



**UNIVERSITY OF NAIROBI**

**FACULTY OF ENGINEERING**

**DEPARTMENT OF CIVIL AND CONSTRUCTION ENGINEERING**

**ASSESSMENT OF POST EXPANSION IMPACTS OF MARUBA DAM IN  
MACHAKOS COUNTY; A CASE STUDY OF MIWANI ESTATE IN MACHAKOS  
TOWN**

**JOSEPH KARIUKI NGARI**

**Registration Number F56/67369/2013**

**A Thesis submitted in partial fulfillment of the requirements for the award of degree of  
Master of Science in Civil Engineering (Water Resources Engineering Option) of the  
University of Nairobi**

**August 2022**

**DECLARATION**

I, **Joseph Kariuki Ngari**, declare that this thesis is my original work and has never been presented for any academic award in this university or any other university.

Signature  .....

Date: 05 08 2022

This thesis has been submitted for examination with our approval and as university supervisors.

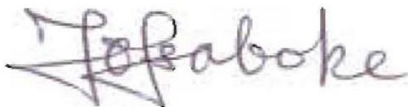
**Lead supervisor:** Professor Ezekiel Nyangeri Nyanchaga



Signature.....

Date: 08 08 2022

**Second supervisor:** Dr. Zablon Isaboke Oonge



Signature.....

Date: 11<sup>th</sup> August 2022

## DECLARATION OF ORIGINALITY

**Name of Student:** Joseph Kariuki Ngari

**Registration Number:** F56/67369/2013

**Faculty/School/Institute:** Faculty of Engineering

**Department:** Department of Civil and Construction Engineering

**Course Name:** Master of Science Degree in Civil Engineering

**Title of the Work:** Assessment of Post Expansion Impacts of Maruba Dam in Machakos County; A Case Study of Miwani Estate in Machakos Town

1. I understand what Plagiarism is and I am aware of the University's policy in this regard.
2. I declare that this thesis is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my own work has been used, this has been properly acknowledged and referenced in accordance with University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work.
4. I have not allowed and shall not allow anyone to copy my work with the intention of passing it off as his/her own work.
5. I understand that any false claim in respect of this work shall result in disciplinary action, in accordance with University of Nairobi anti-plagiarism policy.

**Signature**  .....

**Date:** 05 08 2022

## **DEDICATION**

This thesis is dedicated to my wife Rose, children; Victor, Vicsally and Prince; my parents; Stephen and Gladys. I am grateful for their prayers, support and encouragement without which I could not have completed this research.

## **ACKNOWLEDGEMENT**

I am thankful to God for his grace and guidance throughout the process of this thesis preparation and writing.

I am also grateful for the support, advice and guidance given to me by my supervisors, Professor Ezekiel Nyangeri Nyanchaga and Dr. Zablon Isaboke Oonge. I appreciate their effort, time and wisdom that they shared with me throughout the process of coming up with this thesis.

I also acknowledge the former Chairman Department of Civil and Construction Engineering, Dr. S. O. Dulo for his encouragement.

I appreciate the support accorded to me by National Water Harvesting and Storage Authority. In particular, I appreciate Eng. Fredrick Ako for availing useful information and documents for my literature review. I also appreciate the entire management and staff of Machakos Water and Sewerage Company and in particular the Technical Manager, Eng. Joseph Mutende for the valuable information and support they gave me during the field visits.

## TABLE OF CONTENTS

DECLARATION .....	i
DECLARATION OF ORIGINALITY .....	ii
DEDICATION.....	iii
ACKNOWLEDGEMENT .....	iv
TABLE OF CONTENTS.....	v
ABBREVIATIONS AND ACRONYMS .....	viii
LIST OF TABLES.....	x
LIST OF FIGURES .....	xi
ABSTRACT.....	xii
CHAPTER ONE: INTRODUCTION.....	1
1.1 Background to the Study .....	1
1.2 Problem Statement .....	4
1.3 Scope of the Study.....	5
1.4 Overall Objective of the Study.....	6
1.4.1 Specific objectives .....	6
1.5 Significance of the Study .....	6
1.6 Justification for the Study .....	7
1.7 Limitations of the Study.....	7
CHAPTER TWO: LITERATURE REVIEW .....	8
2.1 Introduction .....	8
2.2 Economic Impacts .....	10
2.2.1 Economic Benefits .....	10
2.2.2 Economic Costs .....	12
2.3 Environmental Impacts .....	13
2.3.1 Environmental Benefits .....	13
2.3.2 Environmental Costs.....	14
2.4 Social Impacts .....	18
2.4.1 Social Benefits .....	18
2.4.2 Social Costs.....	19
2.5 Environmental Management Plan .....	20
2.6 Conceptual Framework .....	23
CHAPTER THREE: MATERIALS AND METHODS .....	25
3.1 Introduction .....	25

3.2	Overview of Machakos County .....	25
3.2.1	Water Supply for Machakos Town .....	26
3.3	Objectives for Expansion of Maruba Dam.....	27
3.4	Background Information on Miwani Estate .....	28
3.5	Research Methodology Framework .....	30
3.6	Research Instruments .....	38
3.7	Pre-test of Survey Instruments .....	38
3.8	Data Collection Techniques .....	39
3.9	Sampling.....	40
3.9.1	Sample size .....	41
3.10	Data Analysis .....	41
<b>CHAPTER FOUR: RESULTS AND ANALYSIS.....</b>		<b>43</b>
4.1	Introduction .....	43
4.2	Economic Impacts .....	44
4.2.1	Economic Benefits .....	44
4.2.2	Economic Costs .....	50
4.3	Environmental Impacts .....	51
4.3.1	Environmental Benefits .....	51
4.3.2	Environmental Costs.....	55
4.4	Social Impacts .....	59
4.4.1	Social Benefits .....	59
4.4.2	Social Costs.....	62
4.5	Observations Made.....	64
4.5.1	Observations pointing to Economic Impacts .....	64
4.5.2	Observations pointing to Environmental Impacts.....	64
4.5.3	Observations pointing to Social Impacts .....	66
4.5.4	Additional information from MAWASCO .....	66
4.6	Comparative Analysis of the Impacts .....	67
4.6.1	Benefits.....	67
4.6.2	Costs .....	68
4.7	Schematic Correlation of Impacts .....	69
4.7.1	Analysis of Positive Impacts .....	71
4.7.2	Analysis of Negative Impacts .....	72
4.7.3	Overall Summation of Impacts .....	74
4.8	Status of Implementation of the Environmental Management Plan .....	77

4.9	Water Quality .....	78
4.9.1	Secondary data for physical-chemical analysis of raw water .....	78
4.9.2	Secondary data for physical-chemical analysis of tap water .....	78
4.9.3	Secondary data for bacteriological results of raw water .....	79
4.9.4	Secondary data for bacteriological results of treated water.....	79
4.9.5	Primary data for physical-chemical analysis of tap water .....	80
4.10	Analysis of the Quality of Water.....	80
4.11	Overall Summary of the Findings .....	81
CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS .....		83
5.1	Conclusion.....	83
5.2	Recommendations .....	84
5.3	Recommendations for Further Study .....	85
REFERENCES .....		86
APPENDICES .....		94



## **ABBREVIATIONS AND ACRONYMS**

AIDS	-	Acquired Immune Deficiency Syndrome
ASAL	-	Arid and Semi-Arid Lands
CBD	-	Central Business District
EIA	-	Environmental Impact Assessment
EMP	-	Environmental Management Plan
ESIA	-	Environmental and Social Impact Assessment
HIV	-	Human Immunodeficiency Virus
ICOLD	-	International Commission on Large Dams
IEBC	-	Independent Electoral and Boundaries Commission
IUWM	-	Integrated Urban Water Management
KEBS	-	Kenya Bureau of Standards
KES	-	Kenya Shilling
m	-	Meter
MAWASCO	-	Machakos Water and Sewerage Company
mm	-	Millimeter
m <sup>3</sup>	-	Cubic meter
NEMA	-	National Environment Management Authority
NGOs	-	Non-Governmental Organizations
NWCPC	-	National Water Conservation and Pipeline Corporation
NWHSA	-	National Water Harvesting and Storage Authority
SDGs	-	Sustainable Development Goals
UNDP	-	United Nations Development Programme

UNESCO	-	United Nations Educational, Scientific and Cultural Organization
UPVC	-	Unplasticized Polyvinyl Chloride
US	-	United States
WHO	-	World Health Organization
WRA	-	Water Resources Authority
WSB	-	Water Services Board
WSTF	-	Water Sector Trust Fund
WWDA	-	Water Works Development Agency

## LIST OF TABLES

Table 2.1 Environmental Management Plan.....	22
Table 3.1 Research Framework .....	31
Table 4.1 Analysis of Benefits.....	67
Table 4.2 Analysis of Costs .....	68
Table 4.3 Weighting of Positive Impacts.....	71
Table 4.4 Weighting of Negative Impacts.....	73
Table 4.5 Summation of Impacts .....	75
Table 4.6 Secondary Data for Bacteriological Results for Raw Water .....	79
Table 4.7 Secondary Data for Bacteriological Results for Treated Tap Water .....	80

## LIST OF FIGURES

Figure 1.1: Location of Machakos County on the Map of Kenya .....	3
Figure 2.1: Trinity of Impacts Determining Sustainability.....	10
Figure 2.2: Conceptual Framework .....	24
Figure 3.1: Map of Machakos Town Sub-County .....	26
Figure 3.2: Location of Maruba Dam in Relation to Machakos Town and Miwani Estate.....	29
Figure 4.1: Analysis of Economic Benefits .....	45
Figure 4.2: Analysis of Economic Costs.....	50
Figure 4.3: Analysis of Environmental Benefits.....	522
Figure 4.4: Trees and Flower Nurseries Near the Show Ground.....	54
Figure 4.5: Planted Trees along Riparian Land .....	544
Figure 4.6: Analysis of Environmental Costs .....	555
Figure 4.7: Modes of Wastewater Disposal in Miwani Estate.....	566
Figure 4.8: Wastewater From one of the Flats.....	57
Figure 4.9: Wastewater From Athletics Kenya Southern Branch Office.....	57
Figure 4.10: Solid Waste Thrown in Open Space.....	59
Figure 4.11: Analysis of Social Benefits .....	60
Figure 4.12: Part of Machakos People’s Park.....	622
Figure 4.13: Analysis of Social Costs.....	633
Figure 4.14: Top Soil Dumped on the Riparian Land along the Reservoir .....	655
Figure 4.15: Trees Growing on Maruba Dam Embankment.....	66
Figure 4.16: Schematic Correlation among the Various Impacts.....	70

## **ABSTRACT**

Water is a universal need and is considered the principal limiting factor for human life. The objective of this study was to determine the impacts that resulted from the expansion of Maruba dam, within Miwani estate in Machakos town that had an estimated target population of 10,000 people. Data was collected using: semi structured household survey questionnaires that sampled 385 respondents; key informant interview and focus group discussion guide that sampled 12 respondents; physical observations; and desk review of secondary data.

The findings of the study show that, expansion of Maruba dam resulted to both positive and negative economic, environmental and social impacts. The comparison of the impacts showed that economic impacts had a resultant weight of 64.4% while the social and environmental impacts had resultant weights of 33.2% and 2.4% respectively. However, the positive impacts for each of the parameters outweighed the respective negative impacts.

Water coverage in Miwani estate increased from 120m<sup>3</sup>/day (20%) to approximately 958m<sup>3</sup>/day (70%) after the expansion of the dam. Revenue collected from the estate by the local water company increased from KES 101,231 to KES 859,393 per month.

Based on the research findings it was concluded that the expansion of Maruba dam contributed positively to economic, social and environmental well-being of the residents of Miwani estate. It is recommended that the estate be sewerred and be connected to the existing sewerage system. The County Government should improve on solid waste management, so as to mitigate against environmental pollution.

## CHAPTER ONE: INTRODUCTION

### 1.1 Background to the Study

Throughout history and the world over, man has been dependent on adequate water supply for his food security, socio-economic development and general well-being. Water is a universal need and is considered the principal limiting factor for human life. Likewise, the general ecosystem is dependent on adequate water supply for its survival. Of the earth's total surface, seventy percent is covered by water, where only one percent of this can be utilized as a source of potable water (Alphaomega, 2012). Sources of potable water in the world include; rivers, springs, lakes, dams, boreholes, wells among others (Australian Government, 2017).

Communities with inadequate water supply are left with no alternative other than to find local sources of drinking water such as wells, rivers and rain water harvesting among others so as to meet their domestic water needs (Edokpayi et al., 2015). Water from such sources is consumed without any form of treatment and is vulnerable to pollution. This constitutes a major public risk which may cause diarrhea disease, a major cause of child mortality in developing countries. Besides infectious diseases, other components such as fluoride, lead, nitrates and arsenic from contaminated drinking water can lead to cancer, acute nausea, memory lapses, anemia and fetal abnormalities among others (Bain et al., 2014).

Lack of adequate basic infrastructure is a major challenge facing the urbanization process in Africa. Actualizing the dream of water for all is one of the difficult tasks for urban water and sanitation managers in the 21<sup>st</sup> century. It is predicted that in the next 30 years, most urban growth in Africa will take place in the fast-growing small towns. A complex set of social and technical factors is posing a challenge to the actualization of Integrated Urban Water Management (IUWM) strategies in Africa. In addition to the above, there are a myriad of other factors that include; stringent regulatory framework, institutional fragmentation, lack of

suitable financial and economic models which are required so as to provide a platform of incentives for efficient and safe reuse. Many of the IUWM projects in Africa are of uncertain suitability and are mainly at piloting stage (Jacobsen et al., 2013).

In Kenya, the arid and semi-arid land (ASAL) covers about 80% of the total land. Immigration of people from the high potential areas to the ASAL areas has resulted to a rapid increase in population in such areas. Machakos County is one of the areas affected by such immigration. The location of Machakos County in relation to other counties of Kenya is as shown in Figure 1.1. Immense pressure has been exerted on the limited natural resources including the few surface water sources available. The growth in domestic and industrial water demand, has put immense pressure on the capacity of water schemes to supply the commodity in the required quality and quantity. Management of the resulting volumes of effluents and associated sludge is also wanting. Decisions on future urban development must balance considerations of water supply with possible negative impacts of population increase and include innovative strategies of management of effluents and storm water to mitigate their negative impacts (Kaloustian and Diab, 2015).

Water is a right to every Kenyan citizen according to the Constitution of Kenya (Government of Kenya, 2010). Through the enactment of the Water Act 2016, enhanced access to water has been realized across the country. Despite the positive development, millions of Kenyan citizens have no access to safe water or are forced to walk for long distances in search of the valuable commodity.



Figure 1.1: Location of Machakos County on the Map of Kenya

In response to water needs, the Kenyan government and other agencies including Non-Governmental Organizations (NGOs) have engaged in construction of water harvesting structures (dams) to increase water availability. The main objective of the projects is to avail



the resource within minimum distances of travel and in reliable quantities (NWCPC, 2008). Expansion of Maruba dam which is the major source of water for Machakos town is one of the projects implemented by the government in its effort to address the water shortage.

Water reservoirs have the potential to impact positively or negatively on the people and the surrounding environment. Each of the two categories of impacts can further be broken into three major items. These are; economic, environmental and social impacts. According to Butler et al. (2017), most studies conducted on impacts of dams have been biased on the displaced population, the fauna and flora around the reservoir, the downstream effects, sediment flow and the aquatic life. Studies on impacts of water supply dams on the command areas have not been given prominence.

## **1.2 Problem Statement**

National Water Harvesting and Storage Authority (NWHSA), formerly National Water Conservation and Pipeline Corporation was established through the Water Act 2016. The Authority constructed over 200 small dams and pans in Machakos County from 2005 to 2015. This is according to the Authority's end of financial year 2014-2015 projects report (NWCPC, 2015). The Authority has not been able to come up with a study on the post construction or post expansion impacts of these dams and pans including for others that it has been implementing throughout the country. Some of the projects have had enormous positive and negative impacts to the environment and the beneficiaries, which have not been documented. There was therefore need to assess the post construction or post expansion impacts of the implemented dams which would offer a platform for any appropriate measure that may be required. There was also a need to establish whether the recommendations in the Environmental Management Plans (EMPs) are being adhered to.

In order to carry out a thorough study, Maruba dam which is the main source of water for Machakos town and its environs was purposively selected for the study. The dam was constructed in the late 1950s during colonial times and was rehabilitated and expanded by NWHSA during the period 2008 to 2010.

### **1.3 Scope of the Study**

The scope of the study was limited to Miwani estate. The estate is located in Machakos town. The research was limited to the residents who depend on the water supply from Machakos Water and Sewerage Company. The estate was selected because it used to suffer from acute water shortage before the expansion of the dam. Water coverage in the estate was approximately 20% and water rationing was the order of the day before the expansion of the dam (NWCPC, 2008). Currently, the water coverage in the estate is approximately 70% (MAWASCO, 2018).

The parameters that the study explored in the estate are; economic, social and environmental impacts which emanated in the estate as a result of expansion of Maruba dam. These impacts are deemed to be as a result of both internal and external factors. The internal factors are considered as those that resulted from the intensified activities by the initial residents of the estate. The external factors are considered as the activities by the influx of the new population, whose activities loaded into the already existing ones.

The parameters that were analysed under economic impacts are; improvement in water supply, rejuvenation of businesses, establishment of new businesses, employment opportunities, construction of new buildings, establishment of new institutions, appreciation in value of the land and establishment of kitchen gardens. The parameters that were analysed under environmental impacts are; establishment of trees and flower nurseries, planted trees, planted flower beds, wastewater and solid waste disposal. Likewise, the parameters that were analysed

under social impacts are; increase in population, establishment of recreation facilities, access to clean, safe and reliable water, occurrence of water borne diseases and improvement of infrastructure.

The selection of the impacts and the corresponding parameters for each impact for the study emanated from the discussions with the residents of Miwani estate during the field visits and the pre-testing of the questionnaires. The researcher zeroed only on the parameters that the residents identified, since they would have more input regarding them as opposed to proposing different impacts that they could not identify themselves with. The respondents identified more parameters in relation to economic impacts as compared to social and environmental impacts.

#### **1.4 Overall Objective of the Study**

To assess the post expansion impacts of Maruba dam, within Miwani estate.

##### **1.4.1 Specific objectives**

- 1) Determine the economic impacts within Miwani estate and to the Water Service Provider that resulted due to the expansion of Maruba dam.
- 2) Determine the environmental impacts within Miwani estate that resulted due to the expansion of Maruba dam.
- 3) Determine the social impacts within Miwani estate that resulted due to the expansion of Maruba dam.

#### **1.5 Significance of the Study**

This study will inform; Machakos Water and Sewerage Company, NWHSA, Machakos County Government and by extension the National Government, on the impacts that resulted from the expansion of Maruba dam besides supply of water, that may require mitigation measures. This will influence future decision-making during planning and implementation of projects.

## **1.6 Justification for the Study**

The research was important since NWHTSA has not conducted any studies on the impacts of the projects that it has been completing successfully. Previous, studies carried out by other researchers show that dams have the potential to impact positively or negatively on their surroundings.

## **1.7 Limitations of the Study**

The people targeted as respondents for this study were those who were living in Miwani estate before and after the expansion of Maruba dam. However, due to population dynamics in urban areas, some people with valuable information may have migrated to other areas. Some respondents presented some resistance in answering questions.

The researcher overcame this challenge by using research assistants who helped reach the right respondents and also explained to the respondents that the research was purely for academic purpose.

## CHAPTER TWO: LITERATURE REVIEW

### 2.1 Introduction

Dams play an important role in accelerating economic, societal development and improving public service quality by providing water for irrigation, flood protection, drinking water and hydroelectric power (Koirala et al., 2017). By 2017, there were 58,519 dam projects in operation globally according to ICOLD (2018). The Sustainable Development Goals (SDGs) have provided a major focus for water management activities and construction of dams (Bazin, Skinner and Koundouno, 2011). Rampant climatic changes have caused a number of uncertainties on future water resource availability hence more storage needs. The creation of dams plays a significant role in the communities they are initiated. Through the benefit sharing initiatives, dam projects help foster good work relations with the local communities. Good neighbourliness with the local communities helps prevent project delays as well as enhance local cooperation in the conservation of the water catchment areas. In a study on impacts of improved water and sanitation services in Madagascar, by School of International and Public Affairs, Columbia University, SIPA (2008), it was established that, WaterAid's supported projects increased awareness of individual behaviour on the ecosystem functioning and resulted to afforestation projects. The projects also contributed to improved hygiene and personal welfare. They also enabled village beautification projects through flower gardens and by improving cleanliness.

The impact of the activities undertaken during the construction and the operation phases of water supply schemes on the environment is diverse and complex. There are no effective strategies that have been found effective to operationalize environmental sustainability. Projects are mainly developed in view of the benefits that will accrue from them (Scudder, 2019). He continues to argue that, it is therefore paramount that the environmental, social and

economic benefits of a project should outweigh its short term and long term costs. Besides the construction of projects, issues such as efficient management, institutional strengthening, training, information and communication should be given due consideration.

Sustainable development has been attributed to a number of meanings and ideologies. The difference in opinions about sustainable development neither reflect conflict nor materiality, but is likewise related to the interests which the various sectors would like to see represented. Therefore, sustainable development does not necessarily refer to a goal that can be measured in terms of achievement at any specific time, but instead recognizes the striking of a balance in the interaction among economic, social and environmental aspects. Hence, development projects should initiate economic, social and environmental aspects as goals in their development agenda (Soderbaum, 2015). In his study on impacts of small scale community water projects in Chimanimani district of Zimbabwe, Chapungu (2014), established that the water projects contributed to improvement of life in Shinja resettlement area in many ways. He pointed that the impacts were contributory rather than attributory. They included; reduced vulnerability, reduced cases of water and sanitation related diseases, an increase in economic activities, socio-cultural upliftment, improved hygiene, time saving and improved access to food.

The sustainability concept of projects is generally based on social, environmental and economic dimensions and their correlation is as shown in Figure 2.1 (Novotny et al., 2010).

