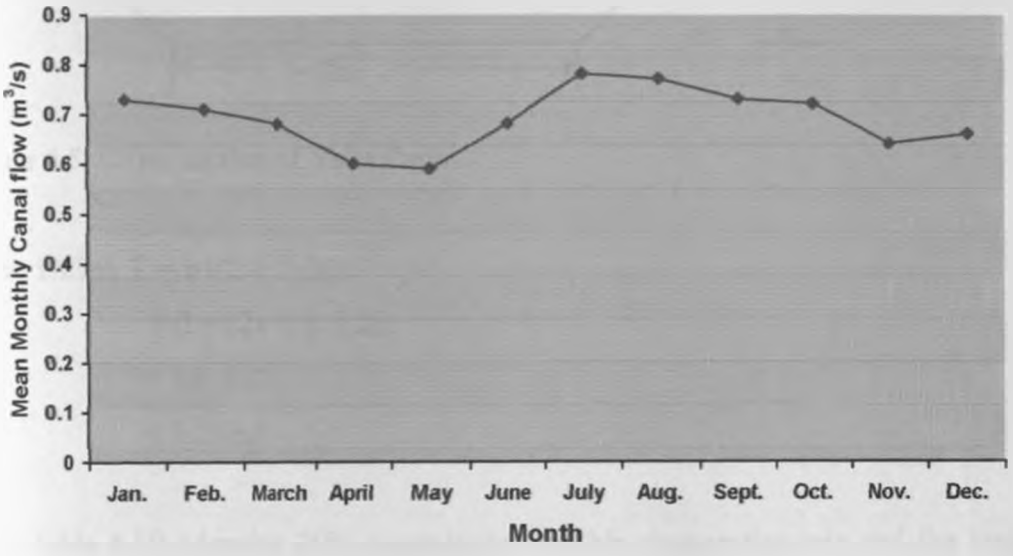

Figure 4.4 Dependable mean monthly canal flow, m^3/s for the period January 1961 to December. 2005

II. Boreholes

There are two boreholes in use in the study area. These are C1493(Kithimani market) and C4566 (NYS Yatta field unit) with yields of 6.28 and 9.06m^3/h respectively.

III. Water pans

There are two pans constructed to supplement water supply from the canal for Matuu town during dry seasons. The total capacity for the two pans is about 18,000m^3.

IV. Shallow wells

Shallow wells are located at feeder streams and are recharged from seepage of the canal. Their discharge is therefore dependent on flow from the canal.

4.1.9.4 Water Loss

I. Yatta Canal

Water is lost through evaporation and seepage.

a) Evaporation

Yatta canal has bottom width of 2m, side slopes two vertical to one horizontal and conveys an average water depth of 1.25m.

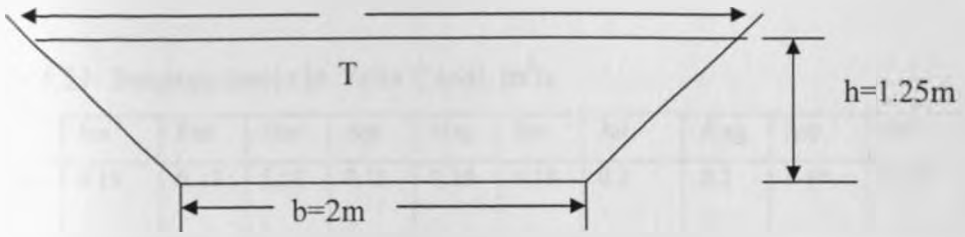

Figure 4.5: Cross section of Yatta Canal

At h= 1.25m, $T = b+(2 \times {}^{1}/_{2}\, h)$

$= 2 + (2x \frac{1}{2} \times 1.25)$

$= 2 + 1.25$

$= 3.25m$

From table 4.10 adopting 20% exceedence monthly evaporation rate and the length of canal of 60Km, the monthly water loss through evaporation is shown in table 4.20. It is assumed that evaporation is effective for 12 hrs per day.

Table 4.20: Monthly water loss through evaporation

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
20% exceedence (mm)	169.8	179.4	218	236.6	145.8	118.9	106.8	127.3	153.3	184.9	169.5	150
Water loss $(m^3)x\ 10^3$	33.1	35	42.5	46.1	28.4	23.2	20.8	24.8	29.9	36.1	33.1	29.3
Water loss m^3/s	0.02	0.03	0.03	0.04	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.02

b) Seepage

Seepage loss along the canal is estimated as 26.5% of canal flow and is based on Ministry of Water development estimation (MWD, 1984).

Seepage losses are computed from table 4.19 after adopting 80% exceedence flow (same as the dependable flow). Their values are shown in table 4.21.

Table 4.21: Seepage losses in Yatta Canal, m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Seepage loss m^3/s	0.19	0.19	0.18	0.16	0.16	0.18	0.2	0.2	0.19	0.19	0.19	0.17

c) Water pans for Matuu water supply .

Field survey established that water from the pans is used during the dry season for a maximum of three weeks. It is assumed that the pans are filled during long rains (March – May) and short rains (September – December) and used for three weeks in the month of June and January for 8 hrs per day. It is also assumed that the water losses due to seepage is 26.5% of total capacity of pans (same as that of canal), and using the evaporation rates in table 4.10 for 20% exceedence probability (and effective evaporation occurring for 12hrs per day), table 4.22 shows the water losses from the pans.

Table 4.22: Water loss from the pans, m^3/s

Month	January	June
Water available before any loss (m^3)	18000	18000
Water available before any loss m^3/s	0.02	0.02
Water loss due to seepage m^3/s	0.006	0.006
Water loss due to evaporation m^3/s	0.0008	0.0006

4.1.9.5 Net Water Supply

To obtain net water available in the study area, the total monthly values of water available from section 4.1.9.3 are obtained and water loss from section 4.1.9.4 subtracted from them. Table 4.23 shows the monthly values for water available from various sources. The sum of water losses from evaporation and seepage gives the aggregated losses. This is shown in table 4.24.

Table 4.23: Water supply from various sources, m^3/s

onth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
atta canal	0.73	0.71	0.68	0.6	0.59	0.68	0.78	0.77	0.73	0.72	0.64	0.66
oreholes	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
ater pans	0.02	-	-	-	-	0.02	-	-	-	-	-	-
otal	0.754	0.714	0.684	0.604	0.594	0.704	0.784	0.774	0.734	0.724	0.644	0.664

Table 4.24: Aggregate monthly water loss in the study area, m^3/s.

onth	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
tta Canal												
epage	0.19	0.19	0.18	0.16	0.16	0.18	0.2	0.2	0.19	0.19	0.19	0.17
vaporation	0.02	0.03	0.03	0.04	0.02	0.02	0.01	0.02	0.02	0.03	0.03	0.02
ter pans												
epage	0.006	-	-	-	-	0.006	-	-	-	-	-	-
vaporation	0.0006	-	-	-	-	0.0006	-	-	-	-	-	-
tal	0.2166	0.22	0.21	0.2	0.18	0.2066	0.21	0.22	0.21	0.22	0.22	0.19

Net monthly water supply in the study area can be obtained by subtracting monthly values of aggregated water loss from total monthly water available. Table 4.25 shows the net monthly water available in the canal and other sources.

Table 4.25: Net monthly water supply in the canal and other sources m^3/s

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Net water available	0.54	0.49	0.47	0.4	0.41	0.5	0.57	0.55	0.52	0.5	0.42	0.47

4.1.9.6: Comparison of Water Demand and Supply

From tables 4.18 and 4.25 the water supply at present, initial, future and ultimate water demand was compared to determine the short falls as per the objectives of the study. Table 4.26 shows this comparison and the corresponding short falls.

Table 4.26: Comparison of water supply and demand in the study area

Period	Present Year 2006	Initial Year 2007	Future Year 2017	Ultimate Year 2027
Water supply, m^3/s	0.46	0.46	0.46	0.46
Water demand, m^3/s	1.28	1.28	1.3	1.32
Water supply shortfall, m^3/s	0.82	0.82	0.84	0.86
Percentage of demand met(%)	38	38	37	36

Table 4.26 shows that the demand outstrips supply in the planning period. The inadequate supply is a potential source of conflict and can be addressed by creating awareness among stakeholders, having effective irrigation scheduling and promoting fair water allocation as is advocated in IWRM practice (GWP, 2000). Feasibility study at intake will establish whether it is viable to construct a dam at Thika river to improve the canal flow especially during dry season.

4.1.9.7 Water Demand Assessment in Matuu Water Supply area

I. Human Population

Matuu water supply mainly serves Matuu sublocation. For the purpose of estimating water demand for the supply area, the population of Matuu sublocation will be assumed to constitute the population served. Thus the urban population given in table 4.7 will be the population to be served by the water supply.

II. Livestock

Because of the inadequate supply of water, livestock served by the water supply is negligible. Therefore livestock water demand is ignored.

III. Schools, Institutional and Commercial water users

Table 4.27:Schools, Institutions and Commercial water users in Matuu town and environs

Category	Number
Day primary school pupils	4,381
Day secondary school students	1,204
Day college / polytechnic students	415
Boarding secondary school students	1,821
Hospitals – hospital beds	122
Dispensaries / private clinics	5
Churches	28
Commercial centers	
Hotels	28
Shops	140
Bars / Restaurants / Lodgings	24
Butcheries	12
Petrol stations	4
Bakery	1

Source: Matuu Town Council Business Register, Divisional Education Office, Yatta Division and Field survey, 2005

Population Projections

Annual growth rate of 1.7% for human population (given by Machakos District Development plan 2002 – 2008) and 5.5% for business / commercial enterprises (as forecasted by Matuu town council in their Local Authority Development plan (1996-2000)) have been adopted (NCA et al, 2005).

Table 4.28: Projected population for Matuu town and environs

Category	Present Year 2006	Initial Year 2007	Future Year 2017	Ultimate Year 2027
1. Human population	9,322	9,480	11,221	13,281
2. Day Primary school pupils	4,381	4,455	5,273	6,241
3. Day Secondary school students	1,204	1,224	1,449	1,715
4. Day college / polytechnic students	415	422	499	590
5. Boarding secondary students	1,821	1,852	2,192	2,594
6. Hospital beds	122	124	146	173
7. Dispensaries / private clinics	5	5	6	7
8. Churches	28	28	33	39
9. Commercial Centres				
Hotels	28	30	51	87
Shops	140	148	253	432
Bars/restaurants/lodgings	24	25	43	73
Butcheries	12	13	22	38
Petrol stations	4	4	7	12
Bakeries	1	1	2	3

Water demand projections

Per capita consumption in table 4.8 have been adopted. Table 4.29 below shows projected water demand for the water supply.

Table 4.29: Water demand projections

Category	Projected water demand m^3/day				
	Per capita consumption l/d	Present Year 2006	Initial Year 2007	Future Year 2017	Ultimate Year 2027
.Human population	40	372.9	379.2	448.8	531.2
. Day & Primary school pupils	5	21.9	22.3	26.4	31.2
. Day Secondary school students	5	6.0	6.1	7.2	8.6
. Day college / polytechnic students	5	2.1	2.1	2.5	3.0
. Boarding secondary students	50	91.1	92.6	109.6	129.7
. Hospital beds	100	12.2	12.4	14.6	17.3
. Dispensaries / private clinics	5000	25.0	25.0	30.0	35.0
. Churches	500	14.0	14.0	16.5	19.5
. Commercial Centres					
Hotels	500	14.0	15.0	25.5	43.5
Shops	100	14.0	14.8	25.3	43.2
Bars/restaurants/lodgings	500	12.0	12.5	21.5	36.5
Butcheries	500	6.0	6.5	11.0	19.0
Petrol stations	1500	6.0	6.0	10.5	18.0
Bakeries	5000	5.0	5.0	10.0	15.0
Total		602.2	613.5	759.4	950.7

Assuming a period of consumption of 8hrs per day, the present, initial, future and ultimate water demand is $0.02m^3/s$, $0.021m^3/s$, $0.026m^3/s$ and $0.033m^3/s$ respectively. From the field survey it was established that when there is normal flow in the canal, the water supply intake flow is $0.018m^3/s$. Assuming 20% water loss due to backwash and unaccounted for water, it is clear that the current supply cannot meet the demand. The percentages of water demand that can be met at different periods is shown in table 4.30.

Table 4.30: Comparison of water supply and demand for Matuu water supply

% of demand met by present supply of $0.018m^3/s$ less 20% ($0.014m^3/s$)				
	Present 2006	Initial 2007	Future 2017	Ultimate 2027
	70	66	54	42

(Note that the supply from water pans is minimal and has been ignored)

Table 4.30 shows that the supply cannot meet even the present demand. As the main water source for the water supply is Yatta canal, effective management both in the canal and water supply is necessary to improve the supply level. Water demand management practice will reduce unaccounted for water and avail more water for beneficial use in line with IWRM (GWP, 2004; Cap Net, 2002). However there is need to carry out feasibility study to identify other alternative sources to supplement the current one. These can be dams, boreholes or exploring the possibility of shifting water supply intake to Thika river.

4.1.10 Water Quality

People are said to be 'water poor' when their water supply is contaminated and cannot afford to use it or have no access to an alternative source (GWP, 2003 (2)). Yatta canal is the source of water for more secondary users than primary ones, and those who are able to access water from it have the responsibility to use it efficiently, with minimal quality degradation so that those downstream are not affected by their misuse. Implementing IWRM practice requires every water user to influence the level of pollution allowed at every stage of water use. Beyond certain level of pollution, water becomes unavailable to some uses and this negates IWRM approach.

4.1.10.1 Water Pollution Sources

The source of pollution depends on types of water use (WB, 2003(4)). The challenge to water quality is pollution emanating from the increased commercial farming, direct access of water from canal for domestic and livestock use and lack of conventional waste water treatment plant for Matuu Town.

Non-point pollution

This is caused by runoff from all categories of agriculture including irrigation, cultivation, animal feedlots, pastures and dairy farming. From the survey, 66% of respondents said they use fertilizer with 50% using inorganic type while 16% organic type. Also 70% said they use pesticides/ insecticides to control diseases.

Point pollution sources

a) Along the canal

These occur due to domestic and livestock water use mainly by direct access of water from the canal. Sources of the pollution are:

i) People washing clothes and body

It is common practice that washing is done at the canal or just a few metres from it, thus releasing wastewater to the canal. Plate 4.5 below shows a person washing cloches in the canal.

Plate 4.5: Washing clothes at the canal banks at Km 6

Attempts have been made to discourage people from washing at the canal by constructing bathrooms and wash areas, however these structures have not been used as people claim they were not consulted before construction and they do not require them. This is not an excuse for people to practice unsanitary lifestyle along the canal. In IWRM practice stakeholder awareness campaign have to be carried out before constructing such structures (Cap Net, 2002).

ii) Fetching water for domestic use

As most of the population is not served by a piped water system, water for domestic use is fetched directly from the canal using jericans and other containers. These usually pollute it as in most cases they are not washed before use.

Plate 4.6: People fetching water for domestic use at the canal at Km 29

IWRM approach requires that this source of pollution be minimized by constructing communal water points, effecting self regulation and training people on how to practice good hygiene (Cap net, 2002).

iii) Livestock

Most of the livestock drink water directly at the canal. Direct drinking of water pollutes the canal through animal faecal contamination and damages canal embankment. IWRM promotes minimum interference of the canal by livestock, as this will reduce its maintenance cost and chances of being polluted. This can be achieved by providing cattle troughs (with ball valves to minimize wastage) at points agreed upon by stakeholders.

v) Waste disposal at the household

Waste is generated through household use byproducts like kitchen waste, human or animal excreta (WHO, 1999). If not well managed at the household level, these wastes are transported to streams during rainy season, polluting them. The safe way of disposing human excreta is through pit latrines while other wastes can be disposed through burning in pits.

97% of the respondents said they use pit latrines to dispose human waste, 1% said they use septic tanks while the rest do not use any safe disposal method. This shows that most of the people safely dispose human faeces at the household level.

Effective public campaigns through meetings will raise awareness on safe disposal of wastes and promote IWRM practice as those downstream will not be threatened by pollution caused by those upstream (GTT, 1997).

b) Matuu town

i)Solid waste disposal

There are several dumping sites located within the town with the most used one being that at the southern end. When it rains, the waste is carried to Kikwa Stream.

Plate 4.7. Dumping site at southern end of Matuu town.