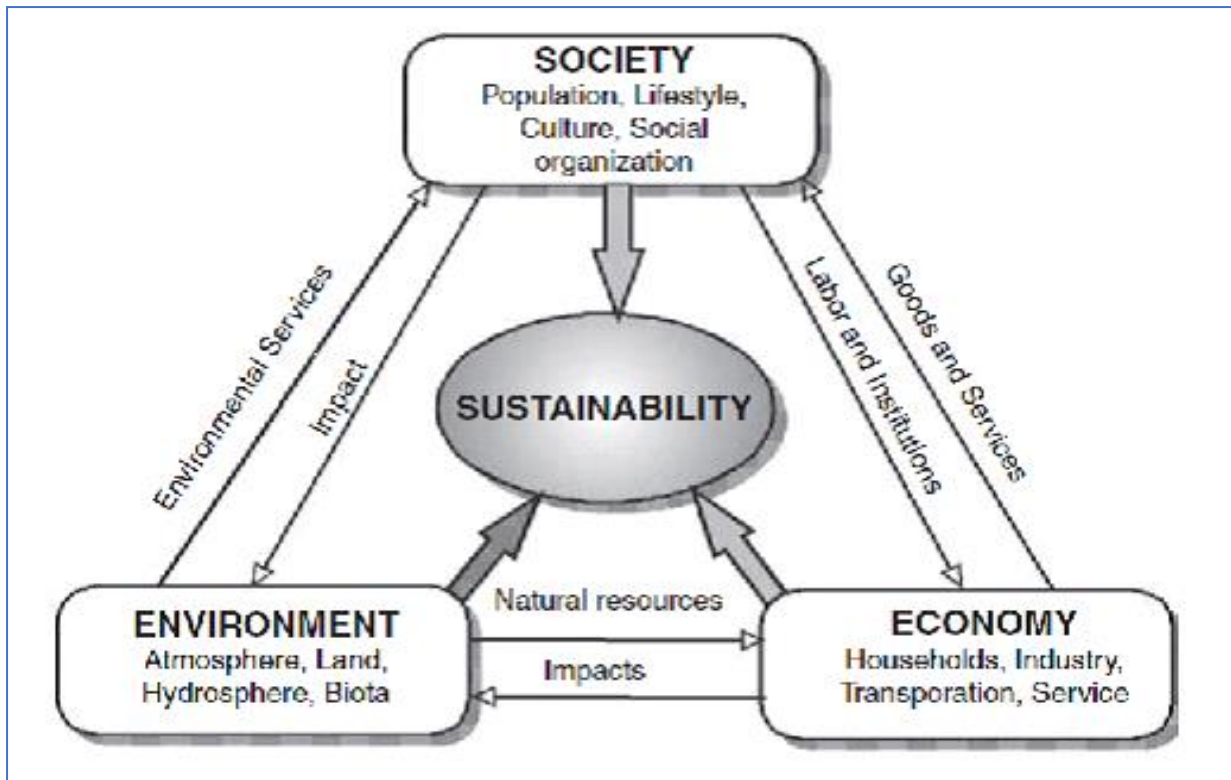


Figure 2.1: Trinity of Impacts Determining Sustainability

## 2.2 Economic Impacts

### 2.2.1 Economic Benefits

Properly planned, structurally sound and a politically transparent dam project is beneficial. The economic benefits of a dam are realized when the contractor operates within the budget estimates and the specified timelines in order to mitigate against their variations. Variations arise when the cost of construction exceeds budgetary estimates (Hilyard, 2008). Effective planning is therefore paramount so as to avoid cost overruns.

According to Reba (2003), water is among the most important resources for economic development in any given community. He continues to argue that poor access to reliable water contributes to food insecurity and hunger. A close examination of the millennium declaration

confirms the central role played by water in sustainable development and that access to safe drinking water can lead to poverty alleviation. According to UN-World Water Development Report (2018), water, sanitation and hygiene are essential in achieving Sustainable Development Goals and hence alleviating global poverty. An investment in the water sector is an investment in all the SDGs.

The Environmental Impact Assessment report conducted by NWCPC (2008) cited that, expansion of Maruba dam was expected to provide adequate water supply to the local communities, consequently improving their livelihood. Time and other extra resources allocated in search of water would then be used for other productive activities. Adequate clean water was expected to impact positively on community health such that diseases associated either with lack of adequate water or use of unsafe water would be reduced. Monies previously used to buy water and pay hospital bills would then be available for other uses.

An improved water source, is one of the key contributors to better human health. Studies show that 80% of all communicable diseases are water related and therefore constitute a major proportion of health care expenditure. Some of the benefits of improved sanitation and water services include averted health related costs (GOK, 2019). The report also states that, adequate water supply and sanitation, contribute to a reduction in maternal mortality resulting to fewer miscarriages.

According to Machakos Water and Sewerage Company annual report of 2018, there is a huge margin in cost when water is bought from water vendors which retails at an average of KES 50 per 20 litres while the same amount of money can afford approximately 1000 litres of piped water (MAWASCO, 2018). The burden of accessibility to water includes the time spent in the collection process. Over two thirds of households globally fetch water from outside the home. Different studies have shown that search for water may take 2-4 hours daily, travelling



distances of over 3 kilometers and carrying a load of between 20-25 kilograms. Culturally, this is a function of women and children (Alaci and Alehegn, 2009). Providing people with reliable and potable water supply has a potential of increasing the income of households. The time and energy saved from search of water can be utilized in undertaking other activities that have economic or social gains (Joshi and Fawcett 2011).

It was anticipated that with an improved water supply for the residents of Machakos town and the subsequent influx of population, there would be up scaling of the existing economic activities and the emergence of new ones. A Study by Furuoka (2005) on population growth and economic development in Malaysia showed that there exists a positive long run cointegration relationship between population growth and economic growth. Flourishing of both local and international tourism was expected due to the close proximity of Machakos to the Nairobi National Park and the Jomo Kenyatta International Airport. Other activities like manufacturing, garages, financial services, wholesale and retail trade among others were also expected to emerge (Government of Machakos County Profile, 2015).

### **2.2.2 Economic Costs**

Pollution of water and unrestrained water withdrawals has had serious ravaging economic effects to the Middle East and North Africa, causing a loss of about US\$9 billion a year (Hussein, 2008). Pollution of ground and surface water heighten human and environmental health risks thus resulting to increased costs of water treatment. Increased water treatment costs limit production of clean safe water (UNESCO, 2017a). Consumption of polluted water results to significant economic losses. The WHO (2016) report postulates that a total of US\$28.4 is incurred in Africa, so as to avert productivity losses and to treat diseases associated with water pollution. Hesselbarth (2005) observed that insufficient water supply may result to; Arsenic contamination and increased levels of salts in drinking water which are associated with kidney

diseases. Stagnant water around the households and water points can contribute to incidences of malaria, particularly in dry areas which have very limited natural mosquito breeding areas.

Duplication of roles by various institutions charged with management of the water sector is a key challenge to the ultimate water consumer. Fragmented institutional arrangement responsible for urban water management poses another challenge to the consumer. There lacks sound organization in the institutions responsible for water resource protection, supply, sewerage and storm water management. The consumer usually is overstretched by the bills required to be paid to each institution. There also exists a gap in the cooperation between the bodies responsible for water, housing, transport, energy, environment and urban planning. Relevant changes in the organizational structure and policy formulation are necessary so as to avert strained sectoral resolutions which burden consumers. This would help foster a more integrated approach towards water management (Pimentel et al., 2004). To achieve improved water access and conservation levels, reasonable water pricing has to be initiated to make it more affordable to the consumers (UNESCO, 2017b).

Increase in population in an area is bound to carry with it other costs besides economic well-being. Some of the negative vices that come with increase in population include; increase in crime rates due to insufficient financial resources, irresponsible waste disposal, decline in social infrastructure, circumventing governance, unemployment, over exploitation of the available resources among others (Eurostat, 2015).

## **2.3 Environmental Impacts**

### **2.3.1 Environmental Benefits**

A water supply dam is more environmentally friendly as compared to dams constructed for many other purposes. The environmental benefits of a dam largely depend on its size, purpose and the geographic location. When constructed in the right scale, dams are the most suitable

sources of water supply and are also environmentally friendly (Evans et al., 2017). In their case study of Kiindu catchment in Kitui, Borst and Haas (2006) cited that, dams help in raising ground water levels in the areas adjacent to them therefore boosting the vegetation cover. Mushrooming of tree and flower nurseries as a result of water availability is a benefit that is usually overlooked. This activity doubles both as an economic and environmentally friendly venture.

Rapid urbanization and scramble for wood and non-wood resources is causing water stress. The euphoria kind of reactions to supplement the inadequate water supply is a short term measure and may accelerate depletion of the available water resources consequently impacting negatively to the environment. Efficient urban water management is critical to guaranteeing environmental and human health. Water management authorities can assist to curb the water shortage menace by sensitizing the general public on efficient water usage as well as proper utilization of other water sources such as storm water (Brown et al., 2019).

Treatment of sewage to the recommended standards by the relevant regulatory institutions can aid in water recovery, lower emission of greenhouse gases and reduce the scarcity associated with the effects of growing populations, urbanization and climate change (UNDP, 2017). Regular assessment of availability of water resource using appropriate tools such as audits, help in quantification and establishment of the resultant demand. The audit reports aid in the formulation of water policies, Government intervention approaches and investment resolutions.

### **2.3.2 Environmental Costs**

There has been increasing public growth awareness globally on environmental issues in the recent past. Consequently, pressure has been put to both public and private sectors to prioritize environmental health during implementation of projects. Through the environmental

awareness, the public are able to expose erroneous actions which may be real or perceived. Both public and private sectors are continually realizing the importance of checking on their social and environmental performances. Improvement is notable in some areas though it is not major so as to modify the current trends of environmental degradation (Welford, 2000).

The quality of environment is lowered due to insufficient waste disposal systems, overpopulation, inadequate planning as well as other human practices. People living in areas with poor sanitation and hygiene conditions are more prone to illnesses. In Kenya, the National Environment Management Authority (NEMA), through Environmental Management and Coordination Act, 1999 is charged with the responsibility of ensuring a clean and healthy environment. Despite this legal provision, some people and some firms still discharge effluents and solid wastes in the available open spaces and open channels.

The environmental impacts of dams are numerous and varied. There are direct consequences to chemical, physical and biological characteristics of the surroundings. Due to the expansion of Maruba dam, new economic activities were anticipated. The new opportunities were expected to attract an influx of population seeking for greener pastures. Subsequently, this would necessitate for more housing, water, health and education services among others. With this influx, environmental degradation in aspects like soil, air and water pollution would be inevitable. Poorly managed industrial and household wastes which in turn affect the available water resources, are a major consequence of rise in population in an area. Some water sources may become unsuitable for certain uses and the cost of treatment may rise due to eutrophication, requiring additional treatment (Sadoff and Muller, 2009).

Emission of greenhouse gases, generation of wastes, as well as land use patterns in urban centers, highly affects the carbon cycle and the climate system. Wastewater treatment results in the production of carbon dioxide, methane and nitrous oxide whose emissions have a

significant impact on the environment (WHO and DFID, 2009). The emissions associated with methane and nitrous oxide from polluted water were anticipated to escalate by almost 50 and 25 percent between the years 1990 and 2020 respectively (IPCC, 2007).

Wastewater effluents in urban areas represent a pollution load that cannot be wished away. Where sewerage infrastructure is not in place or is inadequate, the available natural or artificial channels act as an alternative for wastewater disposal. It is estimated that only 8 percent of Africa's city population use sewered sanitation. The WHO-UNICEF Joint Monitoring Programme (2010) report indicates that, in 2008, approximately 255 million (or 84 percent) urban dwellers in sub-Saharan Africa had onsite sanitation technologies, consisting mainly of pit latrines, pour flush toilets, and septic tanks. These figures are on upward trend. Open defecation is a rampant phenomenon in the informal settlements. As a result, faecal sludge is among the major pollutants of rivers particularly in the Global South. A high percentage of urban wastewater effluents are untreated. These wastewater effluents become hazardous especially when they mix with untreated wastes from industries. This is a rampant phenomenon in various regions of the world. In majority of the African cities, wastewater from the kitchens, bathrooms and laundries is usually released into the drainage system. However, this is water that can be reused for some purposes even without treatment. It mixes with storm water, faecal material emanating from open defecation and solid wastes before entering the existing natural water bodies (Jimenez, 2010).

Inadequate or non-treatment of wastewater poses an enormous risk both to human and environmental health in Africa. Globally, management of wastewater is made complex by duplication and overlapping of roles of authority amongst various sectors. These sectors are mainly agriculture, health and water. Local circumstances such as climate and wastewater sources often dictate the forms of treatment that can be practically employed. World Health Organization guidelines (WHO, 2016) spell out an inclusive prevention management structure

for standards and regulations put in place, from wastewater generation to the consumption of products grown with wastewater and the excreta. However, strict and costly treatment technologies are not universally feasible or tenable (UN-WWAP, 2018).

Some of the basic water pollutants include heavy metals, organic chemicals, microbes and nutrients. Globally, eutrophication has been a major menace in the water bodies. It is a product of high concentration of nutrients, especially nitrogen and phosphorous from agricultural runoff, effluents from households, discharges from industries and derivatives of burnt fossil fuel (Pimentel et al., 2004). Substances from pharmaceutical products such as personal care products, painkillers and antibiotics have found their way in the water bodies at a very high rate. The cropping up of new contaminants pose a more strenuous challenge in water treatment. The contaminants effects on human beings and other ecosystems remain unidentified though they are presumed to act like natural hormones in some species and have the potential of causing serious environmental hazards (UN-WWAP, 2018). To counter the new pollutants and their impacts, the existing water quality standards need to be revised. As a result, this will increase pressure on the already overstretched water facilities. The world is currently said to be on the brink of a water quality menace (Corcoran et al., 2010). There is no significant data on the pollution levels and the water quality variations in many regions of the world, hence the actual pollution rate remains unclear (UN-WWAP, 2018).

Environmental changes including wastewater, increase the high incidences of malaria. For instance, the flow of wastewater in undefined open channels promotes development of pools that favour breeding of mosquitoes which transmit malaria to human beings (Pimentel et al., 2004). Development is one of the key components that continue to ravage on natural resources as well as the environment, as it's quite dependent on both. This is through faster use of natural resources more than nature can produce or replenish and release of contaminants to the environment faster than they could be safely assimilated.

## **2.4 Social Impacts**

### **2.4.1 Social Benefits**

Generally, dams are built for a purpose. Where economic benefits exist, typically social benefits exist as well. Dams manipulate rivers to the benefit of the local population. Dams control floods thus allowing inhabitants to comfortably live along a river without fear of occurrence of floods. In order to assess the social impacts of dams, it is common to request respondents to recall conditions before and after the dam implementation. According to Vanclay et al. (2017), it is difficult to assess the social impacts that result from a specific dam given that the host communities are exposed to multiple interventions. The limitation in the methodological issue constitutes the gap in knowledge.

Social impact assessment provides decision makers with proper strategies to cope with adverse social impacts of development projects. Despite abundant research on social impacts of dams, a commonly recognized frame work is absent (Kirchherr et al., 2016). Some of the social impacts that were cited by Cernea (2018) include; transportation, housing, culture, health and gender. In other scenarios, livelihood value for populations in arid areas increase through provision of adequate water supply (Workman, 2009). Water supply dams can also be used to serve other purposes such as irrigation, afforestation, fishing and recreation therefore contributing to occupations in the agricultural and tourism industries (Workman, 2009).

A case study of Mekong Dam on Mekong River by Kura et al. (2017) showed that some of the socio-economic impacts on population are; social cohesion, cultural knowledge, material culture, infrastructure, wealth and macro impacts. It is worth noting that most of the studies on social impacts done, have been on displaced populations. Studies by the African Population and Health Research Centre show that improved water supply and hygiene are extremely

important in reducing incidences of opportunistic infections for people living with HIV/AIDS (APHRC, 2014).

Water is one of the key ingredients of the social pillar in Kenya Vision 2030 (Government of Kenya, 2009). Its availability draws many actors due to perceived new opportunities, including a rapid growth in population (Barton et al., 2009). Increase in population in Machakos town including Miwani estate demanded an expansion of the existing social services. Therefore, expansion and construction of additional educational facilities, health care amenities, roads, water infrastructure and housing units were inevitable (Government of Machakos County Profile, 2013).

#### **2.4.2 Social Costs**

According to United Nations World Water Development Report of 2018, lack of safe water supply and convenient sanitation in cities leads to serious health problems. The report further states that, as a result of inadequate drinking water and sanitation services, many slum dwellers die each year. Water borne diseases are the most common causes of illnesses and deaths among the poor population and children under five years in developing countries (UN-WWAP, 2018).

Social considerations are critical in any project planning process because poverty is both an effect and a cause of environmental degradation. Communities struggling with poverty and social tensions will not prioritise environment as a significant issue. Therefore, it is expected that the positive impacts of dams should outsize the negative impacts. According to Cernea (2018), the negative social impacts that result from construction of dams can be classified into four. These are; forced population displacement and impoverishment, mushrooming of new settlements as a result of new opportunities, unanticipated changes on the downstream especially in agro-production and loss of cultural heritage assets.



Globally, the construction of dams is delayed by lack of cooperation from the communities that live within the area proposed for dam construction. Politicians and civilians are the main hindrances towards dam construction projects (Hilyard, 2008). Throughout history, the social impacts of dams have been underestimated. Since the beginning of the 19<sup>th</sup> century, approximately 80 million people have been displaced by dams worldwide (Workman, 2009). Even if the communities are compensated, some are unable to reap the benefits of improved water supply owing to their location (Hilyard, 2008). The general decrease in diversity could impact negatively on the local ecotourism (Barcott, 2015).

Water availability in the urban areas has continued to decline over time. This trend needs to be reversed. It is estimated that in the urban areas access to water stands at 84%. The coverage could actually be lower than officially stated due to high percentages of inactive connections. Inactive connections are estimated at 56% in Nairobi, 26% in Kisumu and 38% in Mombasa. The situation is further worsened by unaccounted for water due to unattended to bursts, unauthorized connections and general mismanagement by field personnel, which stands very high with Nairobi standing at 40%, Kisumu 66% and Mombasa 35% (Government of Kenya, 2009). It is worth noting that the current investment in water supply for urban areas is outpaced by the rapid population growth.

## **2.5 Environmental Management Plan**

It is a requirement in Kenya to conduct an Environmental and Social Impact Assessment (ESIA) for every project, before approval for its implementation. However, ESIA's do not present a useful tool for environmental management as it is ought to be, in most of the developing countries. They are often used as documents to clear projects notwithstanding their quality and findings. Often on completion of the approval process, the reports are properly filed and are hardly reviewed or put into force thereafter (Dendena and Corsi, 2015). Usually there

are no follow ups on the mitigation measures that were recommended in the ESIA studies or post implementation evaluation of the project. The lack of post implementation evaluation and monitoring makes it difficult to determine the actual economic, social and environmental impacts resulting from the project. With such practice, every study becomes a discrete and a personal activity that has no relevance to similar studies either before or after. This means that there is no knowledge enhancement for the institutions Dendena and Corsi (2015).

According to Environmental Impact Assessment (EIA) report conducted by NWCPC (2008), there was need to define fundamental environmental concerns relating to the proposed expansion of Maruba dam. These concerns were captured in the Environmental Management Plan with a view to mitigating the negative effects that would arise as a result of the expansion of the dam. Some effects were short term while others were long term. The recommendations that are valid to date were purged from the main EMP and are as shown in Table 2.1. Investigations as pertaining to the adherence of the recommendations were carried out.

Table 2.1: Environmental Management Plan

<b>Parameter</b>	<b>Responsible for Intervention/ Monitoring</b>	<b>Monitoring Method/ Activity Needed</b>	<b>Frequency</b>
Dam siltation	NWCPC	-Sediment load survey -Construction of silt traps	Twice per year Once
Sludge from the treatment works	NWCPC/NEMA	Provide sludge drying beds and replant with suitable weed	Once
Risk of eutrophication/ growth of invasive species	Tanathi WSB/NEMA	Ecological surveys	Twice a year
River flow obstruction during dam filling which may affect the upstream estates e.g Miwani	Tanathi WSB/WRA	Provide suitable flow release mechanism	During operation
Changes in downstream ecology	NEMA	Ecological surveys	Yearly
Creation of favourable habitats for disease vectors	Public health department/NEMA	Epidemiological surveys	Twice a year
Enhanced erosion and changes in topography due to excavation	Tanathi WSB/NEMA	Backfill borrow pit areas and plant vegetation	Yearly
Risk of accidental drowning	Tanathi WSB	Fencing and appropriate dam management	Continuous

## **2.6 Conceptual Framework**

A conceptual framework is a theoretical explanation of the research problem (Ngechu, 2006). It is normally used to present a preferred approach to an idea or to outline the possible courses of action. Figure 2.2 shows the conceptual framework for this study. The diagram highlights the correlation between the independent and the dependent variables. The impacts that according to the researcher could possibly have resulted from the expansion of Maruba dam are categorized into; economic, environmental and social. According to Escalada (2009), independent variables are the presumed causes while the dependent variables are the presumed effects. The study shows a relationship between the dependent and the independent variables such as the economic well-being in the estate due to availability of market for goods and services by the increased population drawn by the improved availability of water resulting from expansion of the dam.

In regard to environmental effects, the researcher deduced that the factor of increase in population subsequently resulted to challenges of wastewater disposal and destruction of the surrounding environment. The destruction of environment was partially through erection of new buildings, expansion of infrastructure, cutting of trees in search of timber and firewood and disposal of solid wastes in undesignated places among other activities.

Some of the social effects that are experienced due to influx of population are; rise in informal settlements, increase in crime rates and vulnerability to diseases due to congestion and dirty environment among others.

**Independent Variable**

**Moderating Variable**

**Dependent Variable**

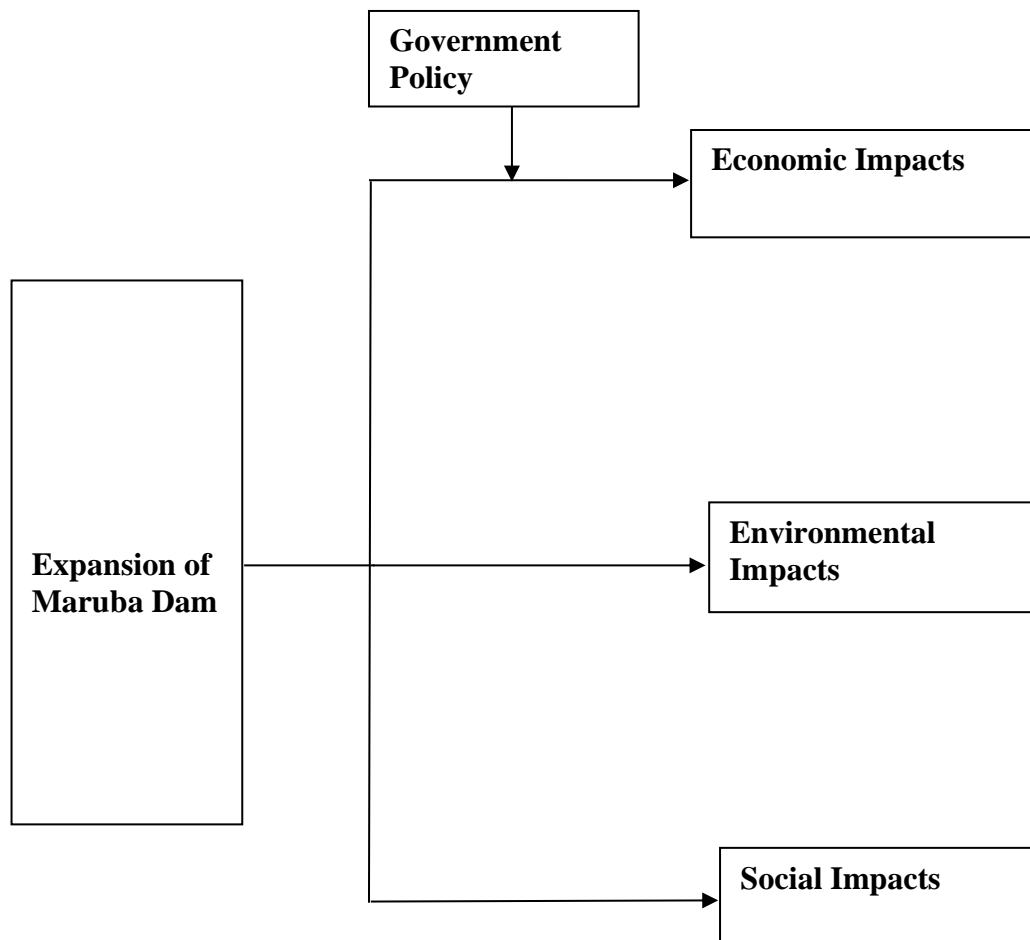


Figure 2.2: Conceptual Framework

## **CHAPTER THREE: MATERIALS AND METHODS**

### **3.1 Introduction**

This chapter describes the procedures that were used in conducting the study. These include; research instruments, techniques for data collection, data analysis and presentation, sampling procedures, sources of data and the study design.