There are other small dumping sites within the town that also drain into this stream. The main dumping site is about two kilometers east of the town. MTC collects the waste from town regularly but the frequency needs to be increased from twice to four times a week and even to daily during rainy season so as to minimize pollution of the stream as it is the source of water to lower riparians. Also town residents need to be sensitized on safe disposal of solid waste. Efficient solid waste management will minimize levels of pollution of water bodies receiving it during rain and promote IWRM.

iii) Sewage and Waste Water disposal

The town has no sewerage reticulation system and wastewater treatment plant. Wastewater generated from business premises like bars, shops, lodgings, and hotels is disposed through unlined open drains. This has compromised public health and is a

problem requiring urgent attention. Only big hotels like Ndallas and M. G. Splendid have septic tanks, the rest of the premises are served by pit latrines.

Although MTC's strategic plan 2005 – 2010 proposes to develop waste treatment plant and sewerage system in the town, there are no immediate plans to start their implementation due to lack of funds. This negates IWRM process, as the waste is a threat to those depending on streams where the waste is disposed and should be given priority (Cap Net, 2002).

4.1.10.2 Effect of Water Pollution

From the survey, 70% of the respondents said they contracted water related diseases while 67% said they contracted water borne diseases in the last one year. The most prevalent water related disease was malaria while amoeba and typhoid were the most prevalent water borne diseases. These diseases are transmitted mainly through contamination of drinking water with domestic human or animal waste (WHO, 1999). Irrigation systems can provide habitat for the vectors transmitting water related diseases such as bilharzia and malaria (WB, 2003(3)).

4.1.10.3 Water Quality Investigation

Evaluation of physical, chemical and microbiological condition of water resource in relation to intended uses helps to check the suitability of the resource for various uses (WB, 2003(5)). It will also help to trace the sources and types of pollution so as to assist stakeholders in decision-making process. To establish the status of water quality, water samples were analyzed for physical, chemical and bacteriological quality at the following sampling points: -

i) Ianguni stream at Makutano-Ndalani
ii) NYS Borehole No.C4566 (Consumer point)
iii) Yatta Canal intake
iv) Kikwa stream near Matuu town along Thika Garissa road
v) Mathauta dam near Matuu water supply treatment works
vi) Mathauta river at Katalani- Matuu
vii) Matuu water supply treatment works (treated water)
viii) Matuu water supply at intake (along Yatta canal)

ix) Kawituuo stream near Sofia shopping center

The results of the analysis are attached in Appendix II

i) Bacteriological analysis

The results show presence of general coliforms, Escherichia Coli, Salmonella and Shigella SPP while Protozoa and Vibrio cholerae are absent at all the sampling points. This means water is polluted by faecal contamination, fertilizers prepared from animal feeds and animal feedstuffs (WHO, 1999) and contains microorganisms that cause typhoid fever, diarrhea and dysentery. Therefore water in Yatta canal and Matuu water supply is not recommended for drinking before treatment because of threat to contracting the above water borne diseases (the disinfection of water in Matuu water supply is not effective and needs to be improved).

During the interview the respondents said they have contracted amoeba and cholera in the last one year, but absence of Protozoa and Vibrio cholerae pathogens in the water samples shows that these diseases were not caused by waterborne transmission.

Hygienic disposal of animal and human waste, safe disposal of residue of animal feeds and efficient application of manures will minimize pollution of water thus reducing cases of waterborne diseases and cost of treating water at Matuu water supply, which is inline with IWRM practice (Cap Net, 2002).

ii) Physical analysis

Results show that colour and turbidity are of higher values than those recommended by WHO except at Matuu water supply treatment works (treated water) and NYS Borehole No.C4566 (Consumer point). This is because of poor land use practices like excess application of water during irrigation and ineffective soil and water conservation methods. During field visits it was established that water in the canal and feeder streams is always turbid (even during dry seasons).

iii) Chemical analysis

Conductivity, sodium absorption ratio are within the allowable WHO standards, but boron is above the allowable limits in the streams and Mathauta dam. Salinity occurs due

to presence of boron caused by high water table resulting from over irrigation and lack of drainage in Kawaani and Kauthulini.

Presence of organic matter in water from animal feedlots, decaying vegetation and waste from humans and animals is the cause of high concentrations of total suspended solids, nitrites, high permanganate value, BOD_5 and COD compared to WHO standards in all samples except in Matuu water supply (treated water). The organic matter comes from agricultural activities in the study area and catchment areas while some of the waste may be from sewage discharged in Thika river from Thika town. High concentration of Selenium is due to pollution from insecticides used in farms. This is toxic and has to be minimized through use of alternative insecticides that contain low concentrations.

Thus IWRM practice is constrained by excess pollution due to water use and poor waste disposal within the study area.

4.2 Water Use

The high water demand, low canal flows due to persistent drought, low flow in Thika river, poorly maintained conveyance infrastructure and unfair water allocation have been the main challenges faced while balancing various water uses against demand. IWRM advocate for sustainable use of water resources by considering each use and user together and creating forums for moderating among competing uses (GWP,2003(2)).

4.2.1 Irrigation

From the survey carried out, 60% of the respondents practice irrigation using canal water. The prevalence of irrigation methods used are shown in figure 4.6.

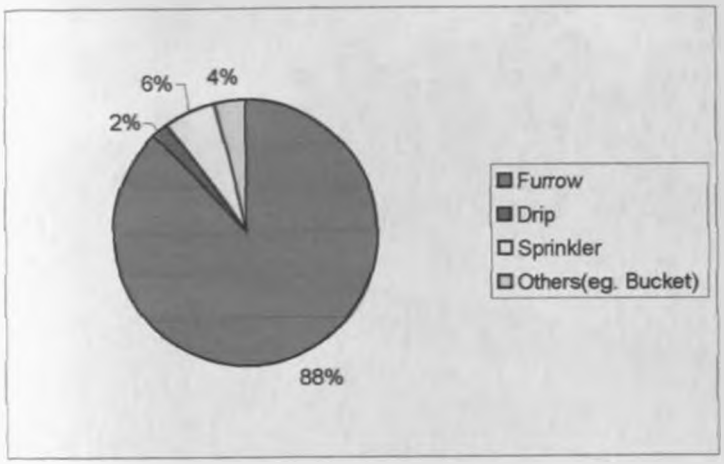

Figure 4.6: Prevalence of irrigation methods

Source: Survey, 2006

The most commonly used method is furrow irrigation because of its low initial investment cost. Those with technical personnel deployed in the farms like National Youth Service (NYS) and Kenya Wine Agencies Limited (KWAL) practice drip and sprinkler irrigation. There is no evidence of design of irrigation system in the smallholder farms.

Plate 4.8: Furrow irrigation (gravity) at Km 34

Plate 4.9: Pumping pipelines for furrow irrigation at Km 16

Plate 4.10: Drip irrigation for grapes at KWAL farm

Among the farmers practicing irrigation, 58% come from Kithimani location, 31% from Matuu location and 11% from Ndalani location. Most farmers come from Kithimani location because this is where the canal starts and water flow is reliable most of the time. This shows there is unfair water allocation among the users as their percentages depend on location. This constrains implementation of IWRM practice.

Furrow irrigation has the lowest water conveyance efficiency due to high water losses at farm level (Micheal, 1983). Improvement of irrigation water conveyance system is necessary to reduce the losses especially those due to deep percolation, as they cannot be beneficially used. While IWRM advocates for efficient water use at farm level, this is not the case as most farmers lack technical expertise and water application and extension services are not readily available (GWP, 2004).

Planting crops of high value for both local and international market motivates irrigation farming. Table 4.31 shows the type of crops grown under irrigation, their yield and average acreage.

Table 4.31: Type of crops grown under irrigation and mean annual yields

Crop type	Current mean acreage under crop (acres)	Mean acreage under crop for the last three years (acres)	Mean yield per farmer in Kg in each year			
			2003	2004	2005	
Sukuma wiki-Kales	0.19	0.22	5610	4119	1965	
French beans	0.39	0.39	5654	3962	6405	
Bananas	0.16	0.16	1244	584	666	(bunches)
Cassava	0.33	0.55	-	2670	-	
Tomato	0.3	0.35	3068	3109	2206	
Maize	0.7	0.75	2288	1372	838	
Mangoes	2.2	1.9	9100	6730	3350	
Sugar cane	0.2	0.16	3900	2300	4922	
Beans	0.4	0.5	1716	758	348	
Potatoes	0.25	0.5	750	525	300	
Pepper	0.25	0.22	380	275	-	
Oranges	5	2.75	3903	3892	380	
Spinarch	0.1	0.1	250	150	100	
Karrera	0.58	0.58	12400	6200	3100	
Onion	-	0.24	-	273	-	
Dudhi	-	0.5	10000	5000	2500	

Source: Survey, 2006

Though from the survey the average size of farms is 3.5 acres, most of the crops have their mean acreage below 0.5 acres because farmers practice mixed farming. Except for French beans and Sugar cane, the yield of other crops shows a decline despite the major rehabilitation carried out in the canal between November 2003 and April 2004. This shows improved water supply for irrigation had no effect on crop acreage or yield and therefore the problem at the farm level is not water availability but efficient water use and availability of favourable market for the produce. By practicing IWRM, water use efficiency will be promoted by ensuring only water required by the crop is released to the furrows and that farmers and other water users advocate for self regulation (Cap Net, 2002).

4.2.2 Drainage and Seepage

Drainage of irrigation water outflows is through depressions at the irrigable farms, which later flows to small seasonal streams. Seepage occurs at the canal and the farms. Underground flow from seepage, which is not lost through deep percolation, is also drained into the feeder streams. Both drainage and seepage supply water to feeder streams and rivers, making them attain permanent regime (MWD, 1984).

Streams that have achieved permanent regime include Ianguni, Kawituuo, Kikwa and Mathauta. They supply water for domestic, irrigation and livestock use to lower parts of Ndalani and Matuu locations. This has reduced pressure on the canal thus reducing its maintenance cost and water conflict, in support of IWRM approach (Cap Net, 2002).

4.2.3 Domestic

From the survey, 76% of the respondents get water for domestic use from Yatta canal, 16% from shallow wells recharged by the canal and Matuu water supply scheme. The rest (i.e. 8%) get water from other sources. This shows Yatta canal is the main source of water for domestic use in the area.

The intake of Matuu water supply is at km 52 in Kaluluini village along the canal. As mentioned in Section 4.1.1.2, the scheme is constrained by unreliable source. Consumers sometimes patrol the canal especially during dry season to ensure that there is no irrigation going on. This has been a recipe for conflict between them and the farmers (GWP, 2000). There is need to practice IWRM concept as it promotes giving domestic water use first priority when water is being allocated (GWP, 2003(1)).

4.2.4 Livestock

Figure 4.7 shows the sources of water for livestock established during the survey.

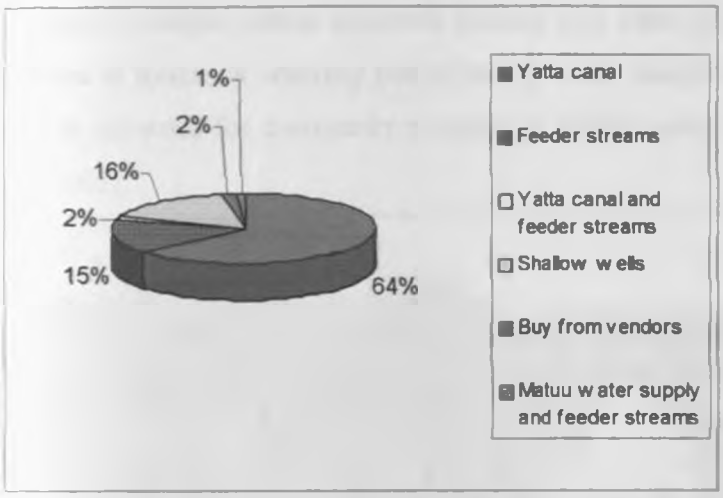

Figure 4.7: Sources of water for livestock

Source: Survey, 2006

Most of the respondents said livestock get water from the canal, which is also the source of the feeder streams, shallow wells and Matuu water supply. Therefore it means that most of the livestock depend on the canal either directly or indirectly.

Plate 4.11: Livestock drinking water at the cattle trough at Km 28

There are only 4 No. cattle troughs used by livestock along the canal. These are not enough given the length of canal and the large number of livestock in the supply area. Where there are no cattle troughs, livestock drink water direct at the canal. This destroys the canal embankment thus increasing siltation, water backflow rate and seepage, therefore raising maintenance cost hence negating IWRM practice (WB, 1998).

A forum is needed where livestock farmers and other stakeholders can decide on the location of livestock watering points before cattle troughs are constructed. Water users need to advocate for community policing to reduce canal destruction by livestock (Cap Net, 2002).

Plate 4.12: Livestock drinking water at the canal at Km 40

4.2.5 Environment

This is water used to support terrestrial and aquatic life along the canal (GWP, 2003(1)). Terrestrial services, including management of forest are essential for moderating hydrological variability and reducing silt (WB, 2004). Maintaining base/reserve flow at the canal will ensure environment water is available. The base/ reserve flow at the canal had been provided for and is given as 143 l/s. This flow is discharged to Mwita Syano river, giving it a perennial regime (MWD, 1984). Currently the flow is only available during the rainy season when its demand is minimal.

4.2.5.1 Forest

According to Divisional Forest Extension Officer, Yatta division, the forest cover in the study area is less than 1% . The Forest department has a tree nursery, which was revived in 2004 when the canal was rehabilitated. By October 2005 there were 12,000 seedlings of various tree species like kei-apple, mango, eucalyptus etc. These are sold locally to farmers. Local communities have also established eight self help groups to support tree nurseries using water from the canal. By October 2005, they had a total of 36,095 seedlings in their nurseries. The groups use water efficiently as they practice bucket

irrigation and are given extension services by forest department. The efficient water use supports IWRM process (GWP, 2004).

4.2.5.2 Advocacy of Environmental Issues

There are no environmental voices to articulate environmental issues in the area. The voices of farmers, livestock and domestic water users have completely blocked environmental voice (Cap net, 2002). IWRM recognizes environmental water needs and supports its consideration during water allocation and therefore there is need to have an environmental voice at the water allocation committee (GWP, 2003(1)). This can be a Forest Department representative or an NGO well versed with environmental water requirements.

4.2.6 Efficient Water Use Incentives

Improving efficiency in the use of water is another way to maximize the economic and social welfare derived from water as a scarce resource, and is an integral part of IWRM approach (GWP, 2004). A few farmers like KWAL, Mr Mangusa and others, who use water efficiently can be models to be emulated by other farmers if incentive instruments are introduced. These instruments, like reducing their water bill by some percentage, need to be agreed on by all stakeholders. However there are no immediate plans to introduce incentives by Yatta Canal Water Users Association (YCWUA) or Athi Water Service Board (AWSB) as the instruments have not yet been introduced in the country.

4.3 Water Management

4.3.1 Institutional

When it was completed in 1959, the canal management was under African Land Development Board (ALDEV) but was later handed over to Masaku County Council. However the council lacked sufficient funds and expertise to maintain it and therefore the Water Apportionment Board appointed Director of Water Development (DWD) as the water undertaker in 1975 (MWD, 1989). It is evident that the policy makers and other stakeholders wanted effective management of the canal so as to achieve the objectives of constructing it. The DWD delegated the management to the District Water Officer,

Machakos, who established the Yatta Canal Field Unit. The Unit had enough capacity in terms of machinery, finance and personnel. The personnel deployed as at 1st October1984 included 1No. Resident Engineer, 4No. Inspector of water supplies, 6No. Technical Assistants, 2No. Drivers, 4No. Plant Operators, 2No. Masons, 1No. Plumber and 23No. Sub Staff (MWD, 1984).

The management was further decentralized by establishing 6 camps along the canal whose responsibilities were routine water surveillance, operation and maintenance. These camps were well staffed and facilitated. However due to increased O&M cost, increase in water demand and dilapidated infrastructure together with decreasing sector funding and embargo on personnel recruitment, the Ministry could not provide service to levels expected by the farmers and other water consumers.

Water users organized themselves in 1994 and established Yatta Furrow Users Development Group, which was registered as a self help group under certificate No. MKS/CD/I/R/S/G/1383 of 8th June 1994. The group's main objective was to assist in annual maintenance activities through mobilizing water users to participate in desilting and bush clearing. The annual maintenance programme received a lot of support from water users and since then, the canal has been closed annually for the exercise. The group did not take over the management of the canal despite being supported by the Ministry of Water and Irrigation because it lacked capacity.