### **3.2 Overview of Machakos County**

Machakos County comprises of eight administrative sub-counties according to Government of Machakos County Profile (2013), namely; Yatta, Kangundo, Masinga, Mwala, Mavoko, Kathiani, Matungulu and Machakos town. Most parts of Machakos County are easily accessible because road network and transport are good. Maruba dam is located in Machakos central ward in Machakos town sub-county which is actually Machakos central constituency. Figure 3.1 shows the location of Machakos central ward in relation to the other wards of Machakos town Sub-County. The map was obtained from <https://www.google.com>. According to Independent Electoral and Boundaries Commission (IEBC) report on constituency and ward boundaries, the constituency has eight wards, namely; Machakos central, Konza, Mua, Mutituni, Mumbuni North, Muvuti/Kiima Kimwe, Kalama and Kola (Government of Kenya, 2012).

Like other regions of Kenya, population dynamics form an integral part of socio- economic and cultural development. The county's population was 1,098,584 according to 2009 population census, comprising of 52% urban and 48% rural population. Machakos County covers an area of 6,208 km<sup>2</sup>. This county borders seven counties; Murang'a to the north west, Kiambu to the west, Nairobi to the west, Kajiado to the south west, Makeni to the south, Kitui to the east and Embu to the north (Government of Kenya, 2009). The Akamba people are the dominant habitants of Machakos County.



Figure 3.1: Map of Machakos Town Sub-County

### 3.2.1 Water Supply for Machakos Town

Machakos town has a population of approximately 210,000 people according to 2009 population census (Government of Kenya, 2009). The town’s water demand is approximately 23,000m<sup>3</sup>/day, against a supply of about 6,500m<sup>3</sup>/day according to estimates from the local Water Service Provider (MAWASCO, 2018). It is served with water from three major sources. These are; Maruba dam, Nol-Turesh pipeline and Iveti boreholes. However, supply from Nol-Turesh does not reach the town due to over-abstraction by the consumers on the upstream. Due to population explosion over the recent years, water from the remaining two sources is

inadequate. The current accessibility to safe domestic water is at 64% and the production of clean safe water is outpaced by the rapidly increasing demand (Government of Machakos County Profile, 2013).

Maruba dam was a 17 m high dam before expansion and was constructed during colonial era in the 1950s, meeting a water demand of approximately 4,000 m<sup>3</sup>/day by then. However, the storage capacity reduced with time due to siltation and the supply reduced almost by half (2,050 m<sup>3</sup>/day) of its initial capacity despite the gradual increase in population. This is what catalyzed the need to raise the dam's embankment by NWHSA. The embankment was raised by approximately 7.5m between 2008 and 2010. This resulted in increasing the storage capacity of Maruba dam by approximately 1,850,000 m<sup>3</sup> of water, which subsequently increased the supply to a potential of about 8,700 m<sup>3</sup>/day (NWCPC, 2008). In addition, the Authority constructed a new water treatment facility with a capacity of 5,000m<sup>3</sup>/day close to the old treatment works (1,500m<sup>3</sup>/day). A clear water uPVC rising main of diameter 225mm which reduces to 160mm diameter was laid from the pump house and feeds into a 6,000m<sup>3</sup> reservoir located at Kiima Kimwe. The water from this reservoir serves the southern and Central Business District (CBD) parts of Machakos town.

The dam's area of command is located wholly within Machakos municipality. The local community is cosmopolitan in nature. The expansion of the dam catalyzed the existing activities and new activities emerged, these latter representing new sources of income for the local population.

### **3.3 Objectives for Expansion of Maruba Dam**

The effectiveness of a project is determined through the impacts it makes measured against its objectives. The primary objective of expanding Maruba dam by NWHSA was to increase water storage capacity of the dam and also to increase water coverage within Machakos town and its



environs (NWCPC, 2008). However, the increase in reliable water coverage generated a multiplier effect of impacts resulting to people migrating from other areas to Machakos town and in particular Miwani estate, in search of opportunities. The influx of population increased the demand for basic amenities and also put pressure on the available resources within the estate. According to MAWASCO (2018) annual report, Maruba dam has had adequate water to meet the requirements for the treatment works from when expansion was completed in 2010 as opposed to some of the previous years before expansion when water levels would recede below the inlet to the treatment works.

### **3.4 Background Information on Miwani Estate**

The estate lies to the north of Maruba dam and is located about 1.5 kilometers to the west of Machakos town CBD, along the Machakos Nairobi road. Machakos Teachers College and Machakos Boys School are located in this estate. Machakos show ground and the office of the Governor are located to the south. The estate's terrain is generally flat with a slope undulating towards the south. The estate is demarcated from the adjacent estates by two streams, one on the eastern and the other on the western side. The areas along the streams are steeper than the rest of the estate and they drain into the streams. The estate dwellers are cosmopolitan in nature. The estate used to suffer from acute water shortage before the expansion of the dam. The main source of water was from individual shallow wells or from the water vendors. There were no storey buildings in the estate and majority of the dwellers were living in low/middle class rental houses. Most of the population was concentrated on the lower part of the estate along the road from Machakos to Nairobi which was easily accessible. The rest of the estate was sparsely populated. Only part of the lower side of the estate where East Kenya Bottlers used to be located was sewerred. The rest of the estate had challenges with wastewater disposal. Generally, road network, water and other infrastructure were not well developed.

Due to expansion of the dam, plot owners from within and without the estate constructed rental houses with a hope that there would be population influx due to emerging opportunities. The population in the estate significantly increased. Most of the activities that take place within the estate, such as farming, garages, petrol stations and household wastes, have a direct bearing to the environment and the dam especially when it rains. A Google map showing the location of Maruba dam in relation to Machakos town CBD and Miwani estate is as shown in Figure 3.2 ([www.maplandia.com/kenya/eastern/machakos](http://www.maplandia.com/kenya/eastern/machakos) website).

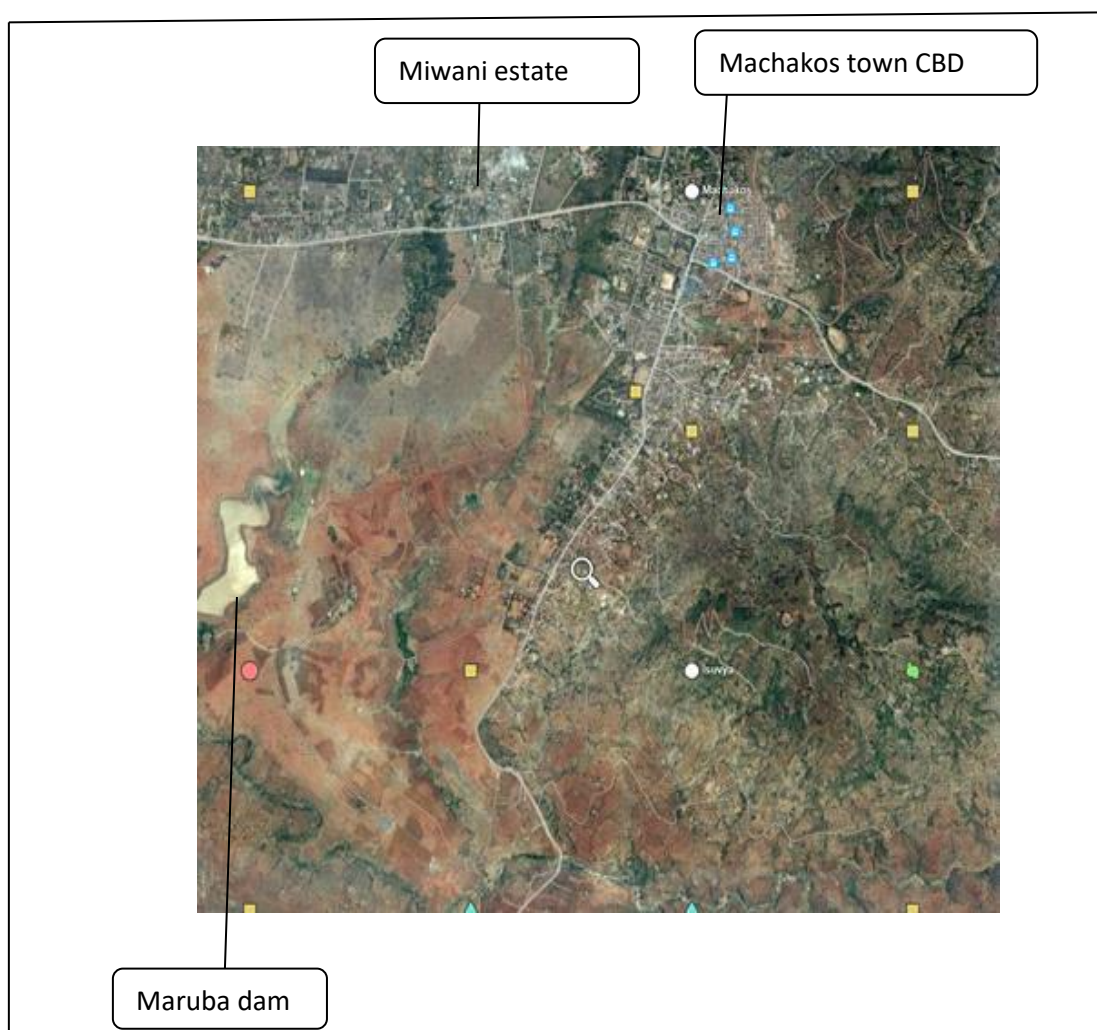


Figure 3.2: Location of Maruba Dam in Relation to Machakos Town CBD and Miwani Estate

### **3.5 Research Methodology Framework**

This study was carried out using a survey research design. Table 3.1 shows the framework that was used for carrying out the research. It presents the research questions, the methodology and the research tools that were employed so as to achieve each of the research objectives.

Table 3.1: Research Framework

No	Research Objectives	Proposed Research Questions	Methodology for Achieving the Objectives	Research Tools
1	Determine the economic impacts within Miwani estate and to the water service provider	<p><b>Questionnaire in Appendix 3.1</b></p> <p>1.How did the expansion of Maruba dam contribute to Miwani estate in terms of:</p> <ul style="list-style-type: none"> <li>• Improvement in supply of water?</li> <li>• Rejuvenation of existing businesses?</li> <li>• Springing up of new business ventures?</li> <li>• Opening up of employment opportunities?</li> <li>• Rapid mushrooming of new buildings?</li> <li>• Establishment of recreation facilities within the vicinity of the estate?</li> <li>• Establishment of new institutions that were not in the estate before?</li> <li>• Appreciation of land value in the estate?</li> </ul> <p>2. List down services that you started paying for after the expansion of the dam that you never used to pay for before.</p>	<p>-Field visits</p> <p>-Collection and review of secondary data, records and documents</p> <p>-Involvement of key informant interview guides</p> <p>-Taking of photographs of the areas and structures relevant to the study</p> <p>-Physical observation of the surroundings and recording the activities that have taken and are taking place</p>	<p>-Semi-structured household survey questionnaires</p> <p>-Secondary data, records and documents</p> <p>-Key informant interview guides</p> <p>-Camera</p> <p>-Focus group discussions</p>

	<p><b>Questionnaire in Appendix 3.2</b></p> <p>3. How did the expansion of the dam affect your water sales in terms of:</p> <ul style="list-style-type: none"> <li>• The profit margins that you get?</li> <li>• Number of trips you make per day?</li> <li>• The future prospects of the water business?</li> </ul> <p>4. Besides selling water, what other economic activities are you engaged in?</p> <p><b>Questionnaire in Appendix 3.3</b></p> <p>1. How did the expansion of the dam affect Miwani estate in terms of;</p> <ul style="list-style-type: none"> <li>• Emergence of informal settlements within the estate?</li> <li>• New settlements in the outskirts of the estate which had no people before the expansion of the dam?</li> </ul> <p>2. Which are the notable developments that are as a result of the improved water supply in your area of administration?</p> <p><b>Questionnaire in Appendix 3.4</b></p> <p>1. What was the total number of active connections in Miwani estate before the expansion of Maruba dam (2010)?</p>		
--	--	--	--

		<p>2. What is the current number of active connections in Miwani estate?</p> <p>5. How much water was supplied from the treatment works per day before the expansion of the dam?</p> <p>6. How much water is supplied currently from the treatment works per day?</p> <p>7. How much was the average revenue collected from water sales on monthly basis before expansion of the dam in Miwani estate (2010)?</p> <p>8. How much is the average revenue collected from water sales on monthly basis currently from Miwani estate?</p> <p>11. How did the expansion of the dam affect the water company in relation to water supply in Miwani estate in terms of:</p> <ul style="list-style-type: none"> <li>• Expansion of the reticulation system in the estate?</li> <li>• Reduction in level of illegal connections in the estate?</li> <li>• Reduction in level of unaccounted for water in the estate?</li> </ul>		
2	Determine the environmental impacts within Miwani estate	<p><b>Questionnaire in Appendix 3.1</b></p> <p>3. How did the expansion of the dam contribute to the estate in terms of:</p> <ul style="list-style-type: none"> <li>• Establishment of trees and flower nurseries?</li> </ul>	-Field visits	-Semi-structured household survey questionnaires

		<ul style="list-style-type: none"> <li>• Increase in the number of trees and flowers planted?</li> <li>• Better wastewater management?</li> <li>• Better solid waste management?</li> </ul> <p>4. List down any other effect that you associate with the expansion of the dam in the estate.</p> <p>5. What is the mode of wastewater disposal from your house?</p> <p>6. What is the mode of solid waste disposal from your house?</p> <p><b>Questionnaire in Appendix 3.3</b></p> <p>1.How did the expansion of the dam affect Miwani estate in terms of:</p> <ul style="list-style-type: none"> <li>• Increase in population?</li> <li>• New settlements in the outskirts of the estate which had no people before the expansion of the dam?</li> <li>• Increase in the number of trees and flowers planted?</li> </ul> <p>2. Which are the notable developments that are as a result of the expansion of the dam in your area of administration?</p> <p>3. Which are the negative impacts that can be attributed to the expansion of the dam in your area of administration?</p>	<p>-Collection and review of secondary data, records and documents</p> <p>-Involvement of key informant interview guides</p> <p>-Taking of photographs of the areas and structures relevant to the study</p> <p>-Physical observation of the surroundings and recording the activities that have taken and are taking place</p>	<p>-Collection and review of secondary data, records and documents</p> <p>-Key informant interview guides</p> <p>-Camera</p> <p>-Focus group discussions</p>
3	Determine the social impacts within Miwani estate	<b>Questionnaire in Appendix 3.1</b>	-Field visits	-Semi-structured household survey questionnaires

		<p>1. How did the expansion of Maruba dam contribute to the estate in terms of establishment of recreation facilities within the vicinity of the estate?</p> <p>7. How did the expansion of the dam contribute to the residents of Miwani estate in terms of:</p> <ul style="list-style-type: none"> <li>• Access to clean, safe and reliable water supply?</li> <li>• Less occurrence of water borne diseases?</li> <li>• Increase in population?</li> <li>• Establishment of new institutions (Schools, clinics etc) that were not there before?</li> <li>• Improvement of infrastructure (Roads, electricity etc)?</li> <li>• Springing up of informal settlements within the vicinity of the estate?</li> <li>• Increase in crimes in the estate as compared to before?</li> <li>• Establishment of kitchen gardens?</li> </ul> <p><b>Questionnaire in Appendix 3.2</b></p> <p>1. How was the water scenario in the estate before the expansion of the dam?</p> <p>2. How is the water scenario in the estate after the expansion of the dam?</p>	<p>-Collection and review of secondary data, records and documents</p> <p>-Involvement of key informant interview guides</p> <p>-Taking of photographs of the areas and structures relevant to the study</p> <p>-Physical observation of the surroundings and recording the activities that have taken and are taking place</p>	<p>-Collection and review of secondary data, records and documents</p> <p>-Key informant interview guides</p> <p>-Camera</p> <p>-Focus group discussions</p>
--	--	---	---	--



	<p><b>Questionnaire in Appendix 3.3</b></p> <p>1. How did the expansion of the dam affect Miwani estate in terms of:</p> <ul style="list-style-type: none"> <li>• Emergence of informal settlements within the estate?</li> <li>• Increase in population?</li> <li>• Rise in the level of crime which can be attributed to the expansion of the dam?</li> <li>• New settlements in the outskirts of the estate which had no people before the expansion of the dam?</li> <li>• Improvement of infrastructure e.g. roads, power connectivity, schools, health facilities etc?</li> </ul> <p>2. Which are the negative impacts that can be attributed to expansion of the dam, in your area of administration?</p> <p>3. Which are the notable developments that are as a result of the expansion of the dam, in your area of administration?</p> <p><b>Questionnaire in Appendix 3.4</b></p> <p>3. What was the percentage of water coverage in Miwani estate before the expansion of the dam?</p> <p>4. What is the current percentage of water coverage in Miwani estate?</p> <p>9. How was the water supply scenario in Miwani estate before the expansion of Maruba dam?</p>		
--	---	--	--

		10. What is the current water scenario in Miwani estate? 11. How is the level of complaints from consumers who have no water in the estate compared to before the expansion of the dam?		
--	--	--	--	--

### **3.6 Research Instruments**

The major research tools for data collection that were employed include:

- Semi-structured household survey questionnaires (Appendix 3.1)
- Key informant interview guides (Appendix 3.2 and 3.3)
- Focus group discussion guides (Appendix 3.4)
- Physical observations (Appendix 3.5)
- Camera
- Secondary data, records and documents.

### **3.7 Pre-test of Survey Instruments**

The semi-structured household survey questionnaire, key informant and focus group discussion questionnaires were pre-tested before the actual data collection, by piloting in order to gauge their reliability in gathering the data required. A sample of 20 respondents was randomly selected to pre-test the semi-structured household survey questionnaires. According to Kothari (2019), a sample of 20 respondents is the smallest number that can yield meaningful results on data analysis for a survey research design. The Key informant and focus group discussion questionnaires were pre-tested with a sample size equivalent to the actual sample sizes of 3 and 5 respondents respectively since the actual sample sizes were small. Corrections were made on the questionnaires as appropriate before being administered.

### **3.8 Data Collection Techniques**

Data for this research was collected from both primary and secondary sources. The semi-structured household survey questionnaires (Appendix 3.1), key informant interview guides (Appendices 3.2 and 3.3), focus group discussion guides (Appendix 3.4) and physical observations (Appendix 3.5) were used to collect primary data. Desk review of secondary data was also done and relevant photographs of interest to the study were taken using a camera. The semi-structured questionnaires were administered randomly to 385 residents of Miwani estate by research assistants, through the support of some staff from the Water Service Provider who manage water infrastructure within the estate. The key informant interview guide was administered to two water vendors and the area chief by the researcher. The researcher administered focus group discussion guides to five top management staff from the local Water Service Provider (Managing Director, Technical Manager, Finance Manager and two supervisors). Secondary data for water analysis for both bacteriological and physical-chemical tests was provided by the WSP as a proof that the quality of water supplied to consumers met the required national standards. Samples of tap water from the estate were taken to the Water Resources Authority laboratory for confirmatory analysis on the secondary data provided by the WSP.

A checklist of the parameters observed is as shown in Appendix 3.5. The observations were done and recorded. Relevant photographs were taken to support the observations made. This was done within Miwani estate and on the upstream of the dam.

The institutions that were cited in the Environmental Management Plan to take lead in monitoring respective parameters were visited for confirmation from the respective Environment Officers, whether the same has been happening. These institutions are; NWHSA, NEMA, Tanathi Water

Works Development Agency (Tanathi WWDA), formerly Tanathi Water Services Board and WRA.

### **3.9 Sampling**

A sample is defined as a representative part of a population according to Conroy (2014). If the population is very large, it is difficult to use the total population as it would take exceptionally long to complete the research (Mugenda and Mugenda, 2003). On the other hand, very small sample sizes are liable to sampling errors. Therefore, the sample size selected should be large enough to facilitate data collection and be a representative of the total population. Simple random sampling was used for this research. In this study the minimum sample size was 385 people which was arrived at using Fisher et al. (1998) formula.

A target population can either be classified as specified population or unspecified population (Cohen, 2007). A specified population means that all the members are recorded in some register and the vice versa for unspecified population. For this research, the population targeted was unspecified population. This is because the specific population that was directly or indirectly affected by the expansion of Maruba dam could not be determined beforehand due to urban population dynamics. Mainly, in urban areas there is a lot of population variations depending on the availability or absence of opportunities. Samples were selected using non-probability sampling which is also referred to as purposive sampling (Mugenda and Mugenda, 2003).

Therefore, purposive sampling was used which enabled the researcher to interview respondents that had the right information in relation to the objectives of the study. The people interviewed were adults who are beneficiaries of the water from the Water Service Provider and who were living in the area prior to the expansion of the dam.

### 3.9.1 Sample size

The target population was estimated at 10,000 people. This is the number of people estimated to be benefiting directly within Miwani estate from the water provided by the area Water Service Provider. This estimate was got from the Water Company and from the local administration.

The residents of this estate are supplied with water from Maruba dam and their activities have a bearing on the objectives of the study. Fisher et al. (1998) formula was used to obtain the sample size needed for the field data collection as shown below;

$$n = p*q*z^2/d^2$$

Where n = desired sample size

p = Proportion in the characteristics being measured

z = standard normal deviate at the required confidence level

q = 1- p

d = the level of statistical significance set

In this case the level of accuracy was set as 0.05, p as 50% and z as 1.96.

Applying the above formula, the sample size was thus calculated to be 385. In this study, 397 people were interviewed. The additional people interviewed are; five staff from Machakos Water and Sewerage Company who man the estate, one area administrator, two water vendors, the officer responsible for following up on EMP from NEMA, the heads of environment in NWHSA, Tanathi WWDA and WRA Machakos regional office.

### 3.10 Data Analysis

Data collected was scrutinized and relevant information to the research was identified. Coding was done for ease of analysis and for purposes of ensuring accuracy. Sorting of data into categories and examination of each, was then done in relation to the set objectives. Quantitative data was

analysed by correlation analysis, description, tabulations, percentages, bar graphs and pie chart techniques as appropriate. Microsoft Excel was employed during the data analysis while Microsoft Office Word 2010 was used to compile the report. The number of respondents for each parameter who either strongly agreed, agreed, uncertain, disagreed or strongly disagreed was converted into a percentage using a calculator. The data for the respective parameters with their corresponding percentages was then entered into an excel sheet. The data was highlighted and using the insert tool bar of the computer, a clustered column chart was produced.

## CHAPTER FOUR: RESULTS AND ANALYSIS

### 4.1 Introduction

This chapter analyses the research data against the set objectives so as to form a basis for recommendations and conclusions. It also seeks to analyse the data obtained from the study and the field findings in order to come up with lessons learnt from the study. This will help Machakos Water and Sewerage Company, NWHSA, the Machakos County Government and the National Government to appreciate the positive impacts from Maruba dam and the negative impacts that require mitigation. In general, it will inform water projects planners and implementers on the impacts that can be realized from a well designed and constructed project. As cited in chapter two, economic, environmental and social impacts emanating from a project determine its sustainability. The economic dimensions mainly gear towards immediate and short term gains ignoring the environmental consequences which are long term and may have adverse impacts to the project. The social impacts have in the past received less consideration among the three pillars of sustainability concept (Xiong W. et al., 2015).

Availability of water, devolution and availability of land were cited by the respondents interviewed as the three key factors that led to increase in population within Machakos town and specifically Miwani estate. Availability of water was cited as a key factor by 212 respondents (55%) of the 385 respondents interviewed, devolution was cited as a key factor by 115 respondents (30%) while availability of land was cited as a key factor by 58 respondents (15%). All the 385 respondents interviewed reported that migration by new entrants to the estate started way back before devolution due to speculation of the expansion of Maruba dam. Even though land was available before the expansion of the dam, rampant migration to the estate was experienced during and after the expansion.



The 385 respondents interviewed using semi-structured household survey questionnaires are consumers of water supplied by Machakos Water and Sewerage Company (MAWASCO). This is the local Water Service Provider charged with supply and management of water and sewerage services in Machakos town and its environs. The Company does not have any other source of water for Miwani estate apart from Maruba dam. However, there is a borehole that was supplying water to the former office of Machakos County Governor, which MAWASCO is pursuing with the county government so that it can be used to supplement water from the dam.

## **4.2 Economic Impacts**

### **4.2.1 Economic Benefits**

Water is one of the development enablers across the world. It is considered as the principal limiting factor for life and the ecosystem. As stated earlier, the primary objective of expanding Maruba dam was to increase water storage in the dam and to increase water coverage within Machakos town and its environs. However, the improved water supply brought about complex direct and indirect secondary impacts that affected the economic activities in Miwani estate (Government of Machakos County Profile, 2013). Figure 4.1 shows the views of the 385 respondents on some of the economic benefits that resulted from the increase in water supply after the expansion of Maruba dam. The data used in Figure 4.1 was derived from the semi-structured household survey questionnaire responses shown in Appendix 4.1 and economic benefits data shown in Appendix 4.2.

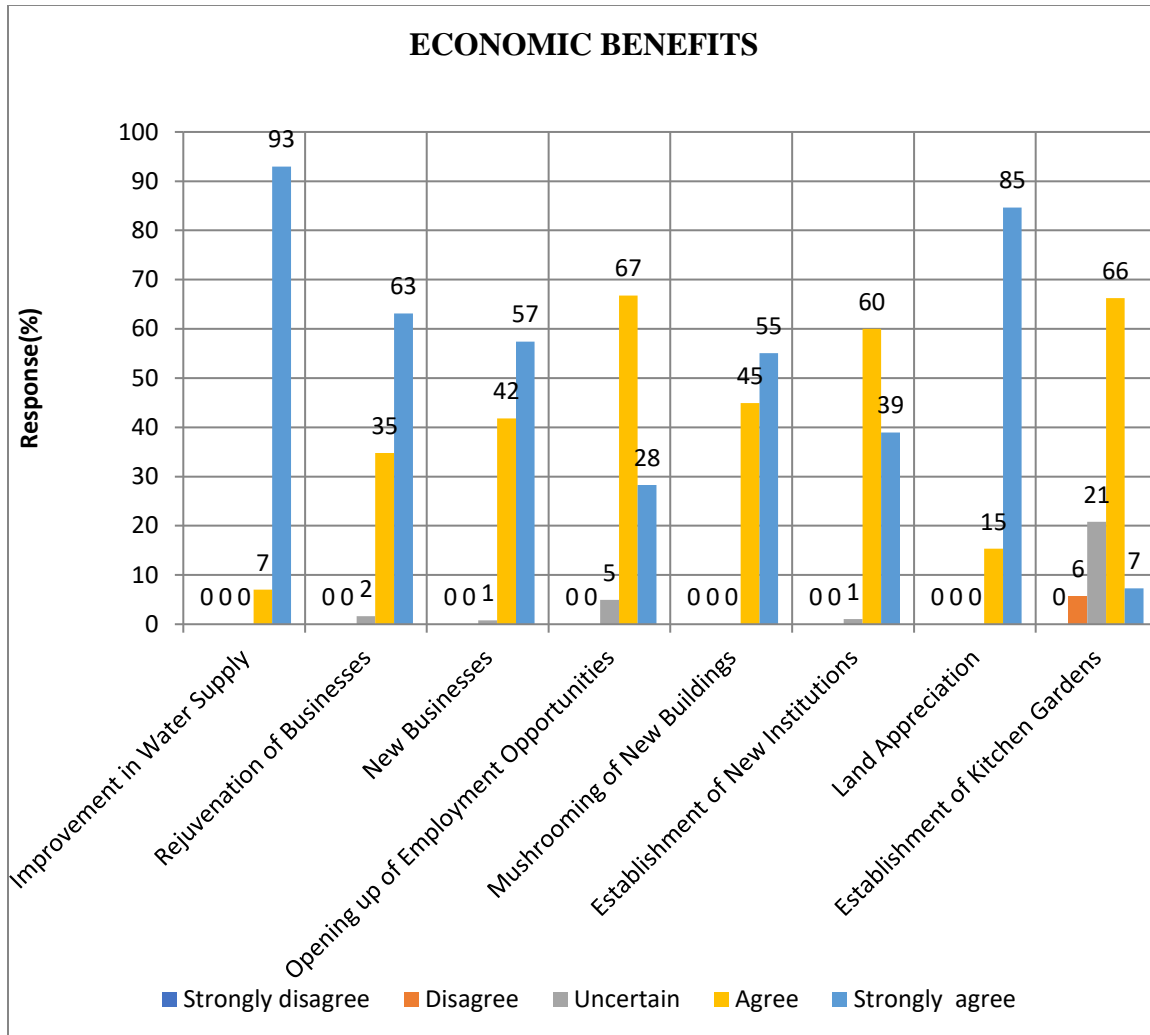


Figure 4.1: Analysis of Economic Benefits

Majority of the respondents agreed or strongly agreed that the expansion of the dam contributed positively to the economy of the estate as depicted by the percentages for various economic growth indicators shown in Figure 4.1. The respondents' views were summarized as follows:

- Out of the total 385 respondents, 27 respondents (7%) agreed and 358 respondents (93%) strongly agreed that expansion of Maruba dam resulted in improvement of water supply.

- Of the 378 of the respondents, 135 respondents (35%) agreed and 243 respondents (63%) strongly agreed that there was rejuvenation of existing businesses.
- Of the 382 of the respondents, 162 respondents (42%) agreed and 220 respondents (57%) strongly agreed that new businesses were established.
- Of the 366 of the respondents who were positive that employment opportunities were created, 258 respondents (67%) agreed and 108 respondents (28%) strongly agreed.
- All the 385 respondents, 174 respondents (45%) agreed and 211 respondents (55%) strongly agreed that new buildings were constructed.
- Of the 382 of the respondents who were positive that new institutions were established, 231 respondents (60%) agreed and 151 respondents (39%) strongly agreed.
- Out of the 385 respondents, 58 respondents (15%) agreed and 327 respondents (85%) strongly agreed that land value appreciated.
- Of the 281 of the respondents, 254 respondents (66%) agreed and 27 respondents (7%) strongly agreed that kitchen gardens were being practiced in Miwani estate.

The above results show that, besides the achievement of the primary objective, a well-planned and well executed water project can have a multiplier effect of secondary impacts that may not have been envisaged. In this case there were direct and indirect economic benefits that resulted from the increased water supply. The availability of water acted as a catalyst for other activities that emerged in the estate, key among them being increase in population.

Some investors identified gaps in services required by the increased population in the estate and took advantage of them. Businesses that are thriving in the estate are; Hotels, petrol stations, supermarkets, car washes, food kiosks, grocery shops, retail shops, exhausters, transport, tree nurseries, fabrication workshops, carpentry shops, rental houses, funeral homes and recreation facilities among others. Some residents practice kitchen gardens which help save expenditure on some of the vegetables and fruits.

Prior to the expansion of the dam, the area was less attractive to development and expansion as compared to the other estates close to the CBD. However, many people developed interest for the area after water supply was guaranteed pushing demand for space and housing. Majority of the people that migrated to the estate did so considering the perceived secondary benefits derived from reliable water supply and the speculation of a market for small scale businesses. The west of Machakos, where Miwani estate is located, is among the fastest growing areas of Machakos town. It was deduced that time and money that used to be allocated in search and purchase of water was currently being used for other beneficial activities. It was also deduced that besides the direct economic benefits, the multiplier effect resulted to other intangible benefits. These include; better health, improved sense of well-being, lower medical expenditure and family health costs on water related diseases among others. Thus, the economic performance and productivity of the residents increased. An economically empowered community is able to pay for the water bills which in turn translate to supporting the sustainability of the water supply. This agrees with a case study of Mekong Dam on Mekong River by Kura et al. (2017) whose outcome was that the dam brought about a myriad of economic benefits to the local population which included; employment creation, water supply, recreation and social cohesion among others.

Machakos People's Park which is supported with water from Maruba dam is within the vicinity of the estate. The park attracts tourists from within and without Machakos town. It is designed to host a myriad of activities and besides being a recreation facility, it is a source of revenue for Machakos County Government. Some of the visitors purchase their supplies from Miwani estate thus boosting its economy.

The two water vendors interviewed were in concurrence that the water scenario in the estate is better as compared to the period before the expansion of the dam. They stated that there was loss of some of the customers due to increased water supply. However, there was a compensation effect by acquiring new customers who settled in areas that did not have water infrastructure. There were also new entrants into the business which amounted to sharing the available customers. The respondents reported that there was minimal variation in the number of trips and profit margins even after the improved water supply. The vendors interviewed have no other source of income apart from water tankering. They were optimistic that the future of the business is promising especially if there will be no supplementary source of water for Machakos town in the near future. The water vendors get their water from privately owned boreholes. A summary of the completed key informant interview guide questionnaire for water vendors is shown in Appendix 4.3.

The five staff of MAWASCO interviewed reported that the water reticulation system in the estate was expanded so as to supply the newly built-up areas. Some sections of the existing water infrastructure were also rehabilitated, thus checking on the unaccounted-for water. A 150m<sup>3</sup> elevated steel tank was erected within the estate which initially gave the residents the comfort of both reliable and adequate water supply at their taps. Water coverage in Miwani estate before the expansion of Maruba dam was 20%. The estate could remain without water for days since priority used to be given to the CBD and government institutions. According to a report by MAWASCO

(2015), complains from the consumers were the order of the day. The supply was not consistent and would cease during times of drought. Water could only be supplied for at most 3 days per week (120m<sup>3</sup>/day) during peak volumes in the reservoir. This was hardly enough to meet the demand. However, the coverage increased to approximately 70% after the expansion of the dam with a daily regular supply of approximately 958m<sup>3</sup>/day. A sample of completed key informant interview guide questionnaire by MAWASCO staff is attached as Appendix 4.4.

According to MAWASCO the days of acute water shortage are gone and the level of complains reduced. However, the current water demand for the estate is approximately 2000m<sup>3</sup>/day which cannot be met by the current water source. Water rationing is done so as to ensure that there is equitable distribution of the resource to most of the residents living in the areas that have water supply infrastructure. MAWASCO has zoned the estate, in its effort to ensure that the water rationing program is fair to all the residents and encourages people to have adequate storage. The increased population translated into increased consumption of water and therefore revenue collected by the local Water Service Provider increased. Machakos Water Supply is a metered scheme. The Water Service Provider instituted additional measures that increased the efficiency of water distribution and also checked on the unaccounted-for water. These include; zonal metering, regular patrols, deploying regional supervisors on rotational basis, improved efficiency in billing system and prompt repairs of bursts. The number of water connections was 80 before the expansion of the dam as compared to the current number of 359 active connections. Before the expansion of the dam, the average revenue collection per month was KES 101,231 as compared to the current collection of average KES 859,393. Besides the continuing increase in water demand due to population increase in the estate, the primary objective of increased water coverage and increased water revenue collection by MAWASCO was achieved.

### 4.2.2 Economic Costs

A revitalized economic environment spelt doom for some of the ventures that resisted change in a fair competition. Some businesses bore the brunt of the side effects of the increased water coverage in Miwani estate. The respondents interviewed who disclosed that there were businesses that closed down due to heightened competition from new ones were 50 in number, which translates to 13%. This resulted to economic losses for the affected business owners and their employees. The respondents who were not aware of any businesses that shut down were 335 which translates to 87%.

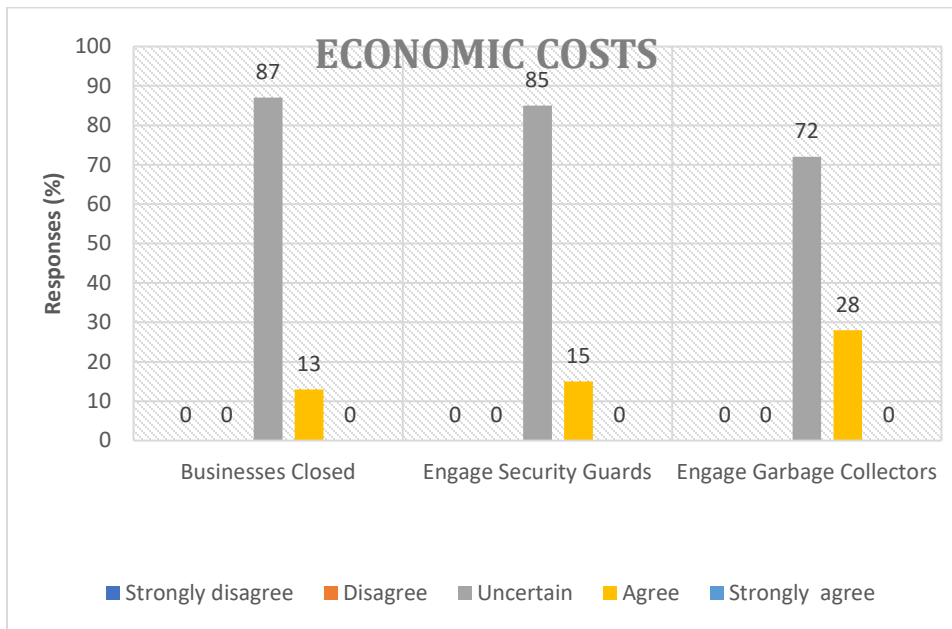


Figure 4.2: Analysis of Economic Costs

Settlements spread to areas that had no water infrastructure. Extension of water infrastructure was done so as to serve some of the new settlements while others remain without water infrastructure to date. The extension of the infrastructure was financed by the Water Sector Trust Fund (WSTF)

according to MAWASCO (2015) progress report. Besides the increased water demand, MAWASCO has not been able to extend the water coverage to the whole estate and therefore loses on revenue collection. It also shows that the company was not prepared to handle the increased water supply from the treatment works.

Areas without water infrastructure depend on water tankering from private boreholes. According to the water vendors interviewed, 10,000 litres of water are sold at an average of KES 4,000. This is a cost that the residents did not envisage since the anticipation was that the whole area would be served with water. Out of the 385 respondents interviewed, 58 respondents reported that they had to engage guards for security purposes which take a proportion of their resources. This was due to the perceived insecurity and moral decay associated with an increasing population. Hundred and nine (109) respondents which is 28%, said that they pay private garbage collectors, who dispose off solid wastes from their premises. The data used in Figure 4.2 was derived from Appendices 4.1 and 4.5.

The five MAWASCO staff interviewed cited cases of vandalism of air valves from the valve chambers located away from the built-up areas. It was also reported that herders occasionally break the plastic pipes during the dry seasons for their animals to have water. The issue of illegal connections was also reported. The above activities result to economic costs for the company. The unaccounted-for water stands at approximately 30%.

### **4.3 Environmental Impacts**

#### **4.3.1 Environmental Benefits**

The environment is usually a key beneficiary from the ripple effects of a well planned and well executed water project. People require extensive infrastructure so as to sustain their lives. During



construction of infrastructure, interfering with the initial state of the environment is inevitable. Therefore, adopting best practices that are friendly to the environment during and after construction means a better world for the future generation. The data used in Figure 4.3 was derived from the semi-structured household survey questionnaire responses attached as Appendix 4.1 and environmental benefits data attached as Appendix 4.6.

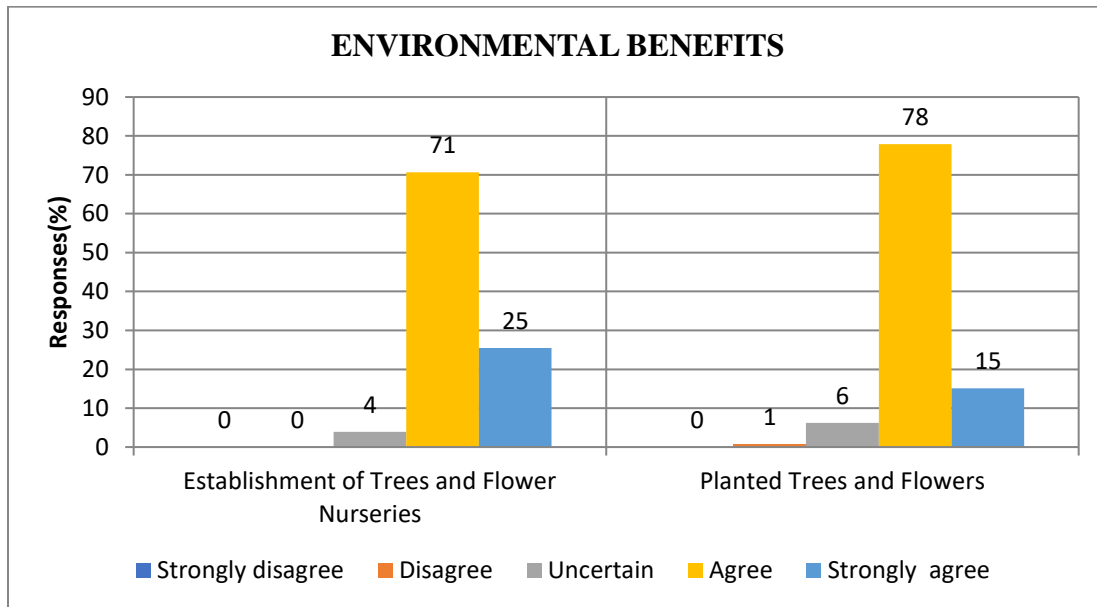


Figure 4.3: Analysis of Environmental Benefits

Figure 4.4 shows that trees and flower nurseries have been embraced in Miwani estate. Of the 370 of the respondents, 274 respondents (71%) agreed and 96 respondents (25%) strongly agreed that trees and flower nurseries had been established in the estate. The respondents who were cognizant of planted trees and flowers were 359. Of the 359 of the respondents, 301 respondents (78%) agreed and 58 respondents (15%) strongly agreed that trees and flowers had been planted in the estate. The three nursery owners interviewed reported that, the thriving of the venture was due to guaranteed water during the dry season and also availability of market for the plants. The planting

of trees and flowers by some of the residents has impacted positively to the environment. The activity doubles both as an economic and an environmentally friendly venture. One of the trees and flower nurseries near the Machakos Show Ground is shown as Figure 4.4. Flower gardens are evident in the estate and along the Machakos-Nairobi road. Trees have been planted on some parts of the riparian land along the river draining into Maruba dam and even in the habited parts of the estate. They help in holding soil, curb erosion and also cool the environment.

There is a Farmers Training Center within the vicinity of the estate which is a major beneficiary of the water from Maruba dam. The reliability of water throughout the year for its training plots is a key milestone in impacting farmers, some of whom are residents of Miwani with practical farming skills. Trained farmers embrace best practices in farming and are therefore able to take care of the environment. Due to the anticipated solid waste from the increased population, the County Government of Machakos has also embarked on distribution of garbage collection bins in the estate which is helping in the management of solid waste. This too is friendly to the environment. Figure 4.5 shows a photo of some of the planted trees on the riparian land.

As stated earlier in chapter three, Miwani estate forms part of the catchment of Maruba dam. Environmental benefits touching on the estate mean well for the dam. There requires a deliberate concerted effort by the county government and the developers in the estate to enhance activities that are environmentally friendly. More often than not, the environment is a beneficiary of secondary activities since it is scarcely planned for.



Figure 4.4: Trees and Flower Nurseries near the Show Ground



Figure 4.5: Planted Trees along Riparian Land

### 4.3.2 Environmental Costs

Sometimes, the gains realized from a successfully implemented water project may be undermined by some of the negative impacts which result from the secondary by products. Miwani estate is not served with a sewerage system and therefore onsite sanitation technology consisting mainly of pit latrines, soak pits, pour flush toilets, holding tanks and septic tanks is practiced. With the rejuvenated economic environment and increase in population, wastewater and solid wastes were bound to increase. Figure 4.6 shows the opinions of the respondents pertaining to wastewater and solid waste management in the estate. The data used in Figure 4.6 was derived from Appendices 4.1 and 4.7.

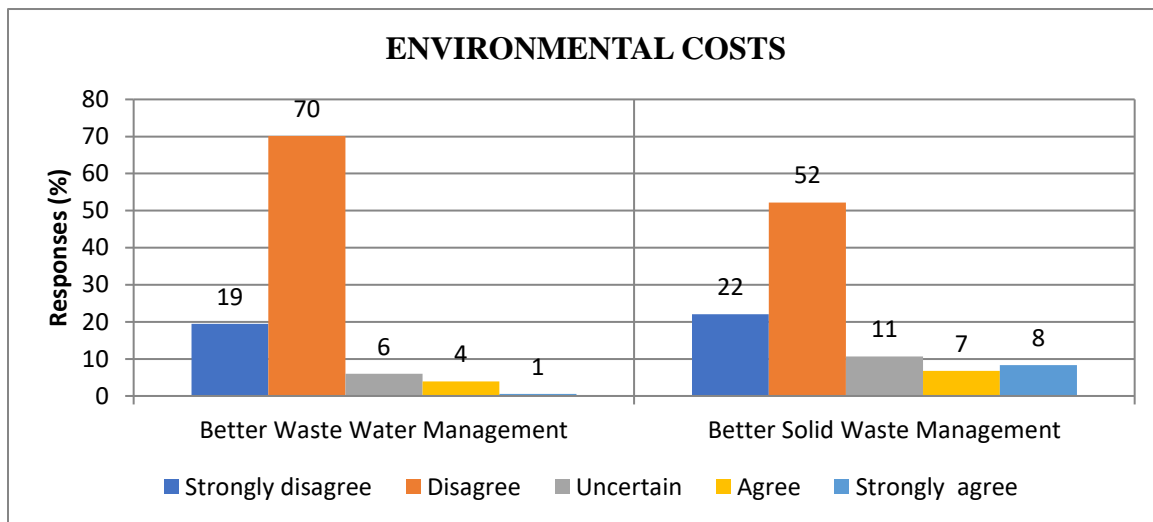


Figure 4.6: Analysis of Environmental Costs

The respondents who were of the opinion that wastewater management was poor in the estate were 343. Of the 343 of the respondents, 73 respondents (19%) strongly disagreed and 270 respondents (70%) disagreed that wastewater management in the estate was better than before. The respondents who were of the opinion that solid waste management was a menace in the estate were 285. Of the

285 respondents, 85 respondents (22%) strongly disagreed and 200 respondents (52%) disagreed that solid waste management was better in the estate than before. As stated earlier, the estate is not connected to the sewer system and therefore onsite technology of wastewater disposal is used. Infiltration of wastewater into the ground has a high potential of polluting ground water and the soil in a given area (Gallego et al.,2008). Figure 4.7 whose data was derived from Appendices 4.1 and 4.8, shows the proportions of the main modes of wastewater disposal from the residential and commercial buildings.