The group's name changed to Yatta Canal Water Users Association (YCWUA) after being registered under the Societies Act Cap 108. The change was motivated by the new Water Act 2002, which provided for establishment of water service providers to manage water and sewerage services in the country. Elections for the Association were held on March 2004.Ten zonal committees each consisting of nine elected members and a central management committee (of 22 members) consisting of chairman, treasurer and secretary (elected direct by all water users), chairmen of zonal committees, NYS, KWAL and ex-officials were formed (MWI, et al, 2005). The Association's decentralized policy of zonal management promotes IWRM practice but the central management committee's size makes it difficult to build consensus during meetings.

The Association has now been registered under the Trustee (Perpetual Succession) Act Cap 164 and the Trust Deed was issued on 2nd September 2005(WA&A, 2005). The Association was changed into a Trustee to attract funding and qualify for tax exemptions for any major purchases of project's materials, plant and equipment (MWI, et al, 2005). The new name of the Association is Yatta Canal Water Association Trust (YCWA Trust). The Trust's overall objective is provision of water and sewerage services in areas described in the agency agreement with AWSB and to spearhead community efforts to conserve and protect the water catchments to ensure sustainability and availability of water for the residents of Yatta .The Trustees represent the following zones and institutions:

A.Sub locations

i) Mamba ii) Ndalani iii) Kithimani iv) Kithendu v) Kakumini vi) Matuu town
vii) Matuu viii) Kaluluini ix) Katulani x) Kyasioni xi) Kitheuni

B.Others

xii) Institutions – Churches, Schools etc xiii) Matuu Town Council
xiv) Large scale farmers – NYS, KWAL etc. (WA&A, 2005).

Zonal committees are supposed to make sure that irrigation schedules are followed and water flow in the canal is not interrupted. However this has not been the case as water demand is high and farmers would not want their crops to dry thus negating the IWRM practice.

The central management committee, called Board of Trustees (BOT) consists of the following members: -

i) Chairman ii) Secretary iii) Treasurer iv) Chairmen of each of the Zonal Committee

The work of BOT is to give policy direction and regulate use of water along the canal. However the Trustee has not fully taken over the canal management as the Service Provider Agreement (SPA) has not been signed with AWSB. (Note that when the questionnaire was being administered to respondents, the management was in the transition stage of changing from YCWUA to YCWA Trust and the respondents were only aware of YCWUA).

During the survey, the respondents were asked whether they are aware of YCWUA; 75% said they are aware of it while 25% said they are not aware. When asked whether YCWUA is effective, 13% said it is effective while 62% said it is not effective, the rest were not aware of it. This shows that although most of the water users know the Association exists, it has not been active enough for the water users to appreciate its existence. As one of the main challenges facing implementation of IWRM is lack of support from all levels, the Association needs to strategize so that it can get support of the water users to succeed (GWP, 2004).

When respondents were asked to propose how to make YCWUA effective, they gave several proposals. Table 4.32 shows the proposals made by respondents. YCWUA has proposed to increase water charges for those using water for irrigation from Kshs.300 per half hectare per year to Kshs.400 per person irrigating in a group with 50mm diameter pipe connection, Kshs.3, 200 for those with 50mm diameter individual connection (gravity) and Kshs. 5,000 for those with 50mm diameter individual connection (pumping). Water users prefer the management to remain with MWI because they fear the change to the unknown. The resistance to change is also due to increase in charges without improving the service. Effective consultation is needed among the stakeholders before a major decision (like increasing water tariffs) is made. This is why water users wanted regular meetings to be educated on the work of YCWUA. The meetings are necessary as the Association need their support to succeed (Cap Net, 2002).

Table 4.32: Methods of making YCWUA effective

Proposed methods of making YCWUA effective	Number of respondents	Percent of respondents
1.Do not know	60	51
2.Officials to talk to people-call meetings	4	3
3.Be given full mandate by AWSB	1	1
4.More women to be included	2	2
5. Training of water users	2	2
6. Management of water be given back to the Ministry of Water and Irrigation	15	13
7. Educate on the functions of YCWUA and provide them with offices	5	4
8. Officials should work in a coordinated manner	10	8
9. Monitoring of YCWUA	3	3
10. Involve local people in decision making	6	5
11. Young men to manage	3	3
12. Having elections regularly	3	3
13. Adequate finances and technical staff	1	1
14. Planting trees and regular cleaning of the canal	1	1

Source: Survey, 2006

Others felt that officials should work in a coordinated manner, local people should be involved in decision making and that women and the youth be involved in water management. IWRM practice promotes full participation of local people especially women and the children in all levels of management (GWP, 2000). The Association needs to formulate ways of ensuring that all water users participate in water management in order to succeed.

Some respondents proposed that inorder for the Association to be effective, it needs adequate technical staff. Currently YCWUA is using the MWI staff deployed in the canal because they have not fully taken over and signed agreement with AWSB. There is need for the Association to either employ its own staff or have the MWI staff seconded to it to effectively supervise them and improve services offered and thus develop good relationship with water users.

4.3.2 Water Demand Management

Improving efficiency in the use of water is another way to maximize the economic and social welfare derived from water as a scarce resource, and is an integral part of an IWRM approach (GWP, 2004). Before a decision is made to construct new and expensive infrastructure, the first step should be to look for opportunities to improve water use efficiency –either by reducing wasteful usage or through reallocation (Cap Net, 2002).

4.3.2.1 Canal Conveyance System

Yatta canal, which is the main canal, is unlined except for a 210 m length. The canal passes through well-drained sandy loam and red clay soils from intake to km 46 (in Kithendu) (MWD, 1984). Michael and Bhattacharya (2003) argue that well-drained soils have relatively high infiltration rate compared to poorly drained soils. The lower part of the canal consists of poorly drained black cotton soils with a tendency to crack on drying. Infiltration rate is high in this section because of water intake through the cracks (Das, 2002). Primary, secondary and tertiary canals in the farms are also not lined.

Water losses through evaporation, seepage and deep percolation occur along the main, primary, secondary and tertiary canals. Water loss through deep percolation and evaporation is not beneficially used and there is need to control it as this negates IWRM practice(Cap Net, 2002).

Water demand management practice is constrained by lack of operation manual for the canal system as it assists in water scheduling and ensures fair distribution among the uses and users, checks on the misuse and provides a mechanism for early detection of system malfunction (ASCE, 1976).

A well-programmed maintenance will keep the canal conveyance system and control structures working at optimal levels. Regular maintenance activities of desilting, bush clearing, grading of access road and cutoff drain, testing and repair of control structures (like flumes, overpasses, Mathauta bifurcation box, off takes, intake gates and sluice valves) should be carried out and good record kept for future reference. This will

minimize non-beneficial water losses, increase the system operating lifespan (ASCE, 1976) and promote IWRM practice. There is no comprehensive maintenance programme that has been prepared and agreed on by the stakeholders as proposed by Cap Net (2002).

4.3.2.2 Farm Level

From its completion, Yatta canal has experienced high demand among various uses and users. The quantity of water available dictates the acreage under irrigation at any given time. During the dry season, water hardly reaches end of the canal. In such times the domestic and livestock water use are given priority (which is what IWRM practice advocates for). But farmers on the upstream at Kaawani (especially between Km 11 to 23) irrigate at night for fear of being arrested despite this use not having priority. Irrigating at night is good water demand management practice though, as there is no water loss through evaporation.

Generally there is minimal water demand management practice on the lower hill part of the canal as water flows by gravity and irrigation is by furrow system, which is characterized by high water losses as stated by Withers and Vipond (1974).

Efficient water use at farm level

The respondents were asked the methods they use to economize on water use at farm level. 27% said they economize through farm terracing, 20% through practicing deficit irrigation while 28% said either through timely removal of weeds, ensuring good soil structure or combining cropping with animal husbandry. These promote IWRM concept since water loss is minimized as it is released only when required, competition with weed is minimized and is used maximumly when cropping is combined with husbandry (Prinz and Malik, undated).

The high water demand for irrigation against a fluctuating supply calls for efficient water use, which can be achieved by practicing water demand management. Effective water demand management at farm level requires that non-beneficial water losses are minimized as much as possible. Improvements on irrigation water use efficiency can make available significant quantities of water for other users (WB, 2003(2)). Irrigation scheduling at farm level is rigidly set among the water connection users. Sharing water

on a rigid rotational basis often leads to wasteful use, since users will generally take their full share at each turn irrespective of the water needs of their crops (WB 2003(2)).

Introducing pricing policy

Theoretically, correct tariffs will not generate financial sustainability for utility if consumers know services will be provided even if they don't pay (GTT, 1997). Water demand can be effectively managed by a pricing policy that makes water wastage expensive. Tariff structure should be such that farmers treat water as a finite good which needs to be economized while at the same time it should not make water too expensive to deprive the poor and vulnerable groups from use (GWP, 2000).

Since the expiry of water undertakership by the DWD on 30th June 2004(MWD, 1984), the YCWUA was supposed to collect revenue from irrigation water use. This has not started as it intends to change the charges but farmers are resisting. Further while the proposed tariff structure is supposed to discourage misuse of water and promote efficient use, this is not the case, as those abstracting water through gravity will pay less than those pumping. This negates IWRM practice as those vulnerable to misuse are encouraged to use water more than those who will have to meet extra cost of pumping and likely to use water efficiently. The tariff policy needs to be revised so that those likely to misuse pay more than those likely to use it efficiently.

4.3.2.3 Household Level

Water is fetched directly at the canal which is tedious and expensive and therefore does not allow for misuse. Therefore water demand management is well practiced as water is efficiently used.

When the respondents were asked whether they are aware of methods they can use to economize water at household level, 54 % said yes while 46% said no. Figure 4.5 shows the methods used to economize on water use. This shows that the most common water demand management practice in the area is water reuse. However the other practices are also very effective in managing demand.

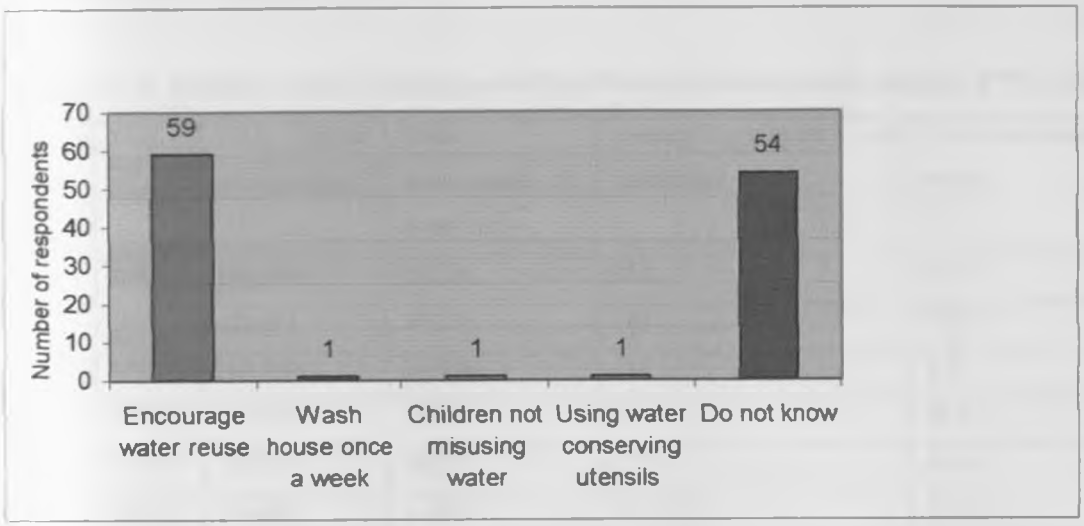

Figure 4.8: Methods used at the household to economize water use

Source: Survey, 2006

4.3.2.4 Matuu Water Supply

Most of the connections are standpipes which are used communally by plot residents or members of the self group (the only exception to this is Ndallas hotel which uses showers and has conventional water distribution system). This minimizes misuse and promotes demand management as water is fetched at the standpipe unlike where the connection is at house level and water flows through the taps at the kitchen or showers.

Most of the houses in the supply area are iron roofed. In order to supplement the supply the residents can be encouraged to construct water tanks to harness rainwater. Rainwater harvesting is a water conservation technique that can greatly reduce the water demand from the water supply especially if water is stored and used during the dry season.

Operation and Maintenance

As earlier stated, the water supply doesn't meet the demand and therefore available water should be used efficiently. It also has no operation manual or maintenance programme. Water demand management requires the water supply to have an operation manual to effectively implement a rationing programme, respond quickly to bursts and pump breakdown and thus reduce unaccounted for water (UFW) (UN-Habitat, 2002). Response is also slow because materials for repairs have to be requested from Machakos district water office. Other causes of UFW are malfunctioning consumer meters, illegal

connections and error in meter reading by readers. Table 4.33 shows the annual UFW in the water supply against water produced, between 1995 and 2005.

Table 4.33: Annual trend of Unaccounted for Water in Matuu water supply, 1995- 2005

Year	Total water produced (m^3)	Total unaccounted for water (m^3)	Average number of consumers	% of unaccounted for water
1995	190,786	21,236	167	11.1
1996	229,051	24,226	180	10.5
1997	194,269	20,726	184	1.6
1998	187,186	18,637	184	10.0
1999	168,195	20,237	179	12.0
2000	194,663	11,485	315	12.1
2001	198,438	29,330	296	14.8
2002	122,294	19,377	263	15.8
2003	128,233	23,194	247	18.1
2004	209,243	43.836	269	20.9
2005	190,117	39,821	380	20.9

Source: Matuu Water Supply Office, 2005

The percentage of UFW doubled between 1995 and 2005. This is not good practice in water demand management since systems efficiency should be as high as possible to minimize any losses. However the 20% unaccounted for water is still low compared to the national average of 50% (NWRMS, 2003). The water supply also requires a maintenance programme to assist in planning for pump service, replacing filter media and old pipes, washing tanks, etc.

4.3.3 Water Rights

The canal was constructed to supply water

a) for irrigation, domestic and livestock along its length

b) in the upper reaches of Mwitasyano river to give it a permanent regime, for domestic and livestock use

c) for domestic and livestock use to seasonal rivers along its length. (MWD, 1989).

d) to Matuu town (MWI, et al, 2005).

The water permit authorizes abstraction of water from Thika river at a rate of 0.283 m^3/s for domestic use and 1.416 m^3/s for general irrigation use (totaling 1.699 m^3/s) (MWD, 1989). Water management is fragmented as AWSB is incharge of water and sewerage services in Machakos and Thika districts where Thika river and Yatta canal are situated while water allocations and permit management along the river are under the jurisdiction of WRMA Tana basin whose regional office is in Embu. Fragmented management constrains implementation of IWRM as different institutions, some of which might be in conflict with each other, make decisions on the same project (Cap Net, 2002).

Only water used for irrigation along the canal and Mathauta river is paid for while domestic and livestock use is free of charge (MWD, 1984). The requirements for application of water abstraction for irrigation are

a) Identity Card
b) Proof of Landownership
c) List of group members (if applicable)
d) Registration Certificate of group
e) Membership of Association

These documents show that one has to be a member of a group or be a landowner to apply for a permit. Thus those who don't own land (usually women and the poor and marginalized) and are not members of a group are discriminated against during authorization. IWRM is about removing barriers to social discrimination to water use (Cap Net, 2002). IWRM concept was initiated because of the need to have equitable access and distribution of water resources to all water users and uses, including women, the poor and marginalized for sustainable development (GWP, 2003(2)). Inorder for YCWA Trust to practice good IWRM, it needs to remove those conditions that discriminate on water allocation. Conditions like proof of land ownership and membership of a group could be replaced with a letter from landowner authorizing use of land by applicant.

YCWA Trust needs to establish a wider stakeholder consultation on how water will be allocated and reallocated as is a prerequisite for good IWRM practice. Water has to be considered as both an economic and social good and it should be allocated to the highest

value uses after taking into account social and environmental as well as economic considerations (GWP, 2000; Cap Net, 2002).

Matuu water supply

Matuu water supply is classified as urban water supply by MWI. Water charges are based on gazetted rates for November 1999 and are shown in table 4.34.