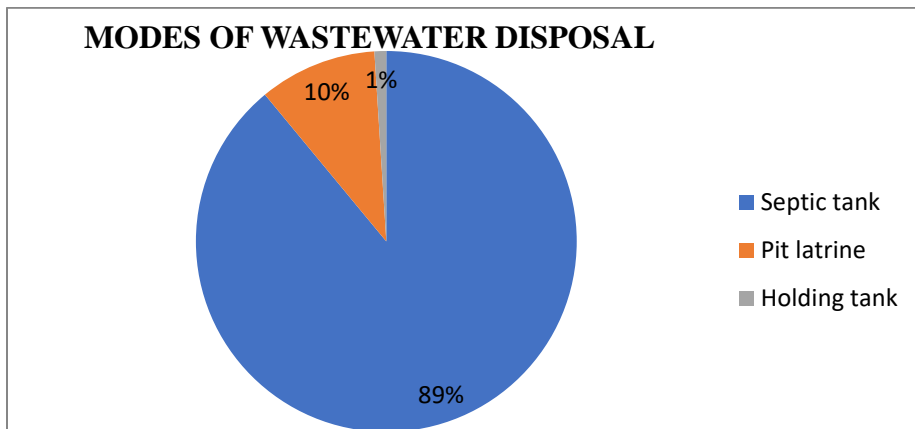


Figure 4.7: Modes of Wastewater Disposal in Miwani Estate

This puts the private boreholes into a risk of contamination. The researcher observed that the spillovers from the sanitation facilities, car washes and effluents from garages find their way into the available natural and man-made channels which act as the alternative destinations for wastewater as is shown in Figures 4.8 and 4.9. The effluents that do not infiltrate into the ground finally find their way into the river draining into Maruba dam. Oils, grease and other petroleum products from garages and car washes were also cited to be a source of environmental cost in the estate. The wastewater scenario in Miwani estate compares well with studies conducted by Mwamburi (2013), who cited that ground water exploitation in most towns is curtailed by pollution

from numerous pit latrines and septic tanks which are mainly the major modes of wastewater disposal.



Figure 4.8: Wastewater from one of the Flats



Figure 4.9: Wastewater from Athletics Kenya Southern Branch Office Located in the Estate

With the increased population in the estate, solid waste disposal is also a menace as was affirmed by 285 out of the 385 respondents interviewed. All the 385 respondents interviewed depend on the County Government for their solid waste disposal. However, the efficiency in garbage collection is low and some of the residents are occasionally forced to engage the services of private garbage collectors. The designated garbage collection points are a distance from most of the residents and therefore there are incidences where you find garbage thrown in the available open spaces as shown in Figure 4.10. During the rainy season, some of the solid wastes are dissolved by rain water while others are washed into the available drainage system. The wastes eventually drain into the river draining into Maruba dam thus affecting the water quality. Poor water quality translates to increased cost for the water treatment. This agrees with studies done by Zhang et al. (2020) who cited that development can lead to increase in pollutants such as effluents, solid wastes, carbon monoxide and carbon dioxide hence exacerbating the environment and worsening effects of climate change.

It is evident that the component of wastewater disposal was not given priority during the project planning. Likewise, management of solid waste emanating from the increased population was also not well planned for. These two components if not checked will undermine the gains realized from the project. The respondents interviewed pointed that, indigenous trees are in danger of depletion in the built-up areas. This is one of the side effects to the environment which is a product of creating room for buildings. It spells the need to put in place environment related adaptation measures and involvement of all relevant stakeholders during project planning as opposed to the discrete manner in which projects are planned.



Figure 4.10: Solid Waste Thrown in Open Space

#### **4.4 Social Impacts**

##### **4.4.1 Social Benefits**

Among the three main pillars that play a key role in the sustainability of a project (Economic, environmental and social), social benefits have been receiving less consideration in the past unlike today. This is because this concept is typically difficult to define and quantify.

Majority of the respondents interviewed were of the view that the expansion of Maruba dam brought about numerous social benefits.



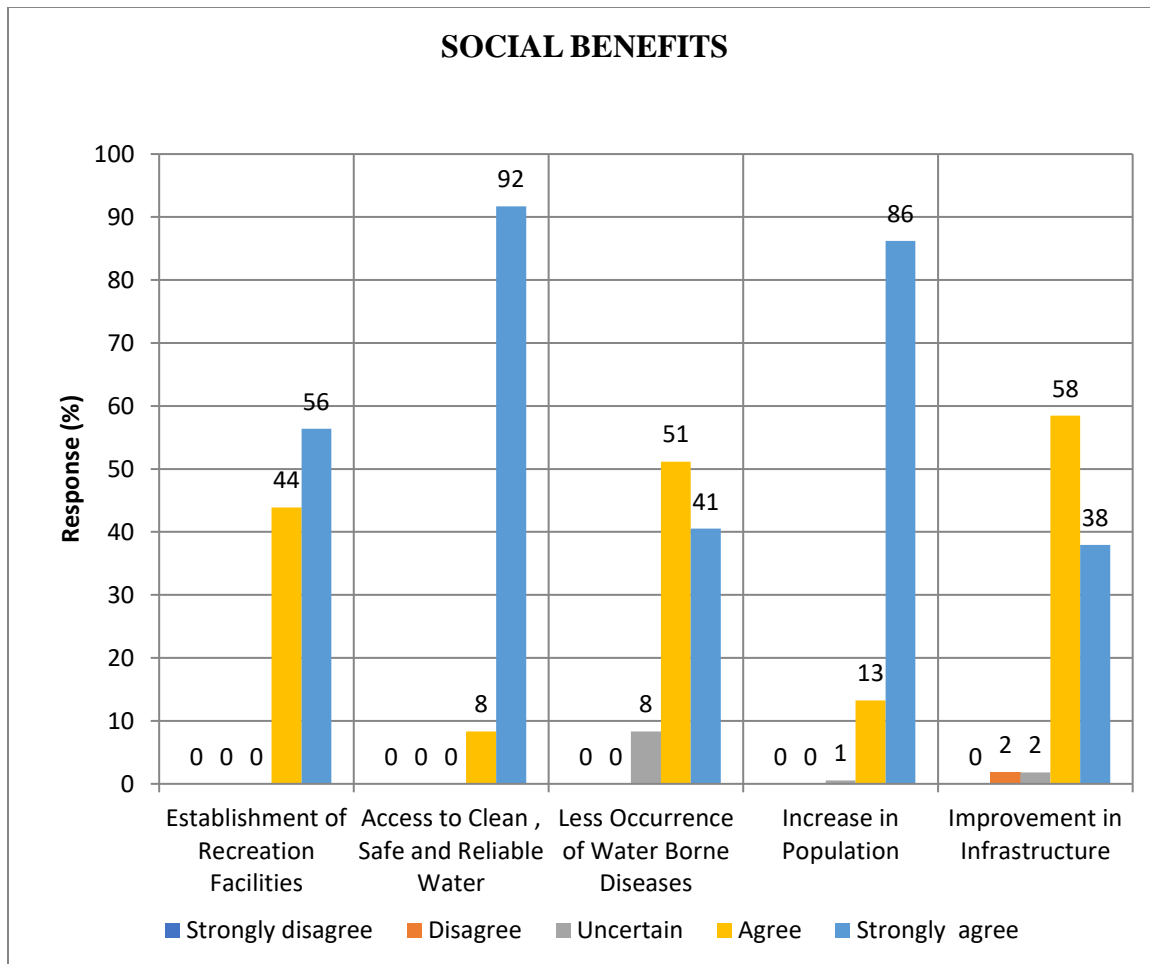


Figure 4.11: Analysis of Social Benefits

Figure 4.11 whose data was derived from Appendices 4.1 and 4.9, displays the views of the respondents on some of the social benefits which were anticipated. The views are summarized as below:

- All the 385 respondents observed that public and private recreation facilities were developed focusing on the reliability of water from the dam. Key among them is the spectacular Machakos People’s Park. Figure 4.12 shows a photo of part of the park.

- All the 385 respondents opined that the expansion of the dam increased access to safe, clean and reliable water in the estate.
- Of the 354 of the respondents, 158 respondents (41%) agreed and 196 respondents (51%) strongly agreed that there was less occurrence of water borne diseases due to increased access to clean water than before.
- Of the 381 of the respondents, 50 respondents (13%) agreed and 331 respondents (86%) strongly agreed that the expansion of Maruba dam and the subsequent improvement in water supply was one of the key drivers of increase in population.
- Of the 369 of the respondents, 223 respondents (58%) agreed and 146 respondents (38%) strongly agreed that there was improvement in infrastructure which include roads, water reticulation system, electricity connectivity among others.

Besides access to clean, safe and reliable water supply which was one of the primary objectives for expansion of Maruba dam, all the other benefits were as a result of the multiplier effects of a well executed water project. Majority of the respondents affirmed that Maruba dam played an important role in light of the fact that a reliable source of potable water especially in urban set ups translates to a growing population.

Social amenities have been given attention by the respective stakeholders. Roads have been improved and extended to reach newly habited areas. Road maintenance in carried out regularly and also some roads have been upgraded to bituminous standards. Electricity connectivity has also been enhanced in the area and has been extended to newly built-up areas. This has revitalized business activities such as welding and movie shops. Water infrastructure was also rehabilitated and extended to some of the areas that did not have access to the commodity before expansion of

the dam. Figure 4.12 shows part of Machakos People’s Park which is a key attraction in the area and a beneficiary of the water from Maruba dam. It can be deduced that, besides the benefits mentioned above, intangible benefits were also realized. These include; released labour, household welfare, more leisure, improvement in living standards, formal and informal social participation among others.



Figure 4.12: Part of Machakos People’s Park

#### 4.4.2 Social Costs

Where social and economic benefits are found, social costs must be behind the scenes. Figure 4.13 demonstrates the views of the respondents in regard to some of the social costs that emanated from the expansion of Maruba dam. The data used to generate Figure 4.13 was derived from the semi-structured household survey questionnaire responses attached as Appendix 4.1 and social costs data attached as Appendix 4.10.

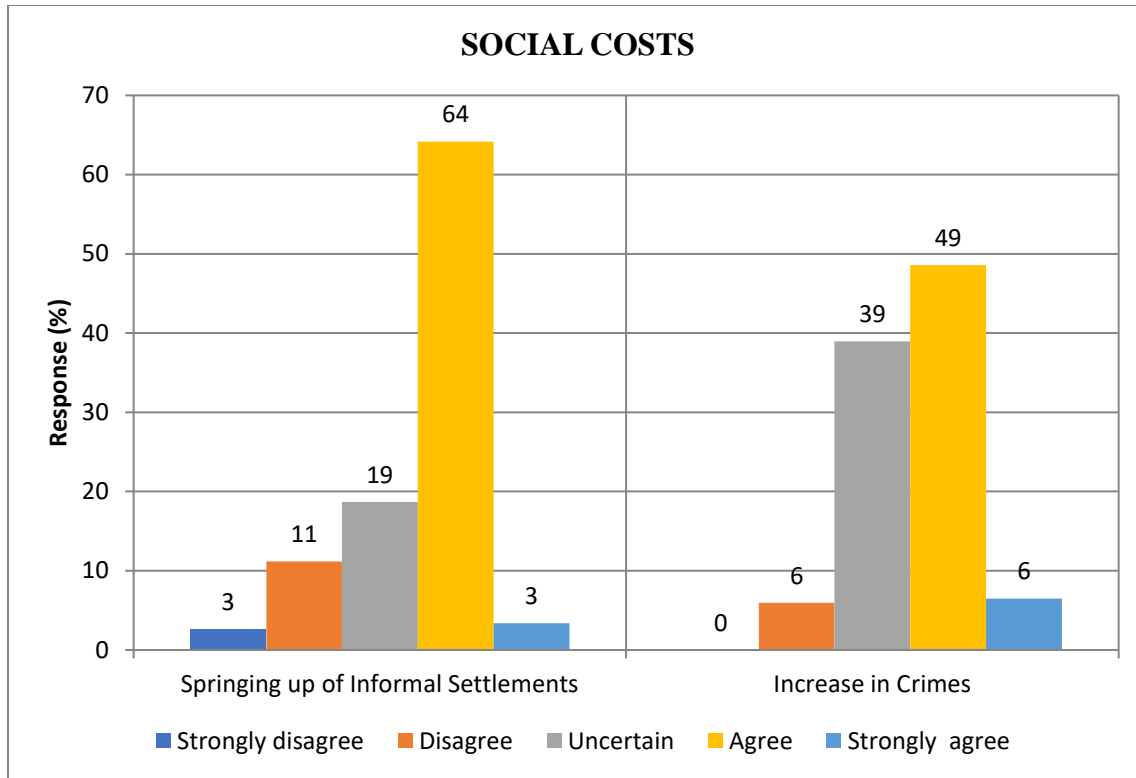


Figure 4.13: Analysis of Social Costs

Majority of the respondents were aware that some informal settlements had sprung up and also insecurity had deteriorated as shown below;

- Of the 258 of the respondents, 247 respondents (64%) agreed and 11 respondents (3%) strongly agreed that they were aware about informal settlements.
- Of the 212 of the respondents, 189 respondents (49%) agreed and 23 respondents (6%) strongly agreed that insecurity had increased partly due to increased population.

According to the respondents, land fragmentation due to increased demand for housing resulted into agricultural land being converted to plots. Some of the households sold all the land they had and mismanaged the dues. Such households are part of those living in informal settlements. Some

of the respondents interviewed opined that insecurity increased in the estate due to unmet expectations by some of the people who migrated to the estate with an expectation of a greener pasture. When their expectations turned into an illusion, they turned into becoming petty thieves thus occasionally terrorizing residents during the night and also breaking into houses. This was confirmed by the area chief. Appendix 4.11 shows the key informant interview guide questionnaire as completed by the chief. Some cases of robbery with violence by armed robbers have been reported in the estate. This has called for regular police patrols especially during the night.

#### **4.5 Observations Made**

Various observations around Maruba dam and Miwani estate were done by the researcher. A sample checklist of the observations done is shown in Appendix 4.12. The observations are recorded below based on the areas of study.

##### **4.5.1 Observations pointing to Economic Impacts**

- Majority of the residents living in Miwani estate are in the middle and high income bracket.
- There are several hotels some with recreation facilities that have come up within Kenya Israel estate, which is a neighbourhood of Miwani estate.
- Most of the recent and upcoming buildings have more than one floor.

##### **4.5.2 Observations pointing to Environmental Impacts**

- Truck exhausters are used to empty septic tanks and the waste is dumped at a decentralized treatment facility downstream of Maruba dam.

- Some developers dump loose excavated top soil along the riparian land of the river draining into Maruba dam and also around the riparian land on the shores of the dam as shown in Figure 4.14.
- The dam is not fenced.
- Domestic animals graze up to the shores of the dam and take water from any point on the upstream. Therefore, animal dung and urine find their way into the dam.
- Big trees have been let to grow on the embankment and this may compromise the soil stability of the embankment in future as shown in Figure 4.15.



Figure 4.14: Top Soil Dumped on the Riparian Land along the Reservoir

Dumped Soil



Figure 4.15: Trees Growing on Maruba Dam Embankment

### **4.5.3 Observations pointing to Social Impacts**

Machakos People's Park which is a recreation facility starts from the shores of Maruba dam. Part of the Park is as shown in Figure 4.12.

### **4.5.4 Additional information from MAWASCO**

The five MAWASCO staff interviewed reported that towards the end of every dry season, there is usually a green layer that forms on the surface of the water in the reservoir. This can be attributed to eutrophication and the domestic effluents from the upstream. The company reported that this was worse in 2017 since the treated water then, had some odour. The additional information was captured in Appendix 4.12.

## 4.6 Comparative Analysis of the Impacts

### 4.6.1 Benefits

For purposes of comparison of impacts, weighting of respondents was undertaken as follows: a weight of 3 points for all responses of 85% and above, 2 points for responses between 70% and 84% and 1 point for responses below 70%. The total number of respondents was 385. Table 4.1 shows the analysis of the respective benefits.

Table 4.1: Analysis of Benefits

Impact Category	Specific Impact	Respondents (%)	Weight	Total Category (Weight)	Representation (%)
Economic benefits	Improvement of water supply	100	3	23	52.3
	Rejuvenation of existing businesses	98	3		
	Springing up of new businesses	99	3		
	Opening of employment opportunities	95	3		
	Mushrooming of new buildings	100	3		
	Establishment of new institutions	99	3		
	Land appreciation	100	3		
	Establishment of kitchen gardens	72	2		
Environmental benefits	Establishment of trees and flower nurseries	96	3	6	13.6
	Planted trees and flowers	93	3		
Social benefits	Establishment of recreation facilities	100	3	15	34.1
	Access to clean, safe and reliable water	100	3		
	Less occurrence of water borne diseases	91	3		
	Increase in population	99	3		
	Improvement of infrastructure	96	3		



During the pre-testing of the questionnaires, the respondents identified more parameters on economic benefits than in environmental and social benefits. From Table 4.1, the specific economic benefits cited were eight with a total weight of twenty-three (23) points, followed by the social benefits with five specific impacts giving a total weight of fifteen (15) points and lastly the environmental benefits with two specific impacts having a total weight of six (6) points. It was deduced that the respondents perceived that the expansion of Maruba dam impacted more positively on the economy which was ranked first at 52.3% of the total weight, followed by social at 34.1% and then environmental aspects ranked third at 13.6% of the total weight.

#### 4.6.2 Costs

For purposes of comparison of costs, weighting of respondents was undertaken as follows: a weight of 3 points was assigned for all responses of 85% and above, 2 points for responses between 70% and 84% and 1 point for responses below 70%. The total number of respondents was 385. Table 4.2 shows the analysis of the respective costs.

Table 4.2: Analysis of Costs

<b>Impact Category</b>	<b>Specific Impact</b>	<b>Respondents (%)</b>	<b>Weight</b>	<b>Total Category (Weight)</b>	<b>Representation (%)</b>
Economic costs	Closure of some businesses	13	1	2	22.2
	Increase in insecurity	3	1		
Environmental costs	Poor wastewater management	89	3	5	55.6
	Poor solid waste management	74	2		
Social costs	Springing up of informal settlements	67	1	2	22.2
	Increase in crimes	55	1		

Each of the categories of costs had two specific impacts. The comparison shows that the environmental costs had the highest weight of 55.6% while both economic and social costs had a weight of 22.2% each. However, from the percentages of specific impacts, the social costs are higher than the economic costs.

#### **4.7 Schematic Correlation of Impacts**

The main objective of the expansion of Maruba dam was to increase its water storage capacity thus increasing the level of water supply per day to the residents of Machakos Town and its environs. Besides the increase in water supply, Figure 4.16 shows a correlation of the positive and negative impacts that resulted from the expansion of the dam. The achievement of increased water supply brought about other secondary impacts that were not part of the objective of expanding the dam. This spells the need for involving other key stakeholders whose infrastructure may be affected by the impacts of a project, during planning stage. A common approach in project planning would help other stakeholders to mobilize resources so as to mitigate against some of the negative consequences on society, economy and environment that may result from a development project.

Rapid population growth is likely to result to an imbalance between the water supply and demand (Brown et al., 2019). Water demand rose from the estimated 1100m<sup>3</sup>/day in 2012 to 2000m<sup>3</sup>/day in 2019. This created a huge gap in the supply and thus water tankering is a common business in the area, geared towards bridging the gap in the water demand. Figure 4.16 shows economic and social benefits being a major contributor to increased wastewater and solid waste in the estate.

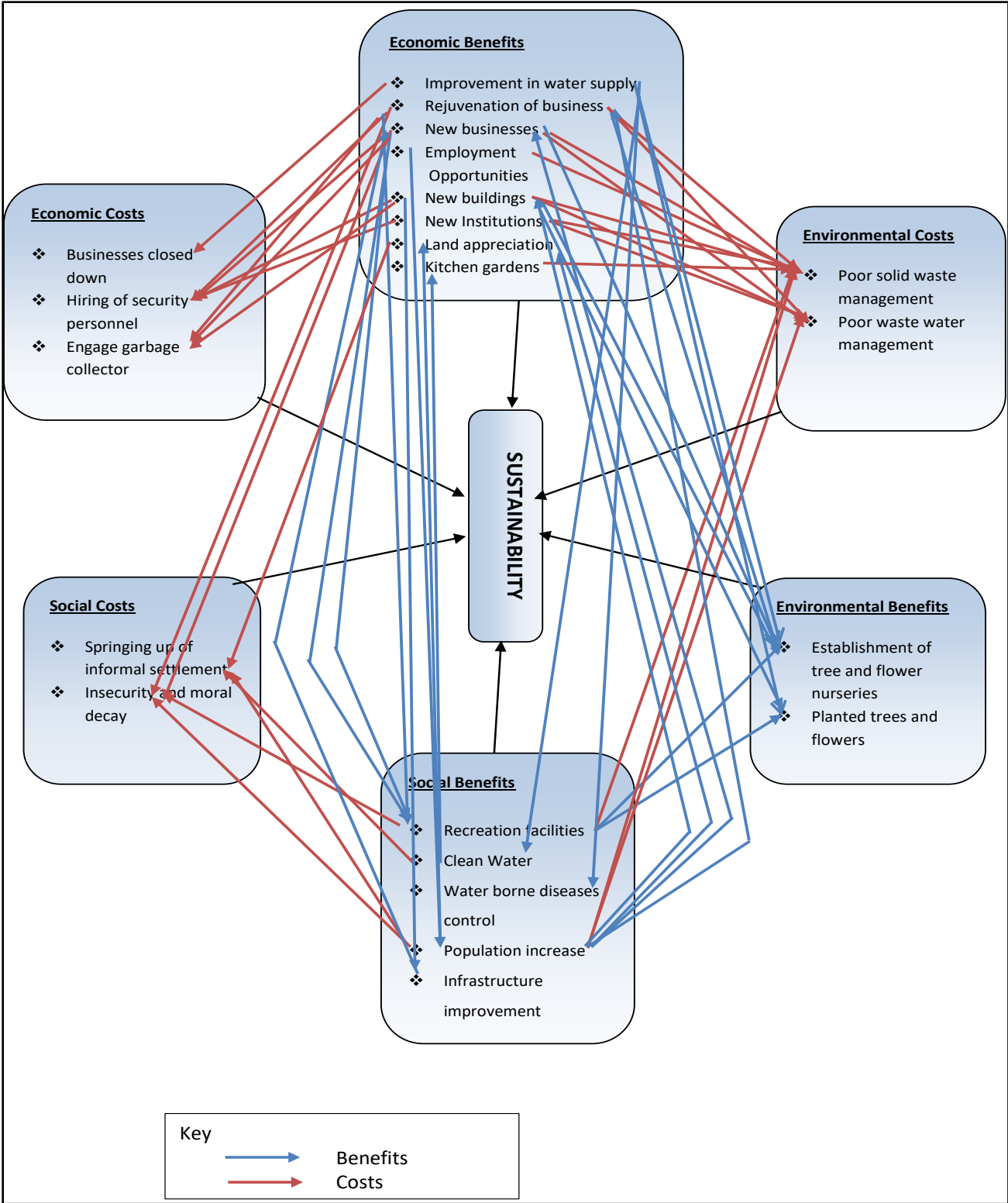


Figure 4.16: Schematic Correlation among the Various Impacts

From Figure 4.16, a weight of one (1) point was assigned to any parameter that was agreed upon by 100% of the respondents. Each arrow pointing towards an impact was then assigned a comparative weight based on the observations made during the field visits of the study area. The benefits were assigned positive weights while the costs were assigned negative weights.

#### 4.7.1 Analysis of Positive Impacts

An extract of arrows from Figure 4.16 whose impacts were positive is as shown in Table 4.3. The positive impacts are also referred to as benefits. Each arrow was assigned a comparative weight based on the observations made during the field assessment. The data used in coming up with Table 4.3 was derived from Appendix 4.13.

Table 4.3: Weighting of Positive Impacts

<b>Impact</b>	<b>Arrow from to</b>	<b>Weight</b>	<b>Total</b>	<b>Representation (%)</b>
Economic benefits	Population increase to new buildings	1	7.64	53.1
	Population increase to new institutions	0.99		
	Population increase to new businesses	0.99		
	Population increase to rejuvenation of businesses	0.98		
	Population increase to employment opportunities	0.95		
	Infrastructure improvement to new businesses	1		
	Population increase to land value appreciation	1		
	Clean water to kitchen gardens	0.73		
Environmental benefits	Improvement of water supply to establishment of trees and flower nurseries	0.3	1.89	13.1
	Rejuvenation of businesses to establishment of trees and flower nurseries	0.2		
	New businesses to establishment of trees and flower nurseries	0.2		
	New buildings to establishment of trees and flower nurseries	0.13		
	Recreation facilities to establishment of trees and flower nurseries	0.13		

	Improvement of water supply to planted trees and flowers	0.5		
	New institutions to planted trees and flowers	0.2		
	Recreation facilities to planted trees and flowers	0.23		
Social benefits	Rejuvenation of businesses to recreation facilities	0.4	4.87	33.8
	New businesses to recreation facilities	0.4		
	Employment opportunities to recreation facilities	0.2		
	Improved water supply to clean water	1		
	Improved water supply to reduction in water borne diseases	0.92		
	New buildings to infrastructure development	0.96		
	Employment opportunities to population increase	0.99		

From the analysis of the percentage representation of each category of impacts in Table 4.3, it was concluded that expansion of Maruba dam impacted more positively on the economy of Miwani estate than on social and environmental aspects. The economic positive impacts ranked first at 53.1%, social positive impacts ranked second at 33.8% while the environmental positive impacts ranked third at 13.1%. This compares well with the results from Table 4.1 where the economic benefits ranked at the top, followed by social benefits and lastly by the environmental benefits.

**4.7.2 Analysis of Negative Impacts**

Arrows representing negative impacts were extracted from Figure 4.16 to Table 4.4 and their corresponding weights were assigned. The data used in Table 4.4 was derived from Appendix 4.13.

Table 4.4: Weighting of Negative Impacts

Impact	Arrow from to	Weight	Total	Representation (%)
Economic costs	Improvement in water supply to businesses closed	-0.13	-0.56	16.4
	Rejuvenation of businesses to hiring of security guards	-0.04		
	New businesses to hiring of security guards	-0.04		
	New buildings to hiring of security guards	-0.03		
	New institutions to hiring of security guards	-0.04		
	Rejuvenation of businesses to engaging garbage collector	-0.1		
	New businesses to engaging garbage collector	-0.1		
	New buildings to engaging garbage collector	-0.08		
Environmental costs	Rejuvenation of businesses to poor solid management	-0.2	-1.63	47.8
	New businesses to poor solid management	-0.2		
	New institutions to poor solid waste management	-0.14		
	Employment opportunities to poor solid waste management	-0.1		
	New buildings to poor solid waste management	-0.2		
	Kitchen gardens to poor solid waste management	-0.05		
	Rejuvenation of businesses to poor wastewater management	-0.2		
	New businesses to poor wastewater management	-0.2		
	New buildings to poor wastewater management	-0.2		
	New institutions to poor wastewater management	-0.14		
Social costs	Clean water to springing up of informal settlements	-0.1	-1.22	35.8
	Population increase to springing up of informal settlements	-0.4		
	Land appreciation to springing up of informal settlements	-0.17		

	Recreation facilities to insecurity and moral decay	-0.15		
	Population increase to insecurity and moral decay	-0.15		
	Rejuvenation of businesses to insecurity and moral decay	-0.1		
	New businesses to insecurity and moral decay	--0.15		

The summation of the weights for the negative impacts for the respective parameters was done. The findings show that environmental negative impacts were the highest at 47.8%, followed by social at 35.8% and lastly by the economic negative impacts at 16.4%. This compares well with the results shown in Table 4.2 where the respondents ranked environmental costs at the top, followed by social costs while economic costs were the least.

**4.7.3 Overall Summation of Impacts**

For purposes of arriving at the resultant impacts, all arrows from Figure 4.16 with their corresponding weights were tabulated as shown in Table 4.5. The benefits were assigned a positive sign while the costs were assigned a negative sign. The data used in Table 4.5 was extracted from Appendix 4.13. Summation of the weights for each category of impacts was done. The findings show that the economic, environmental and social benefits which resulted from the expansion of Maruba dam outweighed their respective costs. Therefore, the resultant impacts for all the three parameters were positive.

Table 4.5: Summation of Impacts

Impact	Specific impact	Arrow from and to	Weight	Sub-Total	Total (Benefit s+Costs)	Repre ntation (%)
Economic	Economic benefits	Population increase to new buildings	1	7.64	7.08	64.4
		Population increase to new institutions	0.99			
		Population increase to new businesses	0.99			
		Population increase to rejuvenation of businesses	0.98			
		Population increase to employment opportunities	0.95			
		Infrastructure improvement to new businesses	1			
		Population increase to land value appreciation	1			
		Clean water to kitchen gardens	0.73			
	Economic costs	Improvement of water supply to businesses closed	-0.13	-0.56		
		Rejuvenation of businesses to hiring of security guards	-0.04			
		New businesses to hiring of security guards	-0.04			
		New buildings to hiring of security guards	-0.03			
		New institutions to hiring of security guards	-0.04			
		Rejuvenation of businesses to engaging garbage collector	-0.1			
		New businesses to engaging garbage collector	-0.1			
New buildings to engaging garbage collector		-0.08				
Environm ental	Environm ental benefits	Improvement of water supply to establishment of trees and flower nurseries	0.3	1.89	0.26	2.4
		Rejuvenation of businesses to establishment of trees and flower nurseries	0.2			
		New businesses to establishment of trees and flower nurseries	0.2			
		New buildings to establishment of trees and flower nurseries	0.13			



		Recreation facilities to establishment of trees and flower nurseries	0.13	-1.63		
		Improvement in water supply to planted trees and flowers	0.5			
		New institutions to planted trees and flowers	0.2			
		Recreation facilities to planted trees and flowers	0.23			
	Environmental costs	Rejuvenation of businesses to poor solid management	-0.2			
		New businesses to poor solid waste management	-0.2			
		New institutions to poor solid waste management	-0.14			
		Employment opportunities to poor solid waste management	-0.1			
		New buildings to poor solid waste management	-0.2			
		Kitchen gardens to poor solid waste management	-0.05			
		Rejuvenation of businesses to poor wastewater management	-0.2			
		New businesses to poor wastewater management	-0.2			
		New buildings to poor wastewater management	-0.2			
		New institutions to poor wastewater waste management	-0.14			
Social	Social benefits	Rejuvenation of businesses to recreation facilities	0.4	4.87	3.65	33.2
		New businesses to recreation facilities	0.4			
		Employment opportunities to recreation facilities	0.2			
		Improved water supply to clean water	1			
		Improved water supply to reduction in water borne diseases	0.92			
		New buildings to infrastructure development	0.96			
		Employment opportunities to population increase	0.99			
	Social costs	Clean water to springing up of informal settlements	-0.1			

		Population increase to springing up of informal settlements	-0.4			
		Land appreciation to springing up of informal settlements	-0.17			
		Recreation facilities to insecurity and moral decay	-0.15			
		Population increase to insecurity and moral decay	-0.15			
		Rejuvenation of businesses to insecurity and moral decay	-0.1			
		New businesses to insecurity and moral decay	-0.15			

Table 4.5 shows that economic impacts ranked first at 64.4% of the overall weight, followed by social impacts at 33.2% while environmental impacts were the least at 2.4%. It was therefore concluded that the respective benefits for each category of impacts outweighed their respective costs.

**4.8 Status of Implementation of the Environmental Management Plan**

The researcher visited the institutions tasked with the implementation of the EMP and enquired about the progress of its implementation. The feedback from the respective institutions was that none of them had implemented the activities that were assigned to them in the EMP. National Water Harvesting and Storage Authority in collaboration with NEMA did not construct silt traps and sludge drying beds. Tanathi WWDA in collaboration with NEMA and WRA did not, conduct ecological surveys, provide suitable flow release mechanisms, backfill borrow pit areas and plant vegetation while public health department and NEMA have never conducted epidemiological surveys. Appendix 4.14 shows the implementation status of the EMP as was recommended in the Environmental Impact Assessment report.

The key challenge cited by each of the four officers interviewed from NEMA, NWHTA, Machakos WRA regional office and Tanathi Water Works Development Agency, was that confusion engulfed the process after devolution came into being in 2013. There were different schools of thought as to who was to provide the budget to implement the activities recommended in the EMP. The county government was of the opinion that it was supposed to implement the EMP while the national institutions were of a contrary opinion. Since the activities of the EMP required a budget and the good will from the county government, the EMP became no one's business and therefore has never been implemented to date. However, the recommendations in the EMP are valid and require to be implemented as appropriate.

#### **4.9 Water Quality**

A desk study on the water quality supplied by the Water Service Provider was done. The sections below show extracts of the water quality results for some of the months randomly sampled in comparison with required standards.

##### **4.9.1 Secondary data for physical-chemical analysis of raw water**

Appendix 4.15 shows secondary data results for Physical-Chemical analysis of Maruba dam raw water. All the parameters were within the required Kenya Bureau of Standards (KEBS) levels except for colour, turbidity and Iron which were above the maximum recommended levels.

##### **4.9.2 Secondary data for physical-chemical analysis of tap water**

Appendix 4.16 shows the results of the Physical-Chemical analysis of Maruba dam treated tap water for diverse dates. All the parameters analysed met the required KEBS standards except for iron which was 0.4mg/l and 0.6 mg/l for November 2019 and January 2020 as compared to 0.3

mg/l, the maximum recommended. A sample of Physical-Chemical analysis results for tap water is shown in Appendix 4.17.

#### 4.9.3 Secondary data for bacteriological results of raw water

Table 4.6 shows some of the sampled results for bacteriological analysis done for Maruba dam raw water. The results show that all the parameters failed to meet the required standards. Therefore, adequate water treatment is recommended. A sample of bacteriological analysis results for raw water is shown in Appendix 4.18.

**Table 4.6: Secondary Data for Bacteriological Results of Raw Water**

Parameter	Date Sampled 20/4/2017	Date Sampled 13/9/18	Date Sampled 9/1/20	KEBS Standard	WHO Standards
MPN of Coliforms organisms per 100ml	>2420	>2420	>2420	Not detectable	Nil
E. Coli per 100ml	>2420	>2420	>2420	Not detectable	Nil

#### 4.9.4 Secondary data for bacteriological results of treated water

Table 4.7 shows some of the sampled results for Bacteriological analysis done for Maruba dam treated tap water. The results show that all the parameters were as per the required standards except for the sample dated 13/9/2018. Therefore, adequate water treatment is recommended. A sample of the bacteriological analysis results for tap water is shown in Appendix 4.19.

**Table 4.7: Secondary Data for Bacteriological Results of Treated Tap Water**

Parameter	Date Sampled 13/09/2018	Date Sampled 24/4/2019	Date Sampled 9/1/20	KEBS Standard	WHO Standards
MPN of Coliforms organisms per 100ml	4	Nil	Not detectable	Not detectable	Nil
E. Coli per 100ml	Nil	Nil	Not detectable	Not detectable	Nil

From the results it was deduced that generally the water provided by MAWASCO meets the required International and Kenyan standards.

#### **4.9.5 Primary data for physical-chemical analysis of tap water**

The researcher took some water samples for analysis. The outcome was consistent with the results in the records of MAWASCO as shown in Appendix 4.20. Therefore, the water supplied to the residents of Miwani estate is clean and safe for domestic use.

#### **4.10 Analysis of the Quality of Water**

The analysed samples of treated water met the required KEBS bacteriological standards. However, the raw water samples analysed, did not fall within the required standards. E.coli and iron were above the allowable levels. The results can be used to deduce the efficiency of the treatment process and suggest that the water treatment process may not have removed some of the other pathogens that were not directly tested, such as protozoan parasites. This is according to Kahler et al. (2016), who cited the need for adequate water treatment so as to ensure that all the pathogens are removed, if the raw water samples did not conform to the laid down standards.

The physical-chemical analysis of raw water showed that the levels of concentration of some of the parameters were higher than the allowable levels by the KEBS standards. Among the

parameters of concern are; colour, turbidity, conductivity and iron. However, the results of the treated water samples show that the treatment process brings the levels of all the parameters to the required KEBS standards except for iron. The levels of manganese, calcium, sodium and potassium fell within the KEBS standards for both the raw and the treated water. Adequate water treatment is recommended so as to ensure that all the parameters of the treated water are within the allowable KEBS standards as per WHO (2011) guidelines.

#### **4.11 Overall Summary of the Findings**

From the analysis of the data collected from the 385 respondents, it was found that the expansion of Maruba dam resulted to both positive and negative economic, social and environmental impacts in Miwani estate. However, the positive impacts outweighed their respective costs in all the three parameters as shown in Table 4.5. The resultant economic impacts had a weight of 64.4%, social impacts had a weight of 33.2% while the environmental impacts had a weight of 2.4%. From the above results, it was deduced that the expansion of Maruba dam resulted to more positive economic impacts in Miwani estate followed by social impacts and lastly environmental impacts. This agrees well with the studies carried out in Madagascar (SIPA, 2008) on impacts of improved water and sanitation services.

The positive economic impacts in Miwani estate that resulted from the expansion of Maruba dam are; improvement in water supply, rejuvenation of businesses, establishment of new businesses, creation of employment opportunities, new buildings, new institutions, appreciation in land value and establishment of kitchen gardens. The revenue collected by Machakos Water and Sewerage Company, the local Water Service Provider increased by approximately KES 758,162 per month from KES 101,231 to KES 859,393 per month. The negative economic impacts that were identified

by the respondents interviewed include: some businesses closed down, some people had to engage security guards and others had to engage services of private garbage collectors.

The positive environmental impacts that were identified by the respondents are: establishment of trees and flower nurseries and planted trees and flowers in Miwani estate. The environmental costs that were identified are; poor wastewater and solid waste management. The above findings concur with the outcome of a study carried out by Chapungu (2014) on Impacts of small scale community water projects in Chimanimani district of Zimbabwe.

Establishment of recreation facilities, access to clean, safe and reliable water, less occurrence of water borne diseases, increase in population and improvement in infrastructure are the social benefits that resulted from the expansion of Maruba dam. The social costs identified are; springing up of informal settlements and increase in crime.

## CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

### 5.1 Conclusion

Based on the research findings, it was established that expansion of Maruba dam resulted to positive and negative economic, environmental and social impacts in Miwani estate. However, after comparison of the benefits and the costs, it was found that the benefits of each of the three parameters outweighed their respective costs. The economic impacts had a resultant weight of 64.4%, environmental impacts had a weight of 2.4% while the social impacts had a resultant weight of 33.2%. From the above findings, the economic benefits ranked the highest, followed by social benefits and lastly environmental benefits.

The specific economic benefits found were; improvement in water supply, rejuvenation of businesses, establishment of new businesses, creation of employment opportunities, new buildings, new institutions, appreciation in land value and establishment of kitchen gardens. The revenue collected by Machakos Water and Sewerage Company, the local Water Service Provider increased by approximately KES 758,162 per month from KES 101,231 to KES 859,393 per month. The economic costs include; some businesses closed down, some residents had to engage private security guards and services of private garbage collectors which consume part of their resources.

The population of the estate increased thus giving birth to new and expanded business ventures. The specific social benefits that resulted from the expansion of Maruba dam include; population increase, establishment of recreation facilities, access to clean, safe and reliable water, less occurrence of water borne diseases and improvement in infrastructure. The environmental impacts which were cited are; establishment of trees and flower nurseries and planted trees and flowers in



Miwani estate. Some of the environmental costs include; poor wastewater and solid waste management.

The combination of the above factors among others gives the assurance that the gains realized in Miwani estate besides improved water supply are contributing positively towards the sustainability of Maruba dam.

Wastewater and solid waste disposal are still a challenge in the estate. They are a major source of environmental pollution. Maruba dam is in danger of increased pollution from domestic, industrial and agricultural sources from Miwani estate. Measures require to be put in place so as to minimize the effluents draining into the river flowing to the dam both during the dry and wet seasons.

## **5.2 Recommendations**

The following is the list of recommendations that if implemented, will help mitigate on the negative impacts to the gains achieved through the expansion of Maruba dam.

1. Miwani estate be sewerred and be connected to the sewerage system of Machakos town.  
This will help check on probable pollution of the ground water, the river draining into Maruba dam and the general environment.
2. Machakos County Government to improve on solid waste management in Miwani estate as this is a source of environmental pollution.
3. The local Water Service Provider and Machakos County Government should put measures in place for sensitizing business people involved in sewerage and wastewater exhausting business on the best practices.
4. Continual sensitization of car wash owners on best practices of wastewater disposal instead of letting the water flow directly into the river channel.

5. Enforcement of the building act on all the developers putting up infrastructure in Miwani estate. This is because some developers disregard the negative impact of their actions to the environment.
6. Sensitization of the people practicing farming in the estate and its upstream on best farming practices.
7. Implementation of the EMP as was recommended in the EIA report be done.

### **5.3 Recommendations for Further Study**

In this study, the researcher was only able to undertake a study on the post expansion impacts of Maruba dam on Miwani estate. It was observed that wastewater and solid waste management are a key challenge in the estate. In view of the above, the following areas are proposed for further study:

1. A comprehensive study on all potential pollutants to Maruba dam emanating from Miwani estate and their specific sources.
2. A study on possible long term supplementary water source for Miwani estate.

## REFERENCES

- African Population and Health Research Center (2014). *Population and health dynamics in Nairobi informal settlements*. Nairobi, APHRC.
- Alaci, D. S. A. and Alehegn, E. (2009). Experiences from Ethiopia and Nigeria: infrastructure provision and the attainment of Millennium Development Goals (MDGs) in decentralized systems of Africa, Paper presented at the Conference on the Role of the Sub-National Jurisdictions in Efforts to achieve the MDGs, Abuja, Nigeria, pp 7-19.
- Alphaomega, (2012). *The Importance of Water*. [www.aomega.com/mpure/water.htm](http://www.aomega.com/mpure/water.htm). Accessed 6 July 2016.
- Australian Government, (2017). *Department of Health and Ageing*. <https://www.sahealth.sa.gov.au>. Accessed 14 October 2017.
- Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., Bartram, J. (2014). Fecal contamination of drinking-water in low- and middle-income countries: A systematic review and meta-analysis. The Water Institute, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.
- Barcott, B. (2015). *The Failures of Compliance Abatement and Mitigation; New Horizons in Environmental Politics*. Massachusetts: Daniel Press.
- Barton, A.B., Smith, A.I., Maheepala, S. and Barron, O. (2009). Advancing IUWM through an understanding of the urban water balance. 18<sup>th</sup> World IMACS/MODSIM Congress, Cairns, Australia, pp 2-7.
- Bazin, F., Skinner, J. and Koundouno, J. (2011). *Sharing the Water, Sharing the Benefits; Lessons learnt from six large dams in West Africa*. London: International Institute for Environment and Development.

- Borst, L., Haas, S.A. (2006). *Hydrology of sand storage, A case study in the Kiindu catchment, Kitui district, Kenya*. Master thesis, Vrije Universiteit, Amsterdam.p.146.
- Brown, T. C., Mahat, V., and Ramirez, J. A. (2019). Adaptation to future water shortages in the United States caused by population growth and climate change. *Earths Future* 7, 219–234.
- Butler, D., Ward, S., Sweetapple, C., Astaraie-Imani, M., Diao, K., and Farmani, R. (2017). Reliable, resilient, and sustainable water management: The safe and sure approach. *Global Challenges* 1, 63–77.
- Cernea, M.M. (2018). *Social Impacts and Social Risks in Hydropower Programs: Preemptive Planning and Counter Risk Measures*. Washington DC: Washington University.
- Chapungu, L. (2014). Impacts of Small Scale Water Projects: The case of Elephant Pumps in Shinja resettlement area, Chimanimani district, Zimbabwe. *International Journal of Development and Sustainability, Vol.3 No. 6*, pp.122-128.
- Cohen, J. (2007). *Statistical Power Analysis for the Behavioral Sciences*. New York: Academic Press.
- Conroy, R. (2014). Sample size: a rough guide, <http://www.surveysystem.com/sscalc.htm>. Accessed 16 August 2016.
- Corcoran, E., Nelleman, C., Baker, E., Bos, R., Osborn, D. and Savelli, H. (2010). *Sick Water? The Central Role of Waste Water Management in Sustainable Development*. Nairobi: United Nations Environment Programme.
- Dendena, B., & Corsi, S. (2015). The Environmental and Social Impact Assessment: a further step towards an integrated assessment process. *Journal of Cleaner Production*, 108, 965–977.

- Edokpayi, J.N., Odiyo, J.O., Msagati, T.A.M. and Potgieter, N (2015). Temporal variations in physical-chemical and microbiological characteristics of Mvudi river, South Africa. *International Journal of Environmental Research and Public Health*, 12,20-30.
- Escalada, D. M. (2009). Writing the thesis outline: Conceptual framework, <http://devcompage.com/?=1409>. Accessed 10 June 2017.
- Fisher, A.A., Laing, J.E., Stoeckel, J.E. and Townsend, J.W. (1998). *Hand book for Family Planning Operations Research Design*. New York: Population Council.
- Furuoka, F. (2005). Population growth and economic development: a case study of Malaysia. *Journal of Population and Social Studies*, 14, 47-66.
- Eurostat (2015). Gross domestic product at current market prices, [http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama\\_r\\_e3gdp&lang=en](http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nama_r_e3gdp&lang=en). Accessed 13 November 2021.
- Evans, B., Hueso, A., Johnston, R., Norman, G., Pérez, E., Slaymaker, T. and Trémolet, S. (2017). Limited services? The role of shared sanitation in the 2030 Agenda for Sustainable Development. *Journal of Water, Sanitation and Hygiene for Development*, 10, 1-4.
- Gallego, A., Hospido, A., Moreira, M. T. and Feijoo, G. (2008). Environmental performance of waste water treatment plants for small populations. *Resources, Conservation and Recycling*, Vol. 52, no 6, 931-940.
- Government of Kenya, Ministry of Health (2019). *Annual health sector performance report*. Nairobi: Government Printer.
- Government of Kenya (2016). *Water Act 2016*. Nairobi: Government Printer.
- Government of Kenya (2012). *IEBC report on constituency and ward boundaries*. Compiled by Independent Electoral and Boundaries Commission. Nairobi: Government Printer.

- Government of Kenya (2010). *The Constitution of Kenya 2010*. Nairobi: Government Printer.
- Government of Kenya, Ministry of Water and Irrigation (2009). *Annual Water Sector Review (AWSR)*. Nairobi: Government Printer.
- Government of Kenya (2009). *Population and housing census results in Kenya*. Compiled by Central Bureau of Statistics. Nairobi: Government Printer.
- Government of Machakos (2015). *Machakos county profile*. Machakos.
- Government of Machakos (2013). *Machakos county profile*. Machakos.
- Hesselbarth, S. (2005). Socio-economic impacts of water supply and sanitation projects, [www.kfw-entwicklungsbank.de/ebank/DE\\_Home/Sektoren/](http://www.kfw-entwicklungsbank.de/ebank/DE_Home/Sektoren/). Accessed 8 November 2021.
- Hilyard, N. (2008). *Dam on Rocks: The Flawed Economics of Large Hydroelectric Dams*. Dorset: The Corner House.
- Hussein, M. A. (2008). Costs of environmental degradation: Analysis in the Middle East and North Africa region. *Management of Environmental Quality*, 19, 17.
- ICOLD (2018). World register of dams, general synthesis, [http://www.icold-cigb.org/GB/World\\_register/general\\_synthesis.asp](http://www.icold-cigb.org/GB/World_register/general_synthesis.asp). Accessed 12 November 2021.
- Intergovernmental Panel on Climate Change (IPCC), (2007). Climate change 2007: Synthesis report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva.
- Jacobsen, M., Webster, M. and Vairavamoorthy, K. (2013). *The Future of Water in African Cities: Why Wastewater?* Washington, DC: World Bank.
- Jimenez, B. (2010). *The unintentional and intentional recharge of aquifers in the Tula and Mexico valleys: The megalopolis needs mega solutions*, Rosenberg symposium, Buenos Aires, Argentina, pp 35-40.