Table 4.34: Current tariff structure in Matuu water supply scheme

Consumption range (m^3) per month	Tariff (Kshs) per month
0 – 10	200.00 (flat rate)
11 – 20	25.00
21 – 50	30.00
51 – 100	45.00
101 – 300	75.00
300 and above	100.00

Source: Neolink Consulting Associates (NCA) et al, 2005

There is no special tariff for the poor and most of them are served at two water kiosks where water is sold at Kshs. 2 per 20-litre jerican (this is the gazetted rate). Water accessibility is discriminative against them as this rate is higher than that charged for flat rate or metered connection, which is not a good IWRM practice (GWP, 2003(2)).

4.3.4 Water Logging

It is not common in the area because the soils are well drained in areas experiencing continuous flow. During the field survey, it was established that areas with poorly drained soils experience water logging during rainy seasons that last less than four days.

Water logging blocks the soil pores which crops use for nutrient uptake reducing the crop yield. Also water on the surface is lost through evaporation, a non-beneficial water loss. The reduced crop yield and non-beneficial water loss negates IWRM practice, as water use is not maximized to benefit the users for socio economic development (GWP, 2003(2)).

4.3.5 Water Conflict Management

Much of IWRM practice is essentially about conflict management (GWP, 2000). IWRM practice is the best way of solving conflicts since all stakeholders will influence water allocation and management between uses and users (Cap Net, 2002). Basically conflict exists between the following groups:

i) Upstream and downstream farmers along the canal

ii) Thika river abstractors (above canal intake) and canal water users.

iii) Farmers and Matuu Water Supply Consumers

iv) Irrigation farmers and livestock/domestic water users.

v) YCWA Trust and water users.

When respondents were asked to state their relationship with upstream water users, 68% said it was bad while 32% said it was good. Table 4.35 gives the reasons why most of the respondents felt their relationship with upstream users was bad.

Table 4.35: Reasons for bad relationship with upstream users

Reason for bad relationship	Number of respondents	% of respondents
1.Canal closure by upstream users	55	47
2. Water use at night	1	1
3. Upstream users use big pipes thus reducing flow	3	3
4. Upstream users use more water than downstream ones	12	10
5. Jealous they report when we use water	1	1
6. They pollute water	7	6

Source: Survey, 2006

Most of the people felt that the upstream users block the canal so as to get more water while those downstream have none. They also pollute water for downstream users. Those upstream said downstream water users assume they block the water during dry season and they come to block their connections when they lack water and that they are jealous and do not participate in canal cleaning.

Other causes of conflict identified by the respondents other than those between upstream and downstream users include mismanagement, unfair water allocation, ineffective rationing programme and unfair water charges. These can be solved through an open and transparent consultative process among all stakeholders, trying as much as possible to build consensus on fair water allocation and agreeing on water charges. Such forum has not been established hence this has negated IWRM practice (Cap Net, 2002).

Since there is no forum to discuss the conflicts, the interviewees were asked to explain the methods used to solve the conflicts. Table 4.36 shows methods used to solve the conflicts when they occur.

Table 4.36: Methods used to solve water conflicts

Method for solving conflict	% of interviewees
1. Keep quiet	2
2. Never solved	12
3. Village elders	3
4. Inform member of parliament	8
5. Agreements- come together and solve, the arrogant ones are fined	18
6. Demonstrate and fight each other	3
7. Report to Resident Engineer, YCWA Trust or District Water Officer	16
8. Report to Provincial Administration-District Officer	6

Source: Survey, 2006

While majority come together and solve their conflicts or use MWI /YCWA Trust officials, there are many who said that the conflicts are never solved. A forum needs to be formed by YCWA Trust to address the conflicts and the government (MWI, AWSB, Provincial Administration etc) be the arbitrator of major conflicts (GWP, 2000).

4.3.6 Coordination among Water and Related Sectors

Water related problems are difficult to solve using conventional, single sector approaches. Some of these examples are groundwater over abstraction, water borne

diseases, land and water degradation and damage to ecosystem (GWP, 2004). IWRM brings together coordination among individual sectors, plus stakeholder participation to achieve effective local management for sustainable socio-economic development (Cap Net, 2002).

No coordination exists in the study area among water and related sectors like forest, land, agriculture and environment though this is not the case at national level where efforts are being made to effect coordination. The water sector is to be represented in the Board of Directors of Kenya Forest Service (Forest Act, 2005) and that water department is the lead agency of water pollution in National Environment and Management Authority (NEMA) (EMCA, 1999). Strategy for Revitalizing Agriculture 2004 – 2014 identifies water conservation, efficient conveyance system and use as key inputs to revitalizing agriculture (MOA and MOLFD, 2004). This can be achieved if a forum for coordination of water and agricultural activities exists. One of the reasons for formulating National Policy on Water Resources Management and Development (Sessional Paper No 1 of 1999) was lack of proper inter-linkages with other water related sectors.

Lack of coordination has been a major constraint in implementing IWRM concept as sectoral projects end up not being supported by other sectors. A coordination committee should be established in Yatta Division to discuss and accept all water related projects that affect Yatta Canal. Members of the committee could include

i) Head of government departments for water, forest, land, livestock, agriculture and provincial administration (as chair). Fisheries and environment departments need to be represented in the committee, as currently they do not have representatives at the division

(ii) Non governmental organizations active in water issues like Plan International, World Vision and German Agro-Action.

4.4 Communication and Stakeholder Participation

Communication helps all stakeholders to construct a realistic picture of water resources availability, use and management. Trying to 'sell' decision made behind closed doors will

not work. IWRM strategies are much more likely to be achieved if women are active participants and decision-makers (GWP, 2000).

Participating platform which entails wide range of forums e.g. informal meetings, workshops, public meeting, focus group interviews, policy dialogues, media events, teaching in schools, universities and colleges can help different groups meaningfully understand and support water demand management issues necessary for IWRM implementation (UN-Habitat, 2002).

Most of the constrains experienced in Yatta Canal like misuse of water by over irrigation, water pollution and ineffective water management are due to poor stakeholder participation. Water users are not made to actively participate in decisions concerning water use. An independent organization, like AWSB, National Irrigation Board, or a reputable NGO can be mandated to effectively sensitize various stakeholders on the benefits of active participation in decision-making process. The MWI needs to monitor and ensure that stakeholder sensitization exercise is successful.

4.4.1 Awareness of Reforms

The challenge facing IWRM is to change conventional practices, attitudes and professional certainties (Cap Net, 2002) to promote decentralized democracy into how water is planned, developed and managed with emphasis on stakeholder participation. These changes can be supported by legal and policy change after which they are institutionalized and implemented. The country's legal and policy changes have been finalized as the National Water Policy and the new Water Act 2002 are in place. However when the respondents were asked whether they are aware of the policy, only 7% said they are aware while 93% said they are not aware. When asked whether they were aware of the new Water Act 2002, 16% said they were aware of it while 84% said they were not aware. This shows that most of the water users are not aware of the reforms going on in the water sector. This could be due to lack of information, understanding, appreciation or motivation/incentives. Developing advocacy programmes targeting the stakeholders can solve the problem of low level of awareness of reforms (GTT, 1997).

4.4.2 Types of Stakeholders

Stakeholders include: -

i) Domestic and Livestock Water Users

- Local Community who depend on water at the canal
- Livestock farmers depending on water at the canal
- Matuu town residents
- Businesses in Matuu town, Sofia, Ndalani, Kauthulini, Kakumini, Kithendu and Kateki Shopping Centres. These include hotels, bars, shops, supermarkets, petrol stations, residential houses etc.
- Children homes like Mully's Children Home.
- Institutions i.e. Primary and Secondary Schools and Colleges.
  e.g. Kithendu Secondary School, Matuu G.H.M. Memorial Girls Secondary School, Matuu High School, Makivenzi Girls Secondary School, Kivandini Secondary School, Kilango Secondary School etc and several Primary Schools
- Hospitals e.g. Matuu Sub-district hospital, Matuu Nursing Home
- NYS Service men and women and staff members
- KWAL farm staff.

ii) Irrigation Farmers

- Smallholder irrigation farmers at Mamba, Ndalani, Kithimani, Kauthulini, Kakumini, Kithendu, Kyasioni, Kitheuni Sublocations located within area of supply of water from the canal.
- Large scale irrigation farmers i.e. NYS, KWAL, Mangusa and Kitana farms (all situated within the first 12Km of Canal).

iii) Non Governmental Organizations

- German Agro-Action
- World Vision International
- Plan International

iv) Government Departments and Local Authorities like Matuu Town Council

v) Local Politicians like the Member of Parliament, councillors from Kithimani, Ndalani, Matuu and Ikombe Locations.

vi) Opinion leaders like senior civil servants and senior citizens from the area.
vii) Policy makers like MWI, AWSB, WRMA, Provincial Administration
viii) Planners like Engineers, Geologists, Hydrologists, Statistians, Sociologists etc.

The BOT has representatives from smallholder and large-scale irrigation farmers, institutions and Matuu Town Council. The membership of the Board is based on Stakeholder representation along the canal only. Other stakeholders like planners (professionals), women, the poor and marginalized, domestic and livestock consumers are not represented.

4.4.3 Participation in Planning, Development and Management

Participatory decision making process by different user groups influences strategies for water resources planning, development and management, bringing additional benefits, as informed users apply self regulation to promote efficient water use for sustainability (Cap Net, 2002).

When the respondents were asked whether they participate in water management, 33% said they do while 67% said they don't. The reasons given for not participating are:
i) they are not given chance to participate
ii) upstream users do not attend meetings so there is no need to participate(as they will not implement decisions of meetings they have not participated in)
iii) there are people who are incharge of managing water
iv) women are supposed to keep quiet
v) no meetings are held
vi) they hardly get any water
Failure by the majority of stakeholders to participate in management denies them the opportunity to influence decisions made by managers and policy makers on the water issues affecting them, a practice that is not advocated in IWRM approach. The women are supposed to keep quiet and thus they have no opportunity to participate in decision-making. Major decisions on planning, development and management have always been made by planners, policy makers and politicians.

Women Stakeholders Participation in BOT

There is no special consideration for women in the membership of BOT and Zonal Committees. This is so despite the fact that they are responsible at household level to ensure water is available for domestic use (Cap Net, 2002) and that one of the principles of IWRM recognizes that they play a central part in provision of water (GWP, 2000). Only one woman, elected competitively, is a member of BOT among the sixteen trustees (WA&A, 2005). For the IWRM practice to be implemented, there should be special representation of women interests in the BOT.

The poor and marginalized

IWRM advocates for views of the poor and marginalized stakeholders to be respected (GWP, 2003(2)). There is no evidence to show that this group of stakeholders have been involved in planning and rehabilitation of Yatta canal in the past despite them being the majority of the beneficiaries. The government has a responsibility to ensure that these people are well represented in all levels of decision making from planning, development and management of both Yatta Canal and Matuu Water Supply (Cap Net, 2002).

Planners

Though not represented in the BOT, they have had influence in development and management because of the importance of their professional advice. However it is important to include them in the BOT, as they will help in providing professional advice during meetings.

NGOs

World Vision and Plan International have been supporting digging of shallow wells along the feeder streams. These structures have helped to relieve pressure on water demand from the canal. On the other hand, German Agro-Action has been supplying food for work for the same projects. These are major stakeholders that are not represented in the BOT (WA&A, 2005). The Trust Deed does not include them because those who were involved in its preparation ignored the role NGOs play in water development programmes in the area. The BOT therefore continues to miss the vast experience and possible financial support from the NGOs. They need to have one representative in the BOT.

4.5 Capacity Building

IWRM practice requires capacity building of professionals in the full range of low-cost and appropriate technologies for water, irrigation and sanitation. Also, capacity building is required at all levels for democratic and demand responsive approaches, especially at the community level to which local planning of resource use, and management and maintenance of services, will increasingly be devolved (GWP, 2003(2)).

4.5.1 Capacity Requirements

Personnel such as Engineers, Hydrologists, Geologists, Pollution Control Officers, Public Administration Officers, Sociologists, etc are needed to implement IWRM. Yatta canal, being a Unit, might not support the full personnel capacity needed for implementing IWRM because of financial constraint. However full time services of a Water/ Irrigation Engineer, Hydrologist, Pollution control officer and Sociologist are needed to improve on the management and raise awareness of stakeholders. There should also be support officers qualified on operation and maintenance of canal and water supply (for Matuu town). AWSB needs to build capacity to support water supplies under its area of jurisdiction especially for personnel not needed on full time basis. Public Administration/ Relation Officers, Poverty Reduction specialists, Water Economists and Institutional Management specialists need to be available at AWSB for use by YCWA when they are needed.

4.5.2 Existing Capacity

The capacity existing in terms of personnel, vehicle, plant and equipment is as follows:

a) Yatta Canal Field Unit

i) Personnel

Table 4.37: Personnel in Yatta Canal Field Unit as at 6th February, 2006

Designation	No. of staff members
1. Resident Technician Engineer	1
2. Senior Inspector of Water Supplies (Deputy RE)	1
3. Charge hand	1
4. Plumber	1
5. Meter reader	1
6. Clerk	1
7. Cleaner	2
8. Watchman	1
9. Mason	1
10. Line Patrollers	10
11. Intake guards	2
Total	22

Source: YCFU, 2006

ii) Vehicle Plant and Equipment

Table 4.38: Vehicle, Plant and Equipment at Yatta Canal Field Unit as at 6th February 2006

Type of Vehicle Unit/Equipment	No. Available
1. Concrete Mixer	1
2. Power Saw	2
3. Poker Vibrator	1
4. 4WD Pick up	1
5. Motor Cycle	1
6. Bicycles	8

Source: YCFU, 2006

The vehicle, plant and equipment were found to be operational during the field survey.

b) Matuu Water Supply

i) Personnel

Table 4.39: Personnel in Matuu water supply as at 6th February 2006

Designation	No. of staff members
1. Senior water supply operator	1
2. Water Supply Operator	1
3. Pump attendant	2
4. Chemical attendant	2
5. Clerical officer	1
6. Plumber	2
7. Cleaners	2

Source: MWSO, 2006

ii) Vehicle, Plant and Equipment

Table 4.40: Vehicle, Plant and Equipment in Matuu water supply as at 6th February 2006

Type of vehicle, plant and equipment	No. Available
1. Motorbike	1
2. Bicycles	5
3. Wheel barrows	2

Source: MWSO, 2006

The capacity for vehicle, plant and equipment is fairly adequate except that telephone services and computerized billing system are lacking. There is need to install telephone services and improve the billing in order to serve consumers effectively.

5. SUMMARY, CONCLUSSION AND RECOMMENDATIONS

5.1 SUMMARY

5.1.1 General

Yatta canal, which is situated in Yatta division, Machakos District, and about 100 Km from Nairobi along Thika Garissa road, is 60km long. It was constructed by Mau Mau detainees from December 1953 and officially opened on 18th September 1959 having costed Kshs. 6,499,680 (US$324,982) (MAAW, 1962). Its source of water is Thika River located in Tana River basin and drains into Mwitasyano river at the boundary of Kitui and Machakos districts. It serves Kithimani, Ndalani and Matuu locations of Yatta Division and Kitheuni and Kyasioni Sub locations of Ikombe location, Katangi Division.

It is unlined except for 210m length (first 80 from intake to washout gate and 130m at Mathauta river bifurcation point). It is authorized to abstract 1.699 m^3/s of water with 0.283 m^3/s for domestic use and 1.416 m^3/s for irrigation. Main objectives of constructing the canal were to supply water:

a) For irrigation, domestic and livestock along its length.
b) In the upper reaches of Mwitasyano river to give it a permanent regime, for domestic and livestock use.
c) For domestic and livestock use to seasonal rivers along its length.
d) To Matuu town and environs.

(MWD, 1989; MWI, et al, 2005).

The seasonal streams made perennial by the seepage and orifices in the flumes along the canal include Ianguni, Kawituuo, Kikwa and Mathauta river. It is the only source of livelihood for inhabitants and those along Mwitasyano river. Over the years, there has been reduced flow in the canal especially during dry seasons, making farmers and other water users move upstream to Thika river to restrain those abstracting water for irrigation. Sometimes the DWD has been imposing total ban on irrigation along the canal and Thika river. Also Matuu town, whose source of water is Matuu water supply with its intake at the canal, has lacked water for several months.

The purpose of the study was to assess the level of efficient water use and establish whether the stakeholders participate in the management of water resources for sustainability as per the IWRM practice (GWP, 2000). The study also aimed at establishing whether the supply is adequate and if not estimate the deficit. It covered both Yatta canal and Matuu water supply.

5.1.2 Water Resources Planning

5.1.2.1 Socio economic Issues

Yatta division has a poverty rate of 67.5% which is higher than average rate for the district (66.2%) (MPND, 2002). From the survey, the mean monthly income per household is Shs. 15,337 while the average number of people in a household is seven, thus each person lives on Kshs. 73 per day, which is less than a US Dollar (Kshs. 75) and hence below poverty line as per United Nations Classification.

No poverty reduction strategies have been introduced in Yatta canal which promotes equity in water use, like prioritizing development of water resources to populations at water risk (those more vulnerable to drought and water scarcity), for instance those around Matuu town and at canal end (GWP, 2003(2)). Also strategies promoting IWRM practice like protection of traditional and customary water rights enjoyed by the poor (for example advocating for reservation of shallow wells and feeder stream flows recharged from the canal) need to be supported by all stakeholders (Cap Net, 2002).

Main source of income is farming (55% of respondents said farming is their main source of income). As the area is ASAL, farming is practiced through irrigation along the canal, confirming that it is the main source of livelihood for the area.

One of the principles of IWRM recognizes that water has an economic value (GWP, 2000) despite the fact that it is also a basic right to have access to clean water and sanitation at affordable price (GWP, 2004). From the survey, 78% of respondents said they are willing to pay more if services are improved but they did not propose a higher tariff than what is now proposed by YCWUA. This may be due to high poverty levels in the area and poor services currently offered.

One of the challenges facing implementation of IWRM is lack of entry point (GWP, 2004). Social groups are forums that can be used to assess the community's cohesiveness and be the entry point for IWRM. When asked whether they are members of at least one self help group 73% of respondents said they are, showing they are cohesive enough to implement IWRM. YCWUA can promote the self-help group approach in its activities to get support of water users to implement IWRM.

IWRM provides positive policies, which address women's specific needs by equipping and empowering them to participate at all levels of water resources programmes (GWP, 2000). Though women are active in self help groups (90% of respondents said women are engaged in leadership of self help groups), they do not participate in planning for the rehabilitation of the canal or Matuu Water Supply. There is only one woman trustee out of sixteen in the BOT of YCWA Trust. In order to promote IWRM practice, there is need to have special representation of women in the BOT.

5.1.2.2 Integrated Approach

IWRM approach in designing and managing infrastructure makes it possible to capitalize on potential synergies, like developing water supply schemes that provide water for domestic and livestock use (GWP, 2004). The main purpose of constructing Yatta canal was to provide water for irrigation, domestic and livestock and to date it has continued to serve these uses thus maintaining integrated approach (MWD, 1984).

5.1.2.3 Water Resources Assessment

Availability of accurate and reliable water resources data, to be used by decision makers, is an important instrument for practicing IWRM (GWP, 2004). Data on daily rainfall, evaporation and mean canal flow for the past record of 24,11 and 45years respectively was obtained for RGS 4CC3 from MWI and analysed using Gumbel's statistical distribution to obtain dependable monthly rainfall (at 80% exceedence probability), optimum monthly evaporation rate (20% exceedence) and dependable mean monthly flow (80% exceedence). Other sources of water are:

(i) Boreholes No. C4566 (at NYS farm) and C1493 (near Kithimani shopping center) with yields of 6.28 m^3/hr and 9.06 m^3/h respectively.

(ii) Two water pans constructed to supplement water supply from the canal for Matuu town during dry season, with a joint capacity of 18,000m^3

(iii) Several shallow wells which are located at feeder streams and are recharged from seepage of the canal and therefore their discharge depend on canal flow.

Analysis of water demand and supply in Yatta Canal

Human, livestock and irrigation water demand was calculated based on population census and irrigated area of 800ha (MWRMD, 2003(1)). Water supply was obtained from dependable mean monthly canal flow for RGS 4CC3, water pans and boreholes. Water losses due to seepage and evaporation rate for the canal and water pans were subtracted from the supply to obtain net water supply. Net water supply was compared with demand to determine the short falls as an important objective of the study.

The initial, future and ultimate demand is 1.28, 1.3 and 1.32m^3/s respectively while the water available is 0.46m^3/s. Therefore the demand outstrips supply within the planning period. The inadequate supply is a potential source of water conflict and can be addressed by creating awareness among stakeholders so that they support irrigation scheduling and promote fair water allocation as is advocated in IWRM practice.

Analysis of water demand and supply in Matuu Water Supply

Water demand was estimated for domestic use (using human population) as livestock served by the water supply is negligible. Present, initial, future and ultimate water demand was estimated as 0.03m^3/s, 0.021m^3/s, 0.026m^3/s and 0.033m^3/s respectively. Main water source for the scheme is the canal but two water pans (of 18,000m^3 capacity) were constructed to supplement the canal source during dry seasons. From the field it was established that under normal flow, the scheme receives 0.018m^3/s from the canal. Assuming 20% water loss due to backwash and unaccounted for water, the water supply supplies 0.014m^3/s to the consumers, showing it cannot meet the demand within the planning period. Effective management in the canal and practicing water demand management (thus reducing unaccounted for water) will avail more water for beneficial use in line with IWRM (GWP, 2004; Cap Net, 2002).

5.1.2.4 Water Quality

Yatta Canal

Sources of non-point pollution in the study area include fertilizer, cultivation, animal feed lots, pasture and dairy farming. From the survey, 66% said they use fertilizer with 50% using inorganic and 16% using organic types. 70% said they use pesticides/ instecticides to control diseases. Point sources of pollution include direct use of water in the canal like people washing, livestock drinking water and fetching water for household use. 97% of the respondents said they use pit latrines to dispose human waste, 1% said they use septic tanks while the rest do not use any safe disposal method. This showed most of the people safely dispose human faeces.

Water samples were collected at nine sampling points on 6th April 2006. The samples were analyzed for physical, chemical and bacteriological quality and the results are shown in Appendix II.

Bacteriological analysis showed presence of general coliforms, Escherichia coli, salmonella shigella ssp while protozoa and vibro cholerae were absent at all sampling points. This means water was polluted by faecal contamination, fertilizers prepared from animal feeds and animal feedstuffs and contains micro organisms that cause typhoid fever, diarrhea and dysentery (WHO, 1999). Therefore water in Yatta canal and Matuu water supply was not recommended for drinking before treatment because of threat to contracting the above water borne diseases (disinfection at Matuu water supply was not effective and need to be improved). Though respondents said they had contracted amoeba and cholera in the last one year, absence of protozoa and vibrio cholerae pathogens in the water samples showed these were not caused by waterborne transmission.

Physical analysis showed higher concentration of colour and turbidity in all samples except at Matuu water supply treatment works (treated water) and NYS borehole No. C4566. This higher concentration was due to poor land use practices.

The chemical analysis showed that salinity in Kaawani and Kauthulini was caused by presence of boron. Presence of organic matter from animal feedlots, decaying vegetation and waste from humans and animals was the cause of high concentration of total

suspended solids, nitrites, high permanganate value, BOD_5 and COD in all samples except in Matuu water supply (treated water). High concentration of selenium was due to pollution from insecticides.

Water analysis results show that pollution was due to water use and poor waste disposal and hence there was need to practice efficient water use to promote IWRM (GWP, 2003(1)). Effective public campaigns through public meetings will raise public awareness on safe disposal of waste and promote IWRM practice (GTT, 1997).

Matuu town

The town has no sewage and waste water disposal system. The waste water generated is drained through natural drains and most of the premises uses pit latrines. Field survey established there are no immediate plans by MTC to construct conventional sewage and wastewater disposal system though their strategic plan 2005 – 2010 recognizes the need to protect the environment. This negates IWRM process, as the waste is a threat to those depending on streams receiving it (Cap Net, 2002).

Effect of water pollution

From the survey, 70% of respondents said they contracted water related diseases (Malaria, Bilharzia) while 67% contracted water borne diseases (diarrhea, cholera and dysentery) in the last one year. Malaria is the most prevalent water related disease while amoeba and typhoid were the most prevalent water borne diseases.

5.1.3 Water Use

From the survey, 60% of the respondents practice irrigation using canal water, showing that most of the people along the canal practice irrigation. For those practicing irrigation, 88% practice furrow, 6% sprinkler, 2% drip and 4% use other methods like bucket. Furrow irrigation is preferred by smallholder irrigation farmers because of low investment and maintenance cost. The outflow from irrigation is used to recharge the feeder streams and ground water aquifers that supply water for domestic, livestock and irrigation to other riparian users and therefore is beneficially used.

Among farmers practicing irrigation, 58% come from Kithimani location, 31% from Matuu location and 11% from Ndalani location. Most farmers come from Kithimani because this is where the canal starts and water flow is reliable most of the time showing that there is unfair water allocation among users which negates IWRM practice (Cap Net, 2002).

From the survey, 76% of respondents get their water for domestic use from the canal, 16% from shallow wells and Matuu water supply scheme (whose main source is the canal), the rest (i.e. 8%) get from other sources.

Matuu water supply has been constrained by unreliable source (due to low flows in the canal) and this has made consumers to patrol the canal during dry season to restrain irrigation farmers from using canal water. This has been a recipe for conflict between them and farmers, negating IWRM practice which advocates for fair water allocation, giving priority to domestic water use (GWP, 2003(1)).

From the survey, 64% of respondents said their livestock get water from the canal, 16% from shallow wells, 15% from feeder streams and the rest from other sources, thus the canal is the main source of water for livestock.

There is no environmental voice to articulate environmental issues during water allocation hence the voices of farmers, livestock and domestic users have completely blocked it (Cap Net, 2002). IWRM recognizes environmental water need and support its consideration during water allocation (GWP, 2003(1)). There is need to have environmental voice in water allocation committee, eg. Forest Department representative or an NGO well versed with environmental water requirements.

5.1.4 Water Management

When it was completed in 1959, the canal management was under ALDEV but was later handed over to Masaku County Council. Later DWD was appointed as the water undertaker in 1975 (MWD, 1989) and delegated the management to the District Water

Officer, Machakos. The District Water Officer established Yatta Canal Field Unit and 6 camps along the canal.

Yatta Canal Water Users Association (YCWUA) was registered in 2004 under Societies Act Cap 108 after enactment of Water Act 2002. The aim of the Association was to be the water service provider along the canal (incharge of water service provision within the Yatta canal supply area).

During the survey, 75% of respondents said they are aware of YCWUA while 25% said they are not aware. When asked whether it is effective 13% said yes while 62% said it is not effective, the rest were not aware of it. This shows that although most of the water users know the Association exists, it has not been effective enough to be appreciated. As one of the main challenges facing implementation of IWRM is lack of support from all levels (GWP, 2004), the Association need to gain support of water users by improving services and responding to their needs effectively.

When respondents were asked to propose methods of making YCWUA effective, majority said they want the management to revert back to the MWI. This is because they fear change to unknown and view YCWUA as an association not interested in improving service but increasing tariff.

Other proposals made by respondents of making YCWUA effective are that more women and youth be included in the committee; officials call regular meetings and work in a coordinated manner; involve local people in decision making; sensitize water users on functions of the association among others. This is in conformity with IWRM practice. The Association needs to formulate ways of ensuring that all water users participate in water management and develop clear consultative processes in decision making which have to be approved by all stakeholders.

Water demand management

Improving efficiency in the use of water is another way to maximize the economic and social welfare derived from water as a scarce resource, and is an integral part of an IWRM approach (GWP, 2004).

From its completion, the canal has experienced high demand among various uses and users, with irrigation being the highest water user. The high demand for irrigation against a fluctuating supply calls for efficient water use, achieved through practicing water demand management. The respondents were asked the methods they use to economize on water use at farm level. 27% said they economize through farm terracing, 20% through practicing deficit irrigation while 28% through timely removal of weeds, ensuring good soil structure or combining cropping with animal husbandry. These are effective water demand management practices. The challenge faced is that irrigation scheduling is rigidly set among the users. Sharing water on a rigid rotational basis often leads to wasteful use, since users will generally take full share at each turn irrespective of the water need of their crops (WB, 2003(2)). This should be discouraged by introducing policies that reduce misuse (like pricing policy with tariff structure that makes water wastage expensive but should not make water too expensive to deprive the poor and vulnerable groups from use and negate IWRM practice (GWP, 2000)).

When respondents were asked whether they are aware of methods they can use to economize water at household level, 54% said yes while 46% said no. The methods used to economize water include encouraging water reuse (50%), washing house once a week (1%), ensuring children do not misuse water (2%) and use water conserving utensils (1%). These are effective water demand management practices at household level.

UFW for Matuu water supply doubled to 20% between 1995 and 2005, which is not a good practice in water demand management. The increase was due to slow response to bursts and breakdowns, malfunctioning water meters, illegal connections and errors in meter reading. These have to be addressed in order to reduce the UFW (though it is still low compared to the national average of 50% (NWRMS, 2003)).

Yatta canal is not lined (except for only 210m) and water losses occur through evaporation, seepage and deep percolation along the main, primary, secondary and tertiary canals. Water loss through deep percolation and evaporation is not beneficiary used and there is need to control it as this negates IWRM practice (Cap Net, 2002). There is also no operation and maintenance manual to assist in effective irrigation

scheduling and fair distribution among uses and users. There is need to prepare the manual in collaboration with stakeholders as proposed by Cap Net, 2002 so as to promote IWRM practice.

Water rights

Water permit for the canal expired on 30th June 2004 and YCWA Trust has applied to WRMA for renewal. While AWSB is responsible for water and sewerage services in Thika and Machakos district where Thika river and Yatta canal are administratively located, water permit management is under WRMA Tana basin. This has constrained implementation of IWRM because the management is fragmented (Cap Net, 2002).

The requirements for authorization to abstract water for irrigation at the canal discriminate against women and the poor and marginalized who usually do not own land and are not members of any group. Conditions like proof of land ownership and membership of a group can be replaced with a letter from land owner authorizing use of land by applicant.

In Matuu water supply, there is no special tariff for the poor and most of them are served at two water kiosks where water is sold at Kshs. 2 per 20-litre jerican (as per gazetted rate). As they are paying above the flat/ metered rate, water accessibility is discriminative against them, which is not a good IWRM practice (GWP, 2003(2)).

Water conflict management

Much of IWRM practice is essentially about conflict management (GWP, 2000). IWRM practice is the best way of solving conflicts since all stakeholders will influence water allocation and management between the following groups:

i) Upstream and downstream farmers along the canal
ii) Thika river abstractors (above canal intake) and canal water users
iii) Farmers and Matuu water supply consumers
iv) Irrigation farmers and livestock / domestic water users.
v) YCWA Trust and water users

When respondents were asked to state their relationship with upstream water users, 68% said it is bad while 32% said it is good. Most people felt that the upstream users block the canal to get more water while those downstream have none. Those upstream said they have bad relationship with downstream users because they assume they block water during dry seasons.

Other causes of conflict identified by the respondents include mismanagement, unfair water allocation, ineffective rationing programme and unfair water charges. These conflicts can be solved if a forum is established to discuss water allocation and charges among the users, which is an IWRM practice. Decisions agreed upon should be respected and implemented (GWP, 2000).

Coordination among water and related sectors

IWRM brings together coordination among sectors, plus stakeholder participation to achieve effective local management for sustainable socio-economic development (Cap Net, 2002). No coordination exists in the study area among water and related sectors like forest, land, agriculture and environment.

One of the reasons for formulating the National Water Policy was lack of proper interlinkages with other water related sectors. Lack of coordination has been a major constraint in implementing IWRM and it is proposed that a coordination committee be established in Yatta division to discuss and accept all projects that affect Yatta canal. Membership of the committee can be heads of government departments related to water and NGO's active in these sectors like Plan International, World Vision and German Agro-Action.

5.1.5 Communication and Stakeholder Participation

Constraints experienced in Yatta canal like misuse of water by over irrigation, water pollution and ineffective water management are due to poor stakeholder participation. Water users are not made to actively participate in decisions concerning water use. An independent organization or a reputable NGO needs to be mandated to effectively

sensitize various stakeholders on the benefits of active participation in decision – making process.

Communication helps all stakeholders to construct a realistic picture of water resources availability, use and management. IWRM strategies are much more likely to be achieved if women are active participants and decision makers (GWP, 2000).