- Joshi, D. and Fawcett, B., (2011). *Water projects and women's empowerment*. Paper for 27<sup>th</sup> WEDC Conference: People and Systems for Water, Sanitation and Health, Lusaka, Zambia.
- Kahler, D.M., Koermer, N.T., Reichl, A.R., Samie, A. and Smith, J.A. (2016). *Performance and Acceptance of Novel Silver-Impregnated Ceramic Cubes for Drinking Water Treatment in Two Field Sites: Limpopo Province, South Africa and Dodoma Region, Tanzania*. *Water*, 8, 1-21. <https://doi.org/10.3390/w8030095>. Accessed 28 November 2021.
- Kaloustian, N. and Diab, Y. (2015). Effects of urbanization on the urban heat island in Beirut. *Urban Climate*, 14, 154–165.
- Kirchherr, J. and Charles, K.J. (2016). The social impacts of dams: A new framework for scholarly analysis. *Environmental Impact Assessment*, 60, 99–114.
- Koirala, S., Hill, D. and Morgan, R. (2017). Impacts of the delay in construction of a large scale hydropower project on potential. *Impact Assess*, 35, 106–116.
- Kothari C.R. (2019). *Research Methodology, Methods and Techniques*. London: fourth edition, New Age International (P) Limited Publishers.
- Kura, Y., Joffre, O., Laplante, B. and Sengvilaykham, B. (2017). Coping with resettlement: A livelihood adaptation analysis in the mekong river basin. *Land Use Policy*, 60, 139–149.
- Machakos Water and Sewerage Company, (2018). *Annual Report*. Machakos.
- Machakos Water and Sewerage Company, (2015). *Water Connections Register*. Machakos.
- Mugenda, O., and Mugenda, A. (2003). *Research Methods*. Nairobi: ACTS Press.
- Mwamburi K. Everlyne. (2013). *Factors affecting access of sustainable water supply in Kisauni area, Mombasa County*. Department of Geography & Environmental Studies, Faculty of Science of the University of Nairobi, Kenya.

- National Water Conservation and Pipeline Corporation, (2015). *End of financial year 2014/2015 projects report*. Nairobi.
- National Water Conservation and Pipeline Corporation, (2008). *Environmental Impact Assessment report for Maruba dam*. Nairobi.
- Ngechu, M. (2006). *Understanding the Research Process and Methods. An introduction*. 1<sup>st</sup> edition. Nairobi: Starbright Services Limited.
- Novotny, V., Ahern, J. and Brown, P. (2010). *Water Centric Sustainable Communities: Planning, retrofitting and building the next urban environment*. Hoboken: New Jersey. John Wiley & Sons Incorporation Publishers.
- Pimentel, D., Berger, B., Filiberto, D., Newton, M., Wolfe, B., Karabinakis, E., Clark, S., Poon, E., Abbett, E and Nandaopal, S. (2004). *Water Resources, Agriculture and the Environment*. New York: New York State College of Agriculture and Life Sciences, Cornell University. Paris: Boulevard Haussman.
- Reba, P., (2003). *Sectoral Trends in the Water Sector (Technology, Policy and Poverty) in South Asia*, Paper presented at South Asia Conference on Technologies for Poverty Reduction, New Delhi, India pp10-11.
- Sadoff, C. and Muller, M. (2009). *Water management, water and climate change adaptation: Early impacts and essential responses*. TEC Background Paper No14, Global Water Partnership, Stockholm.
- Scudder T. (2019). *Large Dams: Long Term Impacts on Riverine Communities and Free Flowing Rivers*. Singapore: Springer Nature Singapore Pvt Ltd.



- SIPA (School of International and Public Affairs, Columbia University), (2008). Valuating Economic and Social Impacts of Improved Water and Sanitation Services, <https://sipa.edu/file/3237/download?token=jzuhEVDu>. Accessed 28 July 2022.
- Soderbaum, P. (2015). *Economics and Ecological Sustainability*. Dordrecht: Kluwer Academic Publishers.
- UNDP (2017). UNDP Kenya annual report, [https://www1.undp.org/content/dam/kenya/docs/UNDP%20Reports/UNDPKE%202017%20Annual%20Report\\_Interactive.pdf](https://www1.undp.org/content/dam/kenya/docs/UNDP%20Reports/UNDPKE%202017%20Annual%20Report_Interactive.pdf). Accessed 28 November 2021.
- UNESCO (United Nations Educational Scientific and Cultural Organization), (2017b). *Sharing Water Resources*. Paris: UNESCO.
- UNESCO (United Nations Educational Scientific and Cultural Organization), (2017a). *Valuing Water*. Paris: UNESCO.
- UN-WWAP (United Nations World Water Assessment Programme), (2018). The United Nations World Water Development Report: Water in a changing World. Paris: UNESCO and London: Earthscan.
- Vanclay, F. (2017). Project-induced displacement and resettlement: From impoverishment risks to an opportunity for development? *Impact Assessment Project Appraisal*, 35, 3–21.
- Welford, R. (2000). *Corporate Environment Management*. London: Earthscan Publications Limited.
- WHO (World Health Organization) (2011). Guidelines for drinking-water quality, fourth edition, [http://www.who.int/water\\_sanitation\\_health/publications/2011](http://www.who.int/water_sanitation_health/publications/2011). Accessed 13 April 2017.

- WHO (World Health Organization) and UNICEF (United Nations Children's Fund), (2010). *Progress on Sanitation and Drinking Water*. United Nations Children's Fund, New York and World Health Organization, Geneva.
- WHO (World Health Organization). (2016). *Guidelines for Safe use of Wastewater, Excreta and Greywater*. World Health Organization, Geneva.
- WHO (World Health Organization) and DFID (United Kingdom Department for International Development), (2009). Summary and policy implications Vision 2030: The resilience of water supply and sanitation in the face of climate change. WHO, Geneva and DFID, London.
- Workman, J. (2009). *Dams Encyclopedia of Environmental Ethics and Philosophy, Vol. I, pp.197-200*. Detroit: Macmillan Publishers.
- Zhang, W., Li, Y., Li, Z., Wei, X., Ren, T. and Liu, J. (2020). Impacts of climate change, population growth, and urbanization on future population exposure to long-term temperature change during the warm season in China. *Environmental Science and Pollution Research*, 27, 8481–8491.
- Xiong W., Yuan F., Liq. and Skibniewski (2015). Performance objective based dynamic adjustment model to balance stakeholders' satisfaction in PPP projects. *Journal of Civil Engineering and Management*, vol. 21, no.5.

## APPENDICES

### Appendix 3.1: Semi-Structured Household Survey Questionnaire

Date.....

Name (optional).....

Gender.....

Phone number (optional).....

Year you started living in Miwaniestate.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Occupation (**Farmer, public servant, private sector employed, business, any other (specify)**)

Your main source of water (**River, borehole, water kiosk, roof catchment, piped water into household**)

Number of years that you have lived in Miwani estate.....

Are you aware that Maruba dam was rehabilitated/expanded between 2008 and 2010? (If the answer is yes, the respondent will be issued with the questionnaire)

S/No	<b>SECTION A</b>	Specific objective addressed based on numbering on page 7
	<p>For question 1 below, please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam on Miwani estate</p> <p>KEY:[1] Strongly disagree, [2] Disagree, [3] Uncertain, [4] Agree [5] Strongly agree</p>	
1	How did the expansion of Maruba dam contribute to the estate in terms of :-	
	<p>1.1 Improvement in supply of water?</p> <p>1[ ]                  2 [ ]                  3[ ]                  4 [ ]                  5 [ ]</p>	I
	<p>1.2 Rejuvenation of existing businesses?</p> <p>1[ ]                  2 [ ]                  3[ ]                  4 [ ]                  5 [ ]</p>	i

	1.3 Springing up of new business ventures? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	1.4 Opening up of employment opportunities? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	1.5 Rapid mushrooming of new buildings (both low and high-rise)? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	1.6 Establishment of new institutions that were not in the estate before? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	1.7 Establishment of recreation facilities within the vicinity of the estate? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i, iii
	1.8 Appreciation of land value in the estate? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
2	List down services that you started paying for after the expansion of the dam, that you never used to pay for, before; ..... .....	i
	<b>SECTION B</b>  For question 3 below, please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam on Miwani estate  KEY:[1] Strongly disagree, [2] Disagree, [3] Uncertain,[4] Agree [5] Strongly agree	
3	How did the expansion of the dam contribute to the estate in terms of:-	
	3.1 Establishment of trees and flower nurseries? <b>1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]</b>	i, ii
	3.2 Increase in the number of trees and flowers planted?	ii

	1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	
	3.3 Better waste water management? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	ii
	3.4 Better solid waste management? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	ii
4	What is the mode of waste water disposal from your house?	ii
5	What is the mode of solid waste disposal from your house?	ii
6	List down any other effect that you associate with the expansion of the dam in the estate; ..... .....	ii
	<b>SECTION C</b>  For question 7 below, please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam on Miwani estate  KEY:[1] Strongly disagree, [2] Disagree, [3] Uncertain,[4] Agree [5] Strongly agree	
7	How did the expansion of the dam contribute to the residents of Miwani estate in terms of; -	
	7.1 Access to clean, safe and reliable water supply? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	iii
	7.2 Less occurrence of water borne diseases? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	iii
	7.3 Increase in population? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	iii
	7.4 Establishment of new institutions (Schools, clinics etc) that were not there before? 1[ ]          2 [ ]          3[ ]          4 [ ]          5 [ ]	iii
	7.5 Improvement of infrastructure (Roads, electricity etc)?	iii

	1[ ]	2 [ ]	3[ ]	4 [ ]	5 [ ]	
7.6 Springing up of informal settlements within the vicinity of the estate?	1[ ]	2 [ ]	3[ ]	4 [ ]	5 [ ]	iii
7.7 Establishment of kitchen gardens?	1[ ]	2 [ ]	3[ ]	4 [ ]	5 [ ]	i, iii
7.8 Increase in crimes in the estate as compared to before?	1[ ]	2 [ ]	3[ ]	4 [ ]	5 [ ]	iii

Appendix 3.2: Key Informant Interview Guide Questionnaire (Water Vendors)

Date.....

Name (optional).....

Gender.....

Phone number (optional).....

Year you started selling water in Miwaniestate.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Your main source of water (**River, borehole, water kiosk, roof catchment, piped water into household**)

Number of years that you have lived in Machakos town.....

S/No	For the following questions please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam  KEY: [1] Very bad, [2] Bad, [3] Neutral, [4] Good, [5] Very good	Specific objective addressed based on numbering on page 7
1	How was the water scenario in the estate before the expansion of the dam?  1[ ]                      2 [ ]                      3[ ]                      4 [ ]                      5 [ ]	iii
2	How is the water scenario in the estate after the expansion of the dam?  1[ ]                      2 [ ]                      3[ ]                      4 [ ]                      5 [ ]	iii
3	How did the expansion of the dam affect your water sales in terms of;-	
	3.1 The profit margins that you get?  1[ ]                      2 [ ]                      3[ ]                      4 [ ]                      5 [ ]	i
	3.2 Number of trips you make per day?  1[ ]                      2 [ ]                      3[ ]                      4 [ ]                      5 [ ]	i

	3.3The future prospects of the water business? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	3.4 Satisfying the customer requirements in terms of water adequacy? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
4	Besides selling water, what other economic activities are you engaged in? ..... .....	i



Appendix 3.3: Key Informant Interview Guide Questionnaire (Local Administration)

Date.....

Name (optional).....

Gender.....

Phone number (optional).....

Name of administration area.....

Year you started living in Machakos.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Number of years that you have lived in Machakos town.....

S/No	For the following questions please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam  KEY:  [1] Strongly disagree, [2] Disagree, [3] Uncertain, [4] Agree  [5] Strongly agree	Specific objective addressed based on numbering on page 7
1	Maruba dam was expanded/rehabilitated between 2008 and 2010. How did the expansion of the dam affect Miwani estate in terms of:-	
	1.1 Emergence of informal settlements within the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i, ii, iii
	1.2 Increase in population?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	ii, iii
	1.3 Rise in the level of crime which can be attributed to the expansion of the dam?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	iii

	1.4 New settlements in the outskirts of the estate which had no people before the expansion of the dam?  1 [ ]            2 [ ]            3 [ ]            4 [ ]            5 [ ]	i, ii, iii
	1.5 Increase in the number of trees and flowers planted?	ii
	1.6 Improvement of infrastructure e.g. roads, power connectivity, schools, health facilities etc?	iii
2	Which are the notable developments that are as a result of the expansion of the dam, in your area of administration? ..... .....	i, ii, iii
3	Which are the negative impacts that can be attributed to expansion of the dam, in your area of administration? ..... .....	ii, iii

Appendix 3.4: Focus Group Discussion Guide Questionnaire (Water Service Provider Staff)

Date.....

Name of officer (optional).....

Phone number (optional).....

Designation.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Number of years that you have lived in Machakos town.....

S/No	Question	Specific objective addressed based on numbering on page 7
1	What was the total number of active connections in Miwani estate before the expansion of Maruba dam (2010)?	i
2	What is the current number of active connections in Miwani estate?	i
3	What was the percentage of water coverage in Miwani estate before the expansion of the dam?	iii
4	What is the current percentage of water coverage in Miwani estate?	iii
5	How much water was supplied from the treatment works per day before the expansion of the dam?	i
6	How much water is supplied currently from the treatment works per day?	i
7	How much was the average revenue collected from water sales on monthly basis before expansion of the dam in Miwani estate (2010)?	i
8	How much is the average revenue collected from water sales on monthly basis currently from Miwani estate?	i
	For the following questions please tick the appropriate answer from the alternatives using a scale of [1] (Least) to	

	[5] (Best) as shown here under to rate the impacts of expansion of Maruba dam  KEY:[1] Very bad, [2] Bad, [3] Uncertain, [4] Good [5] Very good	
9	How was the water supply scenario in Miwani estate before the expansion of Maruba dam?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	iii
10	What is the current water scenario in Miwani estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	iii
11	How did the expansion of the dam affect the water company in relation to water supply in Miwani estate in terms of:-	
	11.1Expansion of the reticulation system in the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	11.2Reduction in levels of complaints from consumers who have no water in the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	iii
	11.3 Reduction in level of unaccounted for water in the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	11.4 Reduction in level of illegal connections in the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	i
	11.5 Waste water disposal in the estate?  1[ ]            2 [ ]            3[ ]            4 [ ]            5 [ ]	ii
12	List any other effect that the expansion of the dam had to the water company.  ..... ..... .....	

Appendix 3.5: Checklist of direct Observations

Date.....

Name of area or estate visited.....

(The following parameters will be noted as applicable)

S/No	Parameter observed	Specific objective addressed based on numbering on page 7
1	Whether the area is served with water.	iii
2	Mode of solid waste disposal	ii, iii
3	Mode of wastewater disposal	ii, iii
4	Whether there are improperly disposed hazardous wastes in the estate(Car batteries, oils agricultural chemicals, clinical wastes etc)	ii
5	Drainage system and whether there are open pools of wastewater	ii
6	Pipe bursts	iii
7	New settlements	i, iii
8	New investments e.g. Hotels, Supermarkets etc	i
9	New industries	i
10	Recreational facilities that are as a result of the expansion of the dam	i, iii
11	Whether farming is done along the riparian land	ii
12	Measures taken to control siltation of the reservoir e.g. silt traps	ii
13	Whether there are some signs of trees and vegetation that were submerged as a result of rise in reservoir levels after expansion	ii
14	Any irrigation taking place using water from the dam	i, ii
15	Whether there is solid waste (polythene papers, sludge, plastic containers etc) floating in the reservoir	ii

16	Whether there are effluents being discharged on the upstream of the reservoir	ii
17	Whether there are tree nurseries that thrive by use of water from Maruba dam.	i, ii
18	Whether afforestation and re-afforestation is being practiced	ii

Appendix 4.1: Summary of Semi-Structured Household Survey Questionnaire Responses

<b>SECTION A</b>					
<b>1.How expansion of Maruba dam contributed to Miwani estate in terms of;</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Uncertain</b>	<b>Agree</b>	<b>Strongly agree</b>
1.1.Improvement in water supply	0	0	0	27	358
1.2.Rejuvenation of existing businesses	0	0	7	135	243
1.3.Springing up of new business ventures	0	0	3	162	220
1.4.Opening up of employment opportunities	0	0	19	258	108
1.5.Rapid mushrooming of new buildings	0	0	0	174	211
1.6.Establishment of new institutions	0	0	3	231	151
1.7.Establishment of recreation facilities	0	0	0	169	216
1.8.Appreciation of land value	0	0	0	58	327
2. Services that started being paid for after expansion of the dam that were not being paid for before;	58 respondents cited security services, 109 cited garbage collection services				
<b>SECTION B</b>					
<b>3. How expansion of Maruba dam contributed to Miwani estate in terms of;</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Uncertain</b>	<b>Agree</b>	<b>Strongly agree</b>
3.1. Establishment of trees and flower nurseries	0	0	15	274	96
3.2. Increase in the number of trees and flowers planted	0	3	23	301	58
3.3. Better wastewater management	73	270	23	15	4
3.4. Better solid waste management	85	200	42	27	31
4. Mode of wastewater disposal	342 cited septic tanks, 39 cited pit latrines, 4 cited holding tanks				
5. Mode of solid waste disposal	287 cited County Government collection points, 98 cited open spaces				
6.Other effects associated with expansion of the dam	200 respondents cited change in land use, 150 respondents cited cutting of indigenous trees while 50 cited closure of some businesses				
<b>SECTION C</b>					
<b>7. How expansion of Maruba dam contributed to residents of Miwani estate in terms of;</b>	<b>Strongly disagree</b>	<b>Disagree</b>	<b>Uncertain</b>	<b>Agree</b>	<b>Strongly agree</b>
7.1. Access to clean, safe and reliable water	0	0	0	31	354

7.2. Less occurrence of water borne diseases	0	0	31	158	196
7.3. Increase in population	0	0	4	50	331
7.4. Establishment of new institutions	0	0	4	231	151
7.5. Improvement of infrastructure	0	8	8	223	146
7.6. Springing up of informal settlements	12	42	73	247	11
7.7. Establishment of kitchen gardens	0	23	81	254	27
7.8. Increase in crimes in the estate as compared to before	0	23	150	189	23



Appendix 4.2: Analysis of Economic Benefits Data

<b>Economic Benefits</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Improvement in Water Supply	0	0	0	7	93
Rejuvenation of Businesses	0	0	2	35	63
New Businesses	0	0	1	42	57
Opening up of Employment Opportunities	0	0	5	67	28
Mushrooming of New Buildings	0	0	0	45	55
Establishment of New Institutions	0	0	1	60	39
Land Appreciation	0	0	0	15	85
Establishment of Kitchen Gardens	0	6	21	66	7

Appendix 4.3: Summary of the responses of Key Informant Interview Guide Questionnaire (Water Vendors)

S/No	Area of concern	Very bad	Bad	Neutral	Good	Very good
1	How was the water scenario in Miwani estate before the expansion of Maruba dam?	1	1	0	0	0
2	How is the water scenario in Miwani after the expansion of the dam?	0	0	0	2	0
3	How did the expansion of the dam affect your water sales in terms of;					
	3.1. The profit margins that you get	0	0	0	1	1
	3.2. Number of trips you make per day	0	0	0	1	1
	3.3. The future prospects of the business	0	0	0	2	0
	3.4. Satisfying the customer requirement in terms of water adequacy	0	0	0	2	0
4	Besides selling water, what other economic activities are you engaged in? Nil for both					

Appendix 4.4: Focus Group Discussion Guide Questionnaire (Water Service Provider Staff)

Date.....9/1/2020.....

Name of officer (optional).....Joseph Mutende.....

Phone number (optional).....

Designation.....Technical Manager.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Number of years that you have lived in Machakos town.....4 years.....

S/No	Question	Specific objective addressed based on numbering on page 7
1	What was the total number of active connections in Miwani estate before the expansion of Maruba dam (2010)?  -80 connections	i
2	What is the current number of active connections in Miwani estate?  -359 connections	i
3	What was the percentage of water coverage in Miwani estate before the expansion of the dam?  -20%	iii
4	What is the current percentage of water coverage in Miwani estate?  -70%	iii
5	How much water was supplied from the treatment works per day before the expansion of the dam?  -120m <sup>3</sup> /day	i
6	How much water is supplied currently from the treatment works per day?  -958m <sup>3</sup> /day	i

7	How much was the average revenue collected from water sales on monthly basis before expansion of the dam in Miwani estate (2010)?  -KES 101,231.00	i
8	How much is the average revenue collected from water sales on monthly basis currently from Miwani estate?  -KES 859,393.00	i
	For the following questions please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam  KEY:[1] Very bad, [2] Bad, [3] Uncertain, [4] Good [5] Very good	
9	How was the water supply scenario in Miwani estate before the expansion of Maruba dam?  1[ <input checked="" type="checkbox"/> ]                      2 [ ]                      3[ ]                      4 [ ] 5 [ ]	iii
10	What is the current water scenario in Miwani estate?  1[ ]                      2 [ ]                      3[ ]                      4 [ <input checked="" type="checkbox"/> ] 5 [ ]	iii
11	How did the expansion of the dam affect the water company in relation to water supply in Miwani estate in terms of; -	
	11.1Expansion of the reticulation system in the estate?  1[ ]                      2 [ ]                      3[ ]                      4 [ <input checked="" type="checkbox"/> ] 5 [ ]	i
	11.2Reduction in levels of complaints from consumers who have no water in the estate?  1[ ]                      2 [ ]                      3[ ]                      4 [ <input checked="" type="checkbox"/> ] 5 [ ]	iii
	11.3 Reduction in level of unaccounted for water in the estate?  1[ ]                      2 [ ]                      3[ <input checked="" type="checkbox"/> ]                      4 [ ] 5 [ ]	i

	<p>11.4 Reduction in level of illegal connections in the estate?</p> <p>1 [ ]            2 [ ]            3 [ ]            4 [✓] 5 [ ]</p>	i
	<p>11.5 Waste water disposal in the estate?</p> <p>1 [✓]            2 [ ]            3 [ ]            4 [ ] 5 [ ]</p>	ii
12	<p>List any other effect that the expansion of the dam had to the water company.</p> <p>-Expanded water coverage -10 additional staff were employed</p>	

Appendix 4.5: Analysis of Economic Costs Data

<b>Economic Costs</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Businesses Closed	0	0	87	13	0
Engage Security Guards	0	0	85	15	0
Engage Garbage Collectors	0	0	72	28	0

Appendix 4.6: Analysis of Environmental Benefits Data

<b>Environmental Benefits</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Establishment of Trees and Flower Nurseries	0	0	4	71	25
Planted Trees and Flowers	0	1	6	78	15

Appendix 4.7: Analysis of Environmental Costs Data

<b>Environmental Costs</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Better Wastewater Management	19	70	6	4	1
Better Solid Waste Management	22	52	11	7	8

Appendix 4.8: Mode of Wastewater Disposal Data

<b>Mode of Wastewater Disposal</b>	<b>Septic tank</b>	<b>Pit latrine</b>	<b>Holding tank</b>
Percentage (%)	89	10	1

Appendix 4:9: Analysis of Social Benefits Data

<b>Social Benefits</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Establishment of Recreation Facilities	0	0	0	44	56
Access to Clean Safe and Reliable Water	0	0	0	8	92
Less Occurrence of Water Borne Diseases	0	0	8	51	41
Increase in Population	0	0	1	13	86
Improvement in Infrastructure	0	2	2	58	38

Appendix 4.10: Analysis of Social Costs Data

<b>Social Costs</b>	<b>Strongly disagree (%)</b>	<b>Disagree (%)</b>	<b>Uncertain (%)</b>	<b>Agree (%)</b>	<b>Strongly agree (%)</b>
Springing up of Informal Settlements	3	1	19	64	3
Increase in Crimes	0	6	39	49	6

Appendix 4.11: Key Informant Interview Guide Questionnaire (Local Administration)

Date.....9/1/2020.....