Awareness of reforms

The country's legal and policy changes have been finalized and supports implementation of IWRM concept, however when respondents were asked whether they are aware of National Water Policy, only 7% said they are aware while 93% said they are not aware. When asked about Water Act 2002, 16% said they are aware of it while 84% said they are not. This shows most of the water users are not aware of the reforms in the water sector. This is due to lack of information, understanding, appreciation or motivation / incentives (GTT, 1997). Developing advocacy programmes targeting the stakeholders can solve the problem of low awareness of reforms.

Types of stakeholders

Stakeholders in the study area include domestic and livestock water users, irrigation farmers, NGO's, government departments and local Authorities, local politicians, opinion leaders, policy makers and planners.

The membership of BOT of YCWA Trust is based on stakeholder representation along the canal only. Other stakeholders like planners (professionals), women and the poor and marginalized, domestic and livestock consumers are not represented, yet planners, policy makers and politicians have been main decision makers.

Participation in planning, development and management

Participatory decision making process by different user groups influences strategies for water resources planning, development and management, bringing additional benefits, as informed users apply self regulation which promote efficient water use for sustainability.

When respondents were asked whether they participate in water management, 33% said they do while 67% said they don't. Failure by the majority to participate in management denies them the opportunity to influence decisions made by managers and policy makers on the water issues affecting them, a practice that is not advocated in IWRM approach.

5.1.6 Capacity Building

IWRM requires capacity building at all levels for democratic and demand responsible approaches, especially at the community level to which local planning of resource use, management and maintenance of services, will increasingly be devolved (GWP, 2003 (2)).

Capacity requirements

In order to implement IWRM in Yatta canal, full time services of Water / Irrigation Engineer, Hydrologist, Pollution Control Officer, Sociologist and support officers qualified in operation and maintenance are required. Other personnel who will be needed on short term basis like Public Administration / Relations Officer, Poverty Reduction Specialist, Water Economist and Institutional Management Specialist can be available at AWSB for use when needed.

Existing capacity

The personnel currently deployed in Yatta Canal and Matuu water supply include Water / Irrigation Engineer and other staff for operation and maintenance. In terms of vehicles, plant and equipment, the unit has enough capacity though it lacks telephone services and efficient billing system. The personnel shortfall needs to be addressed, telephone services installed and billing computerized in order to serve consumers effectively and implement IWRM concept.

5.2 CONCLUSIONS

1. Water sector reforms in Kenya have been guided by IWRM practice since the overall objective of reforms is to involve stakeholder and decentralize management of water resources. However stakeholder participation at local level has not been clearly defined since the functions of WRUA are not defined in the Water Act 2002.
2. The current management structure of the canal, where YCWA Trust is in the process of taking over, support IWRM practice as the Trust is composed of representatives of various stakeholders. The Trust has to improve the services offered to water users and be responsive to their requests and expectations to gain their support to succeed.
3. Lack of Thika river basin management structure where stakeholders are involved, including those in Yatta Canal and Matuu water supply, has constrained implementation of IWRM concept as there is unfair water allocation among the users.
4. Water in the canal is used for irrigation, domestic and livestock while in Matuu water supply scheme it is used for domestic. There is no prioritization on water use though water users are aware that domestic and livestock use are prioritized among the uses. This is implemented when there is intense canal patrol by water managers and police especially during the dry season. There is no consideration of environmental flow though it was provided for as base flow (143 l/s) during design.
5. Only the planners, policy makers and politicians have been involved in planning and rehabilitation of the canal and Matuu water supply. The other stakeholders like women, farmers, domestic/ livestock consumers, NGOs and institutions have not been involved.
6. In YCWA Trust board of trustees, women, the poor and marginalized are not represented so as to advocate for their rights as required in IWRM practice. NGOs and planners are also not represented in the BOT, though it is necessary to have them to guide the Trust on professional and advocacy issues.
7. Integrated approach has been applied during planning and rehabilitation of the canal since its inception.

8. There is no coordination among water and related sectors like agriculture, land, forest, livestock and environment at local level. This has greatly constrained full implementation of IWRM concept.
9. Water rights have been biased against women, the poor and marginalized in the canal. Generally there is unfair water allocation, pollution of feeder streams and unreliable supply due to lack of operation manual and inefficient management.
10. Water sources within the study area are not adequate to meet the demand.
11. Water use at farm level is not efficient as it is driven by availability and not by the requirement, however there is efficient water use at household level.
12. There are no mechanisms that have been laid down to resolve water conflicts among the uses and users.

5.3 RECOMMENDATIONS

1. Currently YCWA lacks goodwill to effect the pricing policy and improve the management for self-sustainability of the project. An independent organization, supported by MWI and AWSB, like National Irrigation Board, need to be contracted for two years to prepare the stakeholders for takeover. This institution should have capacity to develop an operation model which will be used to regulate supply and ensure fair water distribution among users at all times, and develop strategies for effective stakeholder participation (including women and vulnerable groups) at all levels of development and management.
2. Promote water demand management practices like irrigating at night during dry seasons, effecting pricing policy that ensures one pays for what he/ she uses, having efficient water use advocacy campaigns at schools, markets and during public meetings. Encourage irrigation water use on the uphill part of the canal as misuse will be minimal due to pumping requirement.
3. Establish a section in the MWI and AWSB to deal with IWRM policy.
4. Establish consultative forum for upstream water users (Kwakoko Kauthulini, Kakumini and Kithendu) and downstream users (Kauthulini, Kateki, Kyasioni) to openly discuss about water use and constrains each group faces in accessing water and implement their recommendations.
5. Establish Thika river basin water users Association, incorporating most of the stakeholders, including representatives from Yatta canal and Matuu town to advocate for their interest so as to implement IWRM and make water use sustainable.
6. Include women, NGOs, the poor and marginalized and planners in the BOT.
7. Establish strong irrigation extension service to advise farmers on irrigation technologies, practices, and water scheduling.
8. Carry out further study for storage required to meet ultimate demand in Yatta canal, alternative source for Matuu water supply, hydrogeological survey to map up groundwater flow pattern aimed at controlling non-beneficial seepage, and acreage under irrigation.
9. Formulate strategies that ensure water use addresses poverty reduction, the poor and marginalized.
10. Develop operation and maintenance manual for Matuu water supply.

12. Establish coordination committee for water and related sectors at national level(by MWI) and Yatta division (initiated by WRMA) to coordinate sectoral activities affecting Yatta canal.
13. Develop monitoring and evaluation programme to follow up on implementation of IWRM, especially on fair water allocation, stakeholder participation including involvement of women in decision-making and coordination of water related sectors.

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APPENDICES

Q No. ----------

Appendix I:

Questionnaire on assessment of IWRM practice along Yatta Canal and Matuu water supply, Machakos district.

(NB: This questionnaire is to be administered to residents along Yatta Canal and Matuu water supply limit of supply)

1.) Introduction

Personnel details of respondent

a) Name of respondent ----------

b) Sex: Male/Female ----------

c) Marital status:Married/Single/Divorced/Widowed

d) Age ----------

2.Physical details

Location _____ sub location _____ village_____

Land ownership: Owned/Leased/Ancestral/other: specify _____

Land acreage:----------

Side of canal land is located: Lower/Upper

Type of housing: Temporary/ semi permanent/Permanent/Other: Specify _____

No. of houses in the homestead.----------

3. Social data

a) Number of people in the household ----------

b) Sex of household head male/female

c) Level of education of household head: ----------

d) Are you a member of any social welfare group? Yes/No

If yes, which one (s)?, ----------

e) Are there women leaders in your area? Yes/No

If yes, which kind of leadership are they engaged in?----------

f)Type of women group activities in the area: Tree Nurseries/Crop production/Beekeeping/HIV/AIDS awareness/soil & water conservation /Others: Specify:

_____

4. Economic data

a) Sources of income:

Employment/Farming/Business/Others: Specify----------

b) Main source of income ----------

i) If it is employment; specify: Teachers/Civil Servant / Company/ Individual

ii) If it is Business specify: Cereals / Retail shop/ wholesale/ hotel/Transport/ hawking/Butchery/Bar/Boutique/Petrol station/Others: Specify ----------

c) Level of income: (monthly/quarterly/annual)----------

d) Are you paying for water used? Yes/No

If yes, what is the average bill per year (for canal) ----------

If yes, what is the average bill per month (for Matuu water supply)-----

Or average cost of water per 20lt jerican/200 lt drum _____

5. Water supply

a) Volume of water used for domestic purpose per day per household-------

Source of water: canal/Matuu Water Supply /shallow wells/ dam/ borehole/ others specify _____

b) Is the source reliable throughout the year? Yes/No

If No what are the main causes of unreliability? Biased water release/source inadequate/inadequate infrastructure like pipes/unreliable rationing programme/lack of pumping; others: specify _____

c) If water is paid for, are you willing to pay more if the services are improved? Yes/No .

If yes how much for Matuu w/s _____ (monthly)

Yatta canal (Annual) Shs _____

others specify _____

d) Do you have storage facilities at household level? Yes/No

If yes, which ones? Tank size _____lts /Jerrican size-------lts and No.---------- /Others specify ___

6. Farming

a) Size of farm----------acres

b) Do you own the land? Yes/No

If yes, what is the land tenure? Leased/freehold/others specify ----------

If no, what arrangement do you have for use of land? leased/family land/allowed use by owner freely/others specify----------

If leased from landowner, how much do you pay per year per acre?----------

c) Method used in removing weed :hand ploughing / ox ploughing /tractor ploughing/chemical (specify type)/others specify----------

d)Type of fertilizer(s) used----------

Quantity used per acre----------

Frequency of application per year----------

e) Type of pesticide used in the farm and their chemical composition ---------- ----------

---

f) Do you practice soil conservation in the farm? Yes/No

If yes which one? Terracing/vegetation strips /others specify ----------

d) When do you plant your crops? Before rains/less than 10 days after rains/more than 10 days after rains

I. If engaged in rainfed farming

i)Type of crops grown and average acreage for each crop

Type of crop acreage ----------

II. If engaged in irrigation

i) Type of irrigation method used; furrow/drip/sprinkler/ others specify .

ii) Frequency of irrigation:--------times a week/month during dry season

---------times a week /month during wet season

iii) Current acreage under irrigation per crop

Crop type	acreage
----------	----------
----------	----------
----------	----------
----------	----------

iv) Average acreage under irrigation per crop for the last three years

Crop type acreage

---------- ----------

---------- ----------

---------- ----------

---------- ----------

v) Average yield per acre per crop per year

Crop type yield per acre per year (tons)

---------- ----------

---------- ----------

---------- ----------

---------- ----------

Has this yield increased/ decreased for the last say five years? Yes/no

If yes why?----------

vi) What is the average harvest in a year per crop (specify type of crops and harvest for each for the last three years)

Year 2005

Type of crop Harvest(tons)

---------- ----------

---------- ----------

Year 2004

Type of crop Harvest(tons)

---------- ----------

---------- ----------

---------- ----------

---------- ----------

---------- ----------

Year 2003

Type of crop Harvest(tons)

---------- ----------

---------- ----------

---------- ----------

---------- ----------

vii) Which months in the year is water for irrigation available at the canal? ----------

---

viii) How is water drained from your farm? Drainage canal/pipes/flows to stream downstream/not drained/others specify _____

ix) Is there water logging in your farm? Yes/No

If yes is it throughout the year or for how many months per year? ____

x) Is there soil salinity in your farm? Yes/No

If yes, for how long: _____ years

xi) Is market readily available for produce? Yes/No

If yes, how do you market your produce? Through self help groups/cooperative society/through broker/directly to buyer/others specify----------

---

xii) Is credit facilities available easily? Yes/No

If yes, which financial institution(s) give you credit? Commercial banks/sacco/Agricultural Finance Corporation/others specify----------

---

III. For those involved in livestock farming

i) What type and number of animals are currently kept:

Grade cow _____

Local Cattle _____

Sheep _____

Goat _____

ii) Do you use insecticides? Yes/No

If yes how frequently per year ?----------

Name the insecticide and chemical composition used _____

iii) Where do they get their water from?

Yatta Canal/Matuu w/s /dam/feeder streams/others specify _____

iv) What volume of water do they use per day per animal:

_____ lts. per grade cow

_____ lts. per local cow

_____ lts. per sheep

_____ lts. per Goat

v) Is market readily available for livestock? Yes/No

If yes, how do you market your livestock? Through self help groups/cooperative society/through broker/directly to buyer/others specify-------

---

vi) Is credit facilities available easily? Yes/No

If yes, which financial institution(s) give you credit? Commercial banks/sacco/Agricultural Finance Corporation/others specify----------

---

IV .For those engaged in poultry farming

i) Average number of chicks reared in a year _____

ii) Volume of water used in a day _____

iii) Source of water used----------

iv) Is market readily available for poultry? Yes/No

If yes, how do you market your chick(en)? Through self help groups/cooperative society/through broker/directly to buyer/others specify--

v) Is credit facilities available easily? Yes/No

If yes, which financial institution(s) give you credit? Commercial banks/sacco/Agricultural Finance Corporation/others specify----------

---

7. Human Health

i) Have you contracted any water related diseases in the last one year? Yes/No

If yes, which one? Malaria/skin diseases/others specify _____

ii) Have you contracted any water borne diseases in the last one year? Yes/No

If yes which ones bilharzia / Cholera/ Dysentery / Amoeba /others specify____

iii) Are there any HIV/AIDS programmes in your area? Yes/No

How far is your home to nearest health facility?0-5km/5-10km/more than10km

iv) Do you treat water at household level? Yes/No

If yes, which method do you use? Boiling/disinfection(chlorine or water guard)/others specify

v) Do you use bathroom for bathing? Yes/No

If no what do you use? Direct in the canal/open ground/others specify__

8. Water demand management

a) Are you aware of methods you can use to economize on water use at farm level? Yes/No

If yes, which ones: farm terracing/deficit irrigation/reducing water losses/ensuring good soil structure/timely removal of weeds/ right timing of planting the crops/combining cropping with animal husbandry

Others specify _____

b) Are you aware of methods you can use to economize on water use at household level? Yes/No

If yes, which ones?: use of regulated taps at kitchen, handwash basins /small cistern in the toilets/

Ensuring no leakage of water fittings in the house /using water conserving cooking utensils like pressure cookers / encouraging reuse of water e.g. water used for washing clothes is reused for washing house or toilet. Others specify_____

9. Sanitation

a) Which method do you use to dispose human waste? Pit latrine/septic tank/open ground/others specify_____

b) What is the approximate population of your village?

_____People

How many pit latrines are there in your village? ____

10. Catchment management

a) Are you involved in any catchment protection activity? Yes/No

If yes, which one? Tree planting/soil conservation/others specify ----------

b) Are their organized efforts in your area to sensitize locals on catchment protection? If yes, which ones?----------

---

c) What are the main causes of catchment degradation?

Wood fuel/charcoal burning/cutting posts/farming /human settlement.(Tick correct ones)Others specify_____

11. Water management

a) How is water managed in your area? Self help group/ Water Users Association/Local govt./MW & I/Athi Water Services Board /Individual/others specify _____

b) Are you satisfied with water services offered in your area? Yes/No

If yes how? ----------

If no why? ----------

c) Do you have water permit for use of water? Yes/No

If no, who has the permit? Self help group/landowner/none/others specify------- -------

---

d) Relationship with upstream water users: good/bad

If bad reason: _____

If good how? _____

e) Relationship with downstream water users: good/bad

if bad, reason:----------

f) Are there conflicts related to water? Yes/no

If yes, what are the causes? Water use/mismanagement/unfair allocation/ineffective rationing/others specify _____

How do you solve the conflicts? ----------

---

g) Are you aware of YCWUA? Yes/No

If yes, what is its work? _____

h) Are women represented in management committee of YCWUA? Yes/No

If yes, how many? _____

Which office do they hold? _____

i) In your opinion, is YCWUA effective? Yes/No

If No, what do you think needs to be done to improve its performance? -------- ----

---

If yes, how? ----------

---

j) Are you aware of the new water Act 2002? Yes/No

If yes, state one important change proposed in the Act

_____

k) Are you aware of National policy on Water Resources Management and Development, Sessional paper No. 1 of 1999? Yes/No

If yes, when was it passed by Parliament? _____

l) Are you aware of IWRM concept? Yes/No

If yes, list two main principles of IWRM

i)----------

ii)----------

In your opinion, what needs to be done to fully practice IWRM in your area?--- --------

---

---

m) Do you participate fully in water management in your area? Yes/No

If No why? _____

If Yes how? ----------

---

n) Are your views respected and implemented when you attend a water meeting? Yes/No.

If yes, how are they implemented? ----------

If no, why do you think they are not respected? ----------

---

p) Have you attended any water management training in the past? Yes/No

If yes which one? _____

q) Where do you go to seek assistance if you have water problem?

_____

12. Personal opinion

In your own opinion, what do you think can be done to improve the supply of water and use in your farm and / or home in the future? ----------

---

Appendix II

Physical, Chemical and Bacteriological water quality analysis results

REPUBLIC OF KENYA

MINISTRY OF WATER AND IRRIGATION

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NAIROBI

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No.....1..... Date of Sampling...06 – 04 – 06

Source ...Yatta Canal Intake..... Date Received.....06 – 04 – 06

Purpose of Sampling...Research..... Submitted by .....L. N. Simitu.....

Address.....

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.28	6.5 – 8.5
Colour	mgPt/l	600.00	Max. 15
Turbidity	N.T.U.	252.00	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	47.40	Max. 10
Conductivity (25°C)	µS/cm	122.00	Max. 2500
Iron	mg/l	3.74	Max. 0.3
Manganese	mg/l	0.40	Max. 0. 1
Calcium	mg/l	10.40	Max. 100
Magnesium	mg/l	0.98	Max. 100
Sodium	mg/l	14.00	Max. 200
Potassium	mg/l	3.50	Max. 50
Total Hardness	$mgCaCO_3/l$	30.00	Max. 500
Total Alkalinity	$mgCaCO_3/l$	36.00	Max.500
Chloride	mg/l	6.00	Max. 250
Fluoride	mg/l	0.14	Max. 1.5
Nitrate	mgN/l	1.20	Max. 10
Nitrite	mgN/l	0.11	Max. 0.1
B.O.D	mgO_2/l	75.00	Max. 30
C.O.D	mgO_2/l	141.00	Max. 50
Sulphate	mg/l	14.30	Max. 400
4 HR. Permanganate Value	mgO_2/l	26.00	-
Total Suspended Solids	mg/l	560.00	Max. 30
Free Carbon Dioxide	mg/l	3.00	-
Total Dissolved Solids	mg/l	75.60	Max. 1500
S.A.R	-	1.11	-

COMMENTS:

Research.

Ole .....J. N. MUASYA.....
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MINISTRY OF WATER AND IRRIGATION

Central Water Testing Laboratories

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NAIROBI

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No. 2 Date of Sampling 06 – 04 – 06

Source National Youth Service Borehole – Ndalani Date Received 06 – 04– 06

Purpose of Sampling Research Submitted by L. N. Simitu

Address

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.25	6.5 – 8.5
Colour	mgPt/l	10.00	Max. 15
Turbidity	N.T.U.	8.00	Max. 5
Permanganate Value (20 min. boiling)	mgO$_2$/l	0.79	Max. 10
Conductivity (25° C)	µS/cm	339.00	Max. 2500
Iron	mg/l	0.01	Max. 0.3
Manganese	mg/l	0.02	Max. 0. 1
Calcium	mg/l	31.20	Max. 100
Magnesium	mg/l	6.80	Max. 100
Sodium	mg/l	28.80	Max. 200
Potassium	mg/l	3.20	Max. 50
Total Hardness	mgCaCO$_3$/l	106.00	Max. 500
Total Alkalinity	mgCaCO$_3$/l	124.00	Max. 500
Chloride	mg/l	30.00	Max. 250
Fluoride	mg/l	0.14	Max. 1.5
Nitrate	mgN/l	2.10	Max. 10
Nitrite	mgN/l	0.02	Max. 0.1
B.O.D	mgO$_2$/l	5.00	Max. 30
C.O.D	mgO$_2$/l	70.56	Max. 50
Sulphate	mg/l	5.42	Max. 400
4 HR. Permanganate Value	mgO$_2$/l	4.00	-
Total Suspended Solids	mg/l	6.00	Max. 30
Free Carbon Dioxide	mg/l	10.00	-
Total Dissolved Solids	mg/l	210.20	Max. 1500
S.A.R	-	1.21	-

COMMENTS:

Research.

Dic .....J. N. MUASYA.....
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REPUBLIC OF KENYA

MINISTRY OF WATER AND IRRIGATION

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NAIROBI.

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No. 3 Date of Sampling 06 – 04 – 06

Source Ianguni Stream at Makutano-Ndalani Date Received 06 – 04– 06

Purpose of Sampling Research Submitted by L. N. Simitu

Address

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.49	6.5 – 8.5
Colour	mgPt/l	875	Max. 15
Turbidity	N.T.U.	404	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	47.4	Max. 10
Conductivity (25°C)	µS/cm	192	Max. 2500
Iron	mg/l	4.71	Max. 0.3
Manganese	mg/l	0.18	Max. 0.1
Calcium	mg/l	21.6	Max. 100
Magnesium	mg/l	2.9	Max. 100
Sodium	mg/l	14	Max. 200
Potassium	mg/l	0.8	Max. 50
Total Hardness	$mgCaCO_3/l$	66	Max. 500
Total Alkalinity	$mgCaCO_3/l$	70	Max.500
Chloride	mg/l	11	Max. 250
Fluoride	mg/l	0.22	Max. 1.5
Nitrate	mgN/l	1.8	Max. 10
Nitrite	mgN/l	0.12	Max. 0.1
B.O.D	mgO_2/l	100	Max. 30
C.O.D	mgO_2/l	282.24	Max. 50
Sulphate	mg/l	5.70	Max. 400
4 HR. Permanganate Value	mgO_2/l	18	-
Total Suspended Solids	mg/l	240	Max. 30
Free Carbon Dioxide	mg/l	12	-
Total Dissolved Solids	mg/l	119	Max. 1500
S.A.R	-	0.75	Max. 7

COMMENTS:

Research.

Ole .....J. N. MUASYA.....
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REPUBLIC OF KENYA

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NAIROBI

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No... 4 Date of Sampling 06 – 04 – 06

Source Kikwa Stream near Matuu town Date Received 06 – 04– 06

Purpose of Sampling Research Submitted by .L. N. Simitu

Address

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.94	6.5 – 8.5
Colour	mgPt/l	1125	Max. 15
Turbidity	N.T.U.	535	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	44.2	Max. 10
Conductivity (25° C)	µS/cm	132	Max. 2500
Iron	mg/l	9.30	Max. 0.3
Manganese	mg/l	0.2	Max. 0.10
Calcium	mg/l	12	Max. 100
Magnesium	mg/l	2	Max. 100
Sodium	mg/l	13	Max. 200
Potassium	mg/l	0.2	Max. 50
Total Hardness	$mgCaCO_3/l$	38	Max. 500
Total Alkalinity	$mgCaCO_3/l$	42	Max.500
Chloride	mg/l	10	Max. 250
Fluoride	mg/l	0.22	Max. 1.5
Nitrate	mgN/l	1.5	Max. 10
Nitrite	mgN/l	0.13	Max. 0.1
B.O.D	mgO_2/l	75	Max. 30
C.O.D	mgO_2/l	94.08	Max. 50
Sulphate	mg/l	4	Max. 400
4 HR. Permanganate Value	mgO_2/l	52	-
Total Suspended Solids	mg/l	3200	Max. 30
Free Carbon Dioxide	mg/l	18	-
Total Dissolved Solids	mg/l	82	Max. 1500
S.A.R	-	0.91	Max. 7

COMMENTS:

Research.

Ovc .....J. N. MUASYA.....
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REPUBLIC OF KENYA

MINISTRY OF WATER AND IRRIGATION

Central Water Testing Laboratories

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PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No. 5 Date of Sampling 06 – 04 – 06

Source Mathauta river near Matuu water supply T/Works Date Received 06 – 04– 06

Purpose of Sampling Research Submitted by L. N. Simitu

Address

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	8.11	6.5 – 8.5
Colour	mgPt/l	1250	Max. 15
Turbidity	N.T.U.	539	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	55.3	Max. 10
Conductivity (25°C)	µS/cm	120	Max. 2500
Iron	mg/l	12.3	Max. 0.3
Manganese	mg/l	0.6	Max. 0.10
Calcium	mg/l	12.8	Max. 100
Magnesium	mg/l	2.2	Max. 100
Sodium	mg/l	9.5	Max. 200
Potassium	mg/l	0.3	Max. 50
Total Hardness	$mgCaCO_3/l$	41	Max. 500
Total Alkalinity	$mgCaCO_3/l$	44	Max.500
Chloride	mg/l	10	Max. 250
Fluoride	mg/l	0.22	Max. 1.5
Nitrate	mgN/l	0.54	Max. 10
Nitrite	mgN/l	0.40	Max. 0.1
B.O.D	mgO_2/l	250	Max. 30
C.O.D	mgO_2/l	517.44	Max. 50
Sulphate	mg/l	1.14	Max. 400
4 HR. Permanganate Value	mgO_2/l	112	-
Total Suspended Solids	mg/l	3880	Max. 30
Free Carbon Dioxide	mg/l	12	-
Total Dissolved Solids	mg/l	74.1	Max. 1500
S.A.R	-	0.64	Max. 7

COMMENTS:

Research.

O/c .....J. N. MUASYA.....
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MINISTRY OF WATER AND IRRIGATION

Central Water Testing Laboratories

Tel. No (020) 553834, 553957
P.O. Box 30521-00100,
NAIROBI

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No..... 6 ..... Date of Sampling 06 – 04 – 06

Source **Matuu water supply (Treated)** Date Received..... 06 – 04– 06

Purpose of Sampling **Research** Submitted by ..... L. N. Simitu

Address.....

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.75	6.5 – 8.5
Colour	mgPt/l	5	Max. 15
Turbidity	N.T.U.	4	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	<0.4	Max. 10
Conductivity (25° C)	µS/cm	315	Max. 2500
Iron	mg/l	0.07	Max. 0.3
Manganese	mg/l	0.01	Max. 0.10
Calcium	mg/l	16	Max. 100
Magnesium	mg/l	1.95	Max. 100
Sodium	mg/l	48	Max. 200
Potassium	mg/l	5	Max. 50
Total Hardness	$mgCaCO_3/l$	48	Max. 500
Total Alkalinity	$mgCaCO_3/l$	86	Max.500
Chloride	mg/l	24	Max. 250
Fluoride	mg/l	0.14	Max. 1.5
Nitrate	mgN/l	0.56	Max. 10
Nitrite	mgN/l	0.03	Max. 0.1
B.O.D	mgO_2/l	25	Max. 30
C.O.D	mgO_2/l	35.28	Max. 50
Sulphate	mg/l	34.4	Max. 400
4 HR. Permanganate Value	mgO_2/l	20	-
Total Suspended Solids	mg/l	12	Max. 30
Free Carbon Dioxide	mg/l	4	-
Total Dissolved Solids	mg/l	195.3	Max. 1500
S.A.R	-	3.0	Max. 7

COMMENTS:

Research.

O/c .....J. N. MUASYA.....
CENTRAL WATER TESTING LABORATORIES
WATER QUALITY LABORATORY
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REPUBLIC OF KENYA

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NAIROBI

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No..... 7.....

Source **Matuu water supply Intake (Raw)**.....

Purpose of Sampling...**Research** .....

Date of Sampling.....**06 – 04 – 06**.....

Date Received.....**06 – 04– 06** .....

Submitted by .....**L. N. Simitu** .....

Address.....

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.99	6.5 – 8.5
Colour	mgPt/l	1250	Max. 15
Turbidity	N.T.U.	565	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	31.6	Max. 10
Conductivity (25°C)	µS/cm	104	Max. 2500
Iron	mg/l	9.54	Max 0.3
Manganese	mg/l	0.2	Max. 0.10
Calcium	mg/l	9.6	Max. 100
Magnesium	mg/l	1.7	Max. 100
Sodium	mg/l	9.5	Max. 200
Potassium	mg/l	1.2	Max. 50
Total Hardness	$mgCaCO_3/l$	31	Max. 500
Total Alkalinity	$mgCaCO_3/l$	24	Max.500
Chloride	mg/l	10	Max. 250
Fluoride	mg/l	0.22	Max. 1.5
Nitrate	mgN/l	3	Max. 10
Nitrite	mgN/l	0.13	Max. 0.10
B.O.D	mgO_2/l	200	Max. 30
C.O.D	mgO_2/l	658.56	Max. 50
Sulphate	mg/l	3.71	Max. 400
4 HR. Permanganate Value	mgO_2/l	44	-
Total Suspended Solids	mg/l	4920	Max. 30
Free Carbon Dioxide	mg/l	14	-
Total Dissolved Solids	mg/l	64.7	Max. 1500
S.A.R	-	0.74	Max. 7

COMMENTS:

Research.

O/c .....J. N. MUASYA.....
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PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No. ..... 8 ..... Date of Sampling ..... 06 – 04 – 06 .....

Source Mathauta Dam – near T/works ..... Date Received ..... 06 – 04– 06 .....

Purpose of Sampling ..... Research ..... Submitted by ..... L. N. Simitu .....

Address .....

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.38	6.5 – 8.5
Colour	mgPt/l	1000	Max. 15
Turbidity	N.T.U.	251	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	15.8	Max. 10
Conductivity (25°C)	µS/cm	118	Max. 2500
Iron	mg/l	3.76	Max. 0.3
Manganese	mg/l	0.4	Max. 0.10
Calcium	mg/l	10.4	Max. 100
Magnesium	mg/l	2.43	Max. 100
Sodium	mg/l	8.5	Max. 200
Potassium	mg/l	4.2	Max. 50
Total Hardness	$mgCaCO_3/l$	36	Max. 500
Total Alkalinity	$mgCaCO_3/l$	30	Max 500
Chloride	mg/l	10	Max. 250
Fluoride	mg/l	0.13	Max. 1.5
Nitrate	mgN/l	1.9	Max. 10
Nitrite	mgN/l	0.05	Max 0.10
B.O.D	mgO_2/l	125	Max 30
C.O.D	mgO_2/l	329.28	Max. 50
Sulphate	mg/l	7.71	Max. 400
4 HR. Permanganate Value	mgO_2/l	4	-
Total Suspended Solids	mg/l	420	Max. 30
Free Carbon Dioxide	mg/l	8	-
Total Dissolved Solids	mg/l	72.9	Max. 1500
S.A.R	-	0.71	Max. 7

COMMENTS:

Research.

Ole .....J. N. MUASYA.....
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PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No. ....9.... Date of Sampling.....06 – 04 – 06.....

Source **Kawituuo stream near Sofia shopping center** Date Received.....06 – 04– 06.....

Purpose of Sampling...**Research** ..... Submitted by .....L. N. Simitu.....

Address.....

PARAMETERS	UNIT	RESULTS	W.H.O. STDs
pH	pH Scale	7.72	6.5 – 8.5
Colour	mgPt/l	875	Max. 15
Turbidity	N.T.U.	426	Max. 5
Permanganate Value (20 min. boiling)	mgO_2/l	31.6	Max. 10
Conductivity (25°C)	µS/cm	207	Max. 2500
Iron	mg/l	8.39	Max. 0.3
Manganese	mg/l	0.4	Max. 0.10
Calcium	mg/l	20.8	Max. 100
Magnesium	mg/l	1.47	Max. 100
Sodium	mg/l	18	Max. 200
Potassium	mg/l	6.6	Max. 50
Total Hardness	$mgCaCO_3/l$	58	Max. 500
Total Alkalinity	$mgCaCO_3/l$	74	Max. 500
Chloride	mg/l	10	Max. 250
Fluoride	mg/l	0.45	Max. 1.5
Nitrate	mgN/l	3.7	Max. 10
Nitrite	mgN/l	0.08	Max. 0.10
B.O.D	mgO_2/l	90	Max. 30
C.O.D	mgO_2/l	141.12	Max. 50
Sulphate	mg/l	2.86	Max. 400
4 HR. Permanganate Value	mgO_2/l	74	-
Total Suspended Solids	mg/l	1360	Max. 30
Free Carbon Dioxide	mg/l	6	-
Total Dissolved Solids	mg/l	128	Max. 1500
S.A.R	-	1.0	Max. 7

COMMENTS:

Research

O/c .....J. N. MUASYA.....
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P.O. BOX 30521, NAIROBI

MINISTRY OF ENVIRONMENT AND NATURAL RESOURCES

Ref. No. 03/05/06/1

3rd May 2006

WATER SAMPLES RESULTS SUBMITTED BY MR. L. N. SIMITU

Date of Sampling : 06/04/06

Sample No	Sampling Point	mg Total P/l	ppm Se/l	mg B/l
1	Yatta Canal Intake	2.5	17.5	Nil
2	N Y S B/Hole	16.3	10	Nil
3	Ianguni Stream, Makutano	1.3	12	0.6
4	Kikwa Stream near Matuu	5	15	1.5
5	Mathauta River near Matuu w/s treatment works	16.3	50	0.6
6	Treated water , Matuu w/s	5	25	Nil
7	Matuu w/s intake (52km) before treatment	16.3	35	Nil
8	Mathauta dam	2.5	50	1.0
9	Kawituuo stream near Sofia shopping centre	6	25	1.9

E K TANGUS (CHEMIST)
FOR COMMISSIONER MINES AND GEOLOGY

REPUBLIC OF KENYA

MINISTRY OF WATER AND IRRIGATION
Central Water Testing Laboratories

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NAIROBI

REPORT ON BACTERIOLOGICAL EXAMINATION OF WATER

Date of sampling.....06 – 04 – 06...
Date Received..... 06 – 04 – 06

Submitted by....L. N. Simitu.....

SAMPLE NO.	SOURCE	PURPOSE OF SAMPLING	General Coliforms - MPN /100ml	*Escherichia Coli* - MPN /100ml	*Salmonella SPP.* counts/ml	*Shigella SPP.* counts/ml	*Vibrio cholerae.* counts/ml	Protozoa	GENERAL COMMENT
1.	YATTA CANAL INTAKE	RESEARCH	241920	27550	TMTC	50	NIL	Absent	Water for domestic use should be free of the pathogenic micro – organisms.
2.	NYS B II No. C4566 (CONSUMER POINT)	RESEARCH	241920	32	12	NIL	NIL	Absent	
3.	IANGUNI STREAM AT MAKUTANO - NDAI ANI	RESEARCH	198630	7940	100	20	NIL	Absent	
4.	KIKWA STREAM NEAR MATUU TOWN	RESEARCH	241920	61310	90	20	NIL	Absent	
5.	MATHAUTA RIVER AT KATAI ANI - MATUU	RESEARCH	241920	54750	TMTC	TMTC	NIL	Absent	
6.	MATUU WATER SUPPLY TREATMENT WORKS	RESEARCH	460	1	2	NIL	NIL	Absent	
7.	MATUU WATER SUPPLY AT INTAKE (YATTA CANAL)	RESEARCH	173290	51720	TMTC	TMTC	NIL	Absent	
8.	MATHAUTA DAM NEAR MATUU W/S T/WORKS	RESEARCH	155310	61310	NIL	NIL	NIL	Absent	
9.	KAWITUUO STREAM NEAR SOITA S'CENTRE	RESEARCH	241920	17329	60	10	NIL	Absent	

MPN: Most Probable Number.
TMTC: Too many to count.

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O/c.....J.N...MUASYA.....
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REPORT ON BACTERIOLOGICAL EXAMINATION OF WATER

Date of sampling.....06 – 04 – 06.....
Date Received.....06 – 04 - 06.....

Submitted by.....L. N. Simitu.....

SAMPLE NO.	SOURCE	PURPOSE OF SAMPLING	General Coliforms - MPN /100ml	*Escherichia Coli* - MPN /100ml	*Salmonella SPP.* counts/ml	*Shigella SPP.* counts/ml	*Vibrio cholerae.* counts/ml	Protozoa	GENERAL COMMENT
1.	YATTA CANAL INTAKE	RESEARCH	241920	27550	TMTC	50	NIL	Absent	Water for domestic use should be free of the pathogenic micro – organisms.
2.	NYS B.H No. C4566 (CONSUMER POINT)	RESEARCH	241920	32	12	NIL.	NIL.	Absent	
3	IANGUNI STREAM AT MAKUTANO - NDALANI	RESEARCH	198630	7940	100	20	NIL.	Absent	
4.	KIKWA STREAM NEAR MATUU TOWN	RESEARCH	241920	61310	90	20	NIL.	Absent	
5.	MATHAUTA RIVER AT KATALANI – MATUU	RESEARCH	241920	54750	TMTC	TMTC	NIL.	Absent	
6.	MATUU WATER SUPPLY TREATMENT WORKS	RESEARCH	460	1	2	NIL.	NIL.	Absent	
7.	MATUU WATER SUPPLY AT INTAKE (YATTA CANAL)	RESEARCH	173290	51720	TMTC	TMTC	NIL.	Absent	
8	MATHAUTA DAM NEAR MATUU W/S TWORKS	RESEARCH	155310	61310	NIL	NIL.	NIL.	Absent	
9.	KAWITUUO STREAM NEAR SOPIA S/CENTRE	RESEARCH	241920	17329	60	10	NIL.	Absent	

MPN: Most Probable Number.
TMTC: Too many to count.

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O/c .....J.N...MUASYA.....
CENTRAL WATER TESTING LABORATORIES

Appendix III

Hydrological data for RGS 4CC3(Yatta Canal Intake)

Table III.1: Monthly evaporation rate for RGS 4CC3 (Yatta canal intake)in mm.

Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
1981	155.1	181.1	185.6	199.1	101.9	125	94	116	144.4	173.7	148.3	122.7
1982	144.5	158.8	188.3	190	107.2	130.4	121	111.5	143.5	138.1	135.1	130.4
1983	189.9	174.4	178.3	201.2	112.5	119.6	104.2	120	147.3	159.2	142	129.1
1985	156	171.1	255.3	202.3	109.2	106.1	104.7	118.1	163	160.8	109.3	147
1986	163.2	191	171.2	124.9	124.2	118.8	101.7	159.2	147.3	167.8	146.8	117.5
1987	122.2	164.4	176.6	297.3	121.9	103	99.5	115.8	151	184.3	139.2	127.2
1988	148.9	188.2	200.8	259.3	121.2	108.8	100.5	112.5	147.3	175.2	220.1	151.4
1989	163.8	157	194.7	168.6	184.7	109	92.7	91	133.6	157.1	147.5	148.2
1990	142.7	116.6	194.7	207.1	143.5	103.7	99	90.3	147.4	182.6	161.2	148.3
2004	157.9	151.1	210.3	209.9	149.6	100.7	97.6	106.9	147.4	181.2	134.6	140.3
2005	179.3	154.8	237	191	136.3	99	100	116.5	155.6	208.7	163.4	168

Source: MWI records

Table III.2 Monthly rainfall (mm) for RGS 4CC3 (Yatta canal Intake).

Year	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1982	1	3.8	50.8	175.7	109	0	0	2	3.5	182.9	249.7	132.1
1983	3.8	71.9	16.3	223.5	30.9	0	2.3	0	0	32.8	134.6	187.9
1984	24.1	0	46.6	88.2	0	0	2.2	0	12	187.9	208.6	18.2
1985	13.2	92.1	264.1	366.5	16.1	7.4	9.5	2.2	0	50.6	115.2	71.4
1986	63.8	0	114.8	325.5	86.4	1.2	0.2	2.2	0	68.8	432.8	113.5
1987	36.3	2	24	179.3	50.8	83.6	1.2	8.3	0	0	110.1	32.2
1988	24	1.2	119.8	438.5	3.7	3.1	0	3.1	31	15.5	207.9	142
1989	67.2	52.5	96.4	124.3	143	0	0.2	0	14.6	47.6	249.3	108.7
1990	49.8	33.6	291.7	127.1	58.1	0.7	0	0	3.2	153.9	249.1	134.8
1991	23.2	0	118.7	131.7	63.6	1.1	2.2	3.2	0.9	39.6	152.2	91.7
1992	20.9	0	14.1	226.1	112.4	2.3	0.9	0.3	6.1	0	186.5	138.4
1993	244.6	71.1	41.2	72.6	52.9	2.7	0	2.2	0	20.3	269.2	133
1994	0	1	103.6	353.6	59.6	0	0	0.3	5.4	157.9	396.3	109.7
1995	27	103.1	175.5	173.2	17.9	1.3	6	0	0	165	65.8	86.5
1996	20.6	30	192	31.3	34.3	25.1	0	4	0	0	231.1	11.2
1997	3.7	0	11.6	362.6	117.1	0	0	13	0	160.6	479	194
1998	355.8	126.8	119.2	221.7	148.1	25	4	8	6.3	0	76.3	39.5
1999	0	0	235.2	100.2	5.6	0	3.9	0	0	52.6	216.5	186.8
2000	11.4	0	17.1	99.5	8.8	2.5	1.9	1	10.5	10.5	170.2	129.9
2001	207.7	45.5	259.3	102	6.8	2.5	0	4.1	5.6	16.4	194.3	28.8
2002	75.7	11.7	166.5	284.9	163.8	4.4	0.8	0.3	0.5	83.7	213.9	201.1
2003	1.5	15.8	29.2	187	408.5	0	0	0	0	51.9	175.5	49.1
2004	83.3	55.9	90.2	262.4	52.7	0	0	1.2	13.7	79.1	159.6	115.5
2005	82.5	3.2	143.4	162.4	191.8	0	0.5	0	0	4.7	146.2	11.5

Source: MWI Records

Table III.3: Mean monthly canal flow in RGS 4CC3 (Yatta Canal Intake), m^3/s

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1961	0.54	0.64	0.59	1.23	1.23	1.23	1.23	1.23	0.62	0.65	0.4	0.42
1962	0.56	0.66	0.22	0.22	0.23	0.22	0.22	0.22	0.24	0.22	0.22	0.25
1963	0.23	0.22	0.25	0.45	0.27	0.29	0.3	0.3	0.3	0.51	0.6	0.58
1964	0.55	0.54	0.57	0.4	0.56	1.03	0.99	1.04	0.95	0.67	0.54	0.64
1965	0.64	0.78	0.82	0.56	0.52	0.94	0.96	0.95	0.63	0.69	0.61	0.45
1966	0.41	0.46	0.58	0.57	0.55	0.54	0.54	0.54	0.8	0.72	0.53	0.63
1967	0.82	0.89	0.8	0.59	0.51	0.35	0.74	0.99	0.84	0.98	0.7	0.68
1968	0.72	0.72	0.75	0.62	0.52	0.49	0.49	0.49	0.64	0.64	0.55	0.54
1969	0.43	0.49	0.42	0.45	0.45	0.7	0.86	0.72	0.6	0.86	0.76	0.61
1970	1.07	1.1	1.06	0.43	0.37	0.46	0.9	0.93	0.88	0.9	0.9	0.88
1971	1.11	1.21	1.23	0.96	0.65	0.69	0.98	0.98	0.98	1.05	0.98	0.87
1972	0.96	1.02	0.99	1	0.85	0.72	0.66	0.68	0.72	0.69	0.59	0.79
1973	0.73	0.74	0.75	0.75	0.73	0.73	0.85	0.88	0.86	0.8	0.76	0.83
1974	0.99	0.99	0.98	0.4	0.2	0.39	0.84	0.88	0.84	0.8	0.65	0.68
1975	0.75	0.89	0.79	0.83	0.96	1.04	1.01	1.04	1.03	1.04	0.87	0.97
1976	0.96	0.93	0.93	0.88	0.85	0.92	0.93	0.97	0.99	1.08	0.96	0.9
1977	1.09	1.18	1.17	0.87	0.85	1.01	1	1.04	1.05	1.02	0.9	0.86
1978	0.85	0.85	0.86	0.73	0.74	0.99	0.99	0.99	0.91	1.07	0.84	0.57
1979	0.67	0.61	0.65	0.62	0.65	0.63	0.73	0.84	0.79	0.81	0.66	0.75
1980	0.92	0.99	0.81	0.68	0.57	0.8	0.86	0.82	0.79	0.9	0.66	0.69
1981	0.84	0.86	0.74	0.42	0.24	0.66	0.7	0.73	0.75	0.75	0.43	0.88
1982	0.8	0.81	0.82	0.53	0.51	0.72	0.72	0.73	0.9	0.67	0.43	0.45
1983	0.82	0.9	0.88	0.72	1.01	0.95	0.99	0.99	0.97	0.96	0.74	0.89
1984	0.97	1.03	0.91	0.83	0.82	0.61	0.81	0.83	0.82	0.86	0.61	0.64
1985	1.02	1	0.94	0.61	0.87	1.02	1.02	0.98	1.07	1.08	1	1.04
1986	0.98	0.77	0.91	0.57	0.77	1	1.04	1.08	1.04	1.03	0.84	0.96
1987	1.07	1.09	0.97	0.96	1.03	1.12	1.65	1.46	1.14	0.87	0.76	0.96
1988	1.14	0.83	0.94	0.78	1.03	1.19	1.21	1.22	1.22	1.17	1.03	1.14
1989	0.95	1.12	1.13	0.87	0.9	1.16	1.17	1.21	1.26	1.22	0.97	0.82
1990	1.04	1.22	0.94	0.92	1.05	1.21	1.37	1.38	1.37	1.31	0.88	0.85
1991	1.16	1.32	1.28	1.2	1.43	1.38	1.4	1.43	1.4	1.34	1.17	1.17

Table III.4 Continued

Year	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1992	1.1	0.8	0.74	1.26	1.36	1.41	1.43	1.41	1.32	1.29	1.28	1.32
1993	1.34	1.32	1.4	1.4	1.43	1.43	1.44	1.31	0.86	0.73	1.37	1.46
1994	1.16	0.75	0.73	1.42	1.57	1.53	1.43	1.42	1.16	1.2	1.44	1.39
1995	1.44	1.44	1.44	1.75	1.48	1.44	1.44	1.25	1.2	1.44	1.44	1.44
1996	1.44	1.44	1.28	1.28	1.4	1.44	1.44	1.44	1.44	1.14	1.39	1.44
1997	1.19	0.76	0.63	1.4	1.44	1.44	1.44	1.44	1.34	1.37	1.44	1.44
1998	1.44	1.44	1.18	1.25	1.44	1.44	1.44	1.44	1.44	1.35	1.39	1.25
1999	1.23	1.02	1.21	1.44	1.44	1.25	1.44	1.34	1.37	1.04	1.41	1.47
2000	1.45	1.44	1.25	1.32	1.05	0.73	0.88	0.52	0.36	0.25	1.08	1.34
2001	1.36	1.44	1.33	1.5	1.45	1.44	1.32	1.11	0.99	0.93	1.41	1.32
2002	1.07	0.71	1.24	1.28	1.58	1.42	1.38	1.48	1.47	1.45	1.39	1.37
2003	1.38	1.23	1.38	1.41	1.44	1.44	1.44	1.44	1.44	1.44	1.44	1.44
2004	1.44	1.43	1.2	1.44	1.44	1.44	1.38	1.27	1.03	1.12	1.6	1.44
2005	1.26	1.01	1.28	1.41	1.49	1.37	1.47	1.48	1.4	1.27	1.46	1.44

Source: MWI records

Appendix IV

Table IV.1 Crop factor(coefficient) Kc

Crop	Kc (for total growing period)
Sukuma wiki (Kales)	0.7-0.8
French beans	0.85-0.9
Bananas	0.86-0.95
Cassava	0.75-0.85
Tomato	0.75-0.9
Maize	0.75-0.9
Mangoes	0.85-0.9
Sugarcane	0.85-1.05
Beans	0.7-0.8
Potatoes	0.75-0.9
Pepper	0.7-0.8
Orange	0.65-0.75
Spinach	0.7-0.8
Karrera	0.85-0.9
Onion	0.8-0.9
Dudhi	0.85-0.9

Source : MWI, 2005.

Table IV.2 Average monthly effective rainfall as related to monthly ETcrop and monthly rainfall

		Monthly Rainfall (mm)											
		12.5	25	37.5	50	62.5	75	87.5	100	112.5	125	137.5	150
Average	25	8	16	24									
Monthly	50	8	17	25	32	39	46						
ET_{crop}	100	9	18	27	34	41	48	56	62	69			
(mm)	125	9	19	28	35	43	52	59	66	73	80	87	94
	150	10	20	30	37	46	54	62	70	76	85	92	98
	175	10	21	31	39	49	57	66	74	81	89	97	104
	200	11	23	32	42	52	61	69	78	86	95	103	11

Source: MWI, 2005