Name (optional).....

Gender.....Male.....

Phone number (optional).....

Name of administration area...Miwani.....

Year you started living in Machakos.....1970.....

Age in years (**Below 20, 20-25, 25-29, 30-34, 35-39, 40-44, 45-49, 50 and above**)

Highest level of education (**Never went to school, adult literacy class, primary, secondary, post-secondary**)

Number of years that you have lived in Machakos town...50.....

S/No	For the following questions please tick the appropriate answer from the alternatives using a scale of [1] (Least) to [5] (Best) as shown here under to rate the impacts of expansion of Maruba dam  KEY:  [1] Strongly disagree, [2] Disagree, [3] Uncertain, [4] Agree  [5] Strongly agree	Specific objective addressed based on numbering on page 7
1	Maruba dam was expanded/rehabilitated between 2008 and 2010. How did the expansion of the dam affect Miwani estate in terms of; -	
	1.1 Emergence of informal settlements within the estate?  1[ ]            2 [ ]            3 [ ]            4 [√]            5 [ ]	i, ii, iii
	1.2 Increase in population?  1[ ]            2 [ ]            3 [ ]            4 [ ]            5 [√]	ii, iii
	1.3 Rise in the level of crime which can be attributed to the expansion of the dam?  1[ ]            2 [ ]            3 [ ]            4 [√]            5 [ ]	iii



	1.4 New settlements in the outskirts of the estate which had no people before the expansion of the dam? 1[ ]            2 [ ]            3[ ]            4 [ ]            5 [✓]	i, ii, iii
	1.5 Increase in the number of trees and flowers planted? Yes	ii
	1.6 Improvement of infrastructure e.g. roads, power connectivity, schools, health facilities etc? Yes	iii
2	Which are the notable developments that are as a result of the expansion of the dam, in your area of administration? -Infrastructure and real estate development	i, ii, iii
3	Which are the negative impacts that can be attributed to expansion of the dam, in your area of administration? -Increase in petty crimes due to increase in population	ii, iii

Appendix 4.12: List of direct Observations

Date.....6/9/2019.....

Name of area or estate visited...Miwani estate.....

S/No	Parameter observed	Specific objective addressed based on numbering on page 7
1	Whether the area is served with water. Yes, the area is served with water.	iii
2	Mode of solid waste disposal. -Portable dust bins	ii, iii
3	Mode of wastewater disposal. -Septic tanks, pit latrines, holding tanks.	ii, iii
4	Whether there are improperly disposed hazardous wastes in the estate. -Yes; Petroleum products, waste water from households and car washes.	ii
5	Drainage system and whether there are open pools of wastewater  -Area does not have manmade drainage. Effluents from households and pools of water from car washes were observed.	ii
6	Pipe bursts. -None was observed	iii
7	New settlements. -New buildings were observed	i, iii
8	New investments. -Car washes, tree nurseries, funeral home, garages and hotels were cited.	i
9	New industries. -None was cited	i
10	Recreational facilities that are as a result of the expansion of the dam. -Machakos People's Park and middle income level hotels with recreation facilities.	i, iii
11	Whether farming is done along the riparian land. -No farming is done.	ii
12	Measures taken to control siltation of the reservoir e.g. silt traps.	ii

	-None	
13	Whether there are some signs of trees and vegetation that were submerged as a result of rise in reservoir levels after expansion. -Yes	ii
14	Any irrigation taking place using water from the dam. Yes; Bananas and kitchen gardens in some residential plots.	i, ii
15	Whether there is solid waste (polythene papers, sludge, plastic containers etc) floating in the reservoir. -None	
16	Whether there are effluents being discharged on the upstream of the reservoir. -Yes	ii
17	Whether there are tree nurseries that thrive by use of water from Maruba dam. -None	i, ii
18	Whether afforestation and re-afforestation is being practiced. -Yes	ii
NB	Observation number 15 prompted the researcher to make further enquiries from MOWASCO staff. They reported that besides the floating debris, there is a green layer that forms on the water surface in the reservoir towards the end of dry seasons.	Ii

Appendix 4.13: Overall Analysis of Impacts

Impact	Specific impact	Arrow from and to	Respondents		Weight	Sub-Total	Total (Benefits+Costs)
			Number	%			
Economic	Economic benefits	Population increase to new buildings	385	100	1	7.64	7.08
		Population increase to new institutions	382	99	0.99		
		Population increase to new businesses	382	99	0.99		
		Population increase to rejuvenation of businesses	378	98	0.98		
		Population increase to employment opportunities	366	95	0.95		
		Infrastructure improvement to new businesses	385	100	1		
		Population increase to land cost appreciation	385	100	1		
		Clean water to kitchen gardens	281	73	0.73		
	Economic costs	Improvement of water supply to businesses closed	50	13	-0.13	-0.56	
		Rejuvenation of businesses to hiring of security guards	16	4	-0.04		
		New businesses to hiring of security guards	15	4	-0.04		
		New buildings to hiring of security guards	11	3	-0.03		
		New institutions to hiring of security guards	16	4	-0.04		
		Rejuvenation of businesses to engaging garbage collector	40	10	-0.1		
		New businesses to engaging garbage collector	40	10	-0.1		
Environmental	Environmental benefits	Improvement of water supply to establishment of trees and flower nurseries	116	30	0.3	1.89	
		Rejuvenation of businesses to establishment of trees and flower nurseries	77	20	0.2		

		New businesses to establishment of trees and flower nurseries	77	20	0.2		
		New buildings to establishment of trees and flower nurseries	50	13	0.13		
		Recreation facilities to establishment of trees and flower nurseries	50	13	0.13		
		Improvement in water supply to planted trees and flowers	192	50	0.5		
		New institutions to planted trees and flowers	78	20	0,2		
		Recreation facilities to planted trees and flowers	89	23	0.23		
	Environmental costs	Rejuvenation of businesses to poor solid management	77	20	-0.2	-1.63	
		New businesses to poor solid waste management	77	20	-0.2		
		New institutions to poor solid waste management	54	14	-0.14		
		Employment opportunities to poor solid waste management	39	10	-0.1		
		New buildings to poor solid waste management	77	20	-0.2		
		Kitchen gardens to poor solid waste management	19	5	-0.05		
		Rejuvenation of businesses to poor wastewater management	77	20	-0.2		
		New businesses to poor wastewater management	77	20	-0.2		
		New buildings to poor wastewater management	77	20	-0.2		
		New institutions to poor wastewater waste management	54	14	-0.14		
Social	Social benefits	Rejuvenation of businesses to recreation facilities	154	40	0.4	4.87	3.65
		New businesses to recreation facilities	154	40	0.4		
		Employment opportunities to recreation facilities	77	20	0.2		

		Improved water supply to clean water	385	100	1		
		Improved water supply to reduction in water borne diseases	354	92	0.92		
		New buildings to infrastructure development	369	96	0.96		
		Employment opportunities to population increase	381	99	0.99		
	Social costs	Clean water to springing up of informal settlements	39	10	-0.1	-1.22	
		Population increase to springing up of informal settlements	154	40	-0.4		
		Land appreciation to springing up of informal settlements	65	17	-0.17		
		Recreation facilities to insecurity and moral decay	58	15	-0.15		
		Population increase to insecurity and moral decay	58	15	-0.15		
		Rejuvenation of businesses to insecurity and moral decay	38	10	-0.1		
		New businesses to insecurity and moral decay	58	15	-0.15		

Appendix 4.14: Analysis of the Status of Implementation of Environmental Management Plan

<b>Parameter</b>	<b>Responsible for Intervention/ Monitoring</b>	<b>Method/Activity needed</b>	<b>Frequency</b>	<b>Findings</b>
Dam siltation	NWCPC	-Sediment load survey  -Construction of silt traps	-Twice per year  -Once	Has never been executed
Sludge from the treatment works	NWCPC/NEMA	Provide sludge drying beds and replant with suitable weed	Once	Not done
Risk of eutrophication/ growth of invasive species	Tanathi WSB/NEMA	Ecological surveys	Twice a year	Has never been executed
River flow obstruction during river filling which may affect the upstream estates e.g Miwani	Tanathi WSB/WRA	Provide suitable flow release mechanism	During operation	Not usually done
Changes in downstream ecology	NEMA	Ecological surveys	Yearly	Has never been executed
Creation of favourable habitats for disease vectors	Public health department/NE MA	Epidemiological surveys	Twice a year	Has never been executed
Enhanced erosion and changes in topography due to excavation	Tanathi WSB/NEMA	Backfill borrow pit areas and plant vegetation	Yearly	Was not executed
Risk of accidental drowning	Tanathi WSB	Fencing and appropriate dam management	Continuous	Dam fence was vandalized

Appendix 4.15: Analysis of the Physical-Chemical quality of Raw Water


Parameter	Unit	Date Sampled 8/1/19	Date Sampled 12/11/19	Date Sampled 9/1/20	KEBS Standard	WHO Standards
PH	Ph Scale	6.65	7.1	7.0	5.5-9.5	6.5-8.5
Colour	mgPt/l	1500	1300	1250	Max 50	Max 15
Turbidity	N.T. U	1001	813	715	Max 25	Max 5
Conductivity (25° C)	µs/cm	126.9	110	117	Max 2500	Max1500
Iron	mg/l	5.0	5.7	6.1	Max 0.3	Max 0.3
Manganese	mg/l	0.14	<0.01	<0.01	Max 0.5	Max 0.1
Calcium	mg/l	19.2	15	12	Max150	Max 100
Magnesium	mg/l	0.02	3.4	6.3	Max100	Max 100
Sodium	mg/l	2	3	5	Max200	Max 200
Potassium	mg/l	8.6	6.0	5.7	Max 50	Max 50
Total Hardness	mgCaC O <sub>3</sub> /l	48	49	56	Max600	Max 300
Total Alkalinity	mgCaC O <sub>3</sub> /l	44	39	36	Max500	Max 500
Chloride	mg/l	10	13	15	Max250	Max 250
Fluoride	mg/l	0.58	0.52	0.5	Max 1.5	Max 1.5
Nitrate	mgN/l	<0.01	<0.01	<0.01	Max 45	Max 10
Nitrite	mgN/l	<0.01		0.01	Max0.9	Max 0.1
Sulphate	mg/l	Nil	Not Detectable	Not Detectable	Max 400	Max 400
Free Carbon Dioxide	mg/l	126	66	34	-	-
Total Dissolved Solids	mg/l	78.68	75	73	Max1500	Max1000
Arsenic	µg/l	-	-	-	Max 10	Max 10
Others		-	-	-		



Appendix 4.16: Analysis of the Physical-Chemical quality of Tap Water

Parameter	Unit	Date Sampled 13/9/18	Date Sampled 12/11/19	Date Sampled 9/1/20	KEBS Standard	WHO Standards
PH	pH Scale	6.72	6.1	6.0	5.5-9.5	6.5-8.5
Colour	mgPt/l	5	33	38	Max 50	Max 15
Turbidity	N.T.U	17.4	19.1	18	Max 25	Max 5
Conductivity (25 ° C)	µs/cm	294	265	172	Max 2500	Max 1500
Iron	mg/l	0.23	0.4	0.6	Max 0.3	Max 0.3
Manganese	mg/l	0.08	0.35	0.2	Max 0.5	Max 0.1
Calcium	mg/l	19.2	16	12	Max150	Max 100
Magnesium	mg/l	4.37	3.32	3.9	Max100	Max 100
Sodium	mg/l	35	40	20	Max200	Max 200
Potassium	mg/l	3.6	3.9	4.2	Max 50	Max 50
Total Hardness	mgCaCO <sub>3</sub> /l	68	48	46	Max600	Max 300
Total Alkalinity	mgCaCO <sub>3</sub> /l	42	31	26	Max 500	Max 500
Chloride	mg/l	30	20	10	Max250	Max 250
Fluoride	mg/l	0.7	0.5	0.4	Max 1.5	Max 1.5
Nitrate	mgN/l	0.37	1.1	1.4	Max 45	Max 10
Nitrite	mgN/l	<0.01	<0.01	<0.01	Max 0.9	Max 0.1
Sulphate	mg/l	57	33	38	Max 400	Max 450
Free Carbon Dioxide	mg/l	2	8	10	-	-
Total Dissolved Solids	mg/l	182.28	111	107	Max1500	Max1000
Arsenic	µg/l	-	-	-	Max 10	Max 10
Others		-	-	-		

Appendix 4.17: Sample Physical-Chemical Analysis of Tap Water



### WATER RESOURCES AUTHORITY

TITLE: Water Sample Analytical Certificate - Physical Chemical Results	REF. NO : F/9/1/3
DEPARTMENT: Technical	ISSUE NO : 04
ISSUED BY: DTCM	REV. NO : 03
AUTHORISED BY : TCM	Page : 1 of 2

Serial No: .....

Name of Customer: MACHAKOS WATER AND SEWERAGE COMPANY

Purpose of Sampling: DOMESTIC

Date Sampled: 13/09/2018

Source: MARUBA DAM TREATED WATER

Sample No: 0581

Address: .....

County: MACHAKOS

Date Received: 13/09/2018

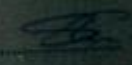
Date Compiled: 28/09/2018

PARAMETERS	UNIT	RESULTS	WHO STANDARDS	KEBS(KS 459-1:2007) STANDARDS
pH	pH Scale	6.72	6.5-8.5	6.5-8.5
Colour	mgPt/l	5	Max 15	Max 15
Turbidity	N.T.U	17.4	Max 5	Max 5
Conductivity (25° C)	µS/cm	294	Max 2500	-
Iron	mg/l	0.23	Max 0.3	Max 0.3
Manganese	mg/l	0.08	Max 0.1	Max 0.5
Calcium	mg/l	19.2	Max 100	Max 150
Magnesium	mg/l	4.37	Max 100	Max 100
Sodium	mg/l	35	Max 200	Max 200
Potassium	mg/l	3.6	Max 50	-
Total Hardness	mgCaCO <sub>3</sub> /l	68	Max 500	Max 300
Total Alkalinity	mgCaCO <sub>3</sub> /l	42	Max 500	-
Chloride	mg/l	30	Max 250	Max 250
Fluoride	mg/l	0.70	Max 1.5	Max 1.5
Nitrate	mgN/l	0.37	Max 10	-
Nitrite	mgN/l	<0.01	Max 0.1	Max 0.003
Sulphate	mg/l	57.0	Max 450	Max 400
Free Carbon Dioxide	mg/l	2	-	-
Total Dissolved Solids	mg/l	182.28	Max 1500	Max 1000
Arsenic	µg/l	-	Max 10	Max 10
Others		-		

Name of Analyst: CELLINE OBUYA

Signature: 



FORME/9/1/3

## WATER RESOURCES AUTHORITY

NHIF building, 9<sup>th</sup> floor, Wing B  
 P.O. Box 49250-00100, Ngong Road, Nairobi  
 Tel: +254-020-2732291/2729018/9  
 Email: [info@wra.go.ke](mailto:info@wra.go.ke)  
 Website: [www.wra.go.ke](http://www.wra.go.ke)

Central Water Testing Laboratories  
 P.O. Box 47201, 00100, Off Dunga Road, Nairobi  
 Tel: +254 273803729  
 Email: [cw@wra.go.ke](mailto:cw@wra.go.ke), [centralwatertestinglabs@gmail.com](mailto:centralwatertestinglabs@gmail.com)

### Physical-Chemical Laboratory Results Certificate

<b>Report Issue Date:</b>	23-01-2020	<b>Sample No:</b> 2659	<b>Year:</b> 2020
<b>Name of Customer:</b>	Joseph Kariuki	<b>Date Received:</b>	14-01-2020
<b>Email Address:</b>	-	<b>Type of Sample:</b>	Treated
<b>Telephone Number:</b>	0725920842	<b>Date of Sampling:</b>	09-01-2020
<b>Sample submitted by:</b>	Joseph	<b>Source of sample:</b>	Maruba Dam Treated before pumping
<b>Purpose of sampling:</b>	Domestic	<b>Received by:</b>	Nicky Sitati
<b>County:</b>	Machakos		

PARAMETERS	UNIT	ANALYTICAL METHOD	RESULTS	KS EAS 12-2018 STANDARDS (MAX.)
pH	pH Scale	APHA 4500-H <sup>+</sup> B	6.1	5.5-9.5 (6.5-8.5)*
Colour	mgPt L <sup>-1</sup>	APHA 2170 B	38	50(25)*
Turbidity	NTU	APHA 2130 B	16	25 (5)*
Conductivity (25 °C)	µS cm <sup>-1</sup>	APHA 2510B	179	2500 (1500)*
Iron	mg L <sup>-1</sup>	APHA 3500-Fe B	0.5	0.3
Manganese	mg L <sup>-1</sup>	APHA 3500-Mn D	0.3	0.1
Calcium	mg L <sup>-1</sup>	A <sup>2</sup> PHA 3500-Ca B	16	150
Magnesium	mg L <sup>-1</sup>	A <sup>2</sup> PHA 3500-Mg B	1.0	100
Sodium	mg L <sup>-1</sup>	A <sup>2</sup> PHA 3500-Na B	19	200
Potassium	mg L <sup>-1</sup>	A <sup>2</sup> PHA 3500-K B	3.9	50
Total Hardness	mgCaCO <sub>3</sub> L <sup>-1</sup>	A <sup>2</sup> PHA 2340 C	44	600 (300)*
Total Alkalinity	mgCaCO <sub>3</sub> L <sup>-1</sup>	A <sup>2</sup> PHA 2320 B	10	500**
Chloride	mg L <sup>-1</sup>	APHA 4500-Cl <sup>-</sup> B	9	250
Fluoride	mg L <sup>-1</sup>	APHA 4500-F C	0.4	1.5
Nitrate	mgNO <sub>3</sub> <sup>-</sup> L <sup>-1</sup>	APHA 4500-NO <sub>3</sub> <sup>-</sup> D	1.1	45
Nitrite	mg NO <sub>2</sub> <sup>-</sup> -N L <sup>-1</sup>	APHA 4500-NO <sub>2</sub> <sup>-</sup> B	<0.01	0.9
Sulphate	mg L <sup>-1</sup>	APHA 4500-SO <sub>4</sub> <sup>2-</sup> E	36	400
Free Carbon Dioxide	mg L <sup>-1</sup>	APHA 4500-CO <sub>2</sub> C	8	-
Total Dissolved Solids	mg L <sup>-1</sup>	APHA 2510 A	111	1500 (1000)*

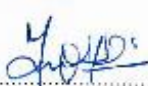
\*Maximum limit for treated potable water; \*\*MTC maximum guideline value; APHA: American Public Health Association (2005) - Standard methods for the examination of water & waste water; °C: water below method detection limit; ND: Not detectable

**Comments:**

The water is suitable for domestic use although Iron level is slightly above the threshold for domestic use.

  
 Rachel Oonga  
 Laboratory Analyst

**WATER RESOURCES AUTHORITY**  
 CENTRAL WATER TESTING LABORATORY  
 Tel: 0773 903 729  
 P.O. Box 49250 - 00100, NAIROBI  
[centralwatertestinglabs@gmail.com](mailto:centralwatertestinglabs@gmail.com)  
[cw@wra.go.ke](mailto:cw@wra.go.ke)

  
 Dr. Kenneth K'oreje  
 Assistant Technical Coordination Manager

Appendix 4.18: Sample Bacteriological results of Raw Water

WATER RESOURCES MANAGEMENT AUTHORITY	
TITLE: Water Sample Analytical Certificate - Bacteriological Results	REF. NO : F/9/1/6
DEPARTMENT: Technical	ISSUE NO : 01
ISSUED BY: DTCM	REV. NO : 00
AUTHORISED BY : TCM	DATE OF ISSUE: 15 <sup>th</sup> April 2013
	PAGE : 1 OF 2

SERIAL NO \_\_\_\_\_ Sample No. 2466

Name of Customer: MACHAKOS WATER AND SEWERAGE COMPANY Address: 547-90100

Purpose of sampling: DOMESTIC County: MACHAKOS

Date Sampled: 20/4/17 Date Received: 20/4/17

Source: MARUBA DAM UNTREATED WATER Date Compiled: 26/4/17

Is it protected? YES

If so, how? FENCED  
*(Is it completely covered, or sides only?)*

Is there a pump? NO

If so, how long has it been in use? N/A

Has it been overhauled recently? N/A

EXACT SITE SAMPLE TAKEN FROM DIRECT FROM DAM  
*(i.e. tap in kitchen, through cistern or direct from the mains)*

IS IT A CHLORINATED SUPPLY? *(Indicate Residual Levels)* NO

POSSIBLE SOURCE OF CONTAMINATION: \_\_\_\_\_

EXAMINATION RESULTS


MPN of Coliforms organisms per 100 ml >2420

*E. Coli* per 100ml >2420

Legionella ssp per 100ml \_\_\_\_\_



Appendix 4.19: Sample Bacteriological Results of Tap Water

	TITLE: Water Sample Analytical Certificate - Bacteriological Results	REF. NO : F/9/1/6
	DEPARTMENT: Technical	ISSUE NO : 01
	ISSUED BY: DTCM	REV. NO : 00
	AUTHORISED BY : TCM	PAGE 1 OF 2

SERIAL NO \_\_\_\_\_ Sample No 0584

Name of Customer MACHAKOS WATER AND SEWERAGE COMPANY Address \_\_\_\_\_

Purpose of sampling DOMESTIC County MACHAKOS

Date Sampled: 13/09/2018 Date Received: 13/09/2018

Source: MAKUBA DAM (TREATED) Date Compiled 19/09/2018

Protected? YES

If so, how? TREATED AND PIPED  
*(Is it completely covered, or sides only?)*

Is there a pump? YES

If so, how long has it been in use? FIVE YEARS

Has it been overhauled recently? NO

EXACT SITE SAMPLE TAKEN FROM TAP  
*(i.e. tap in kitchen, through cistern or direct from the mains)*

IS IT A CHLORINATED SUPPLY? (Indicate Residual Levels) YES NIL

POSSIBLE SOURCE OF CONTAMINATION: N/A

EXAMINATION RESULTS

MPN of Coliforms organisms per 100 ml 4

*E. Coli* per 100ml NIL

Legionella spp per 100ml \_\_\_\_\_

Micro-organisms \_\_\_\_\_

Appendix 4.20: Primary Data for Physical-Chemical Analysis of Tap Water

Parameter	Unit	Date Sampled 13/2/19	Date Sampled 21/11/19	Date Sampled 9/1/20	KEBS Standard	WHO Standards
PH	pH Scale	6.60	7.1	6.0	5.5-9.5	6.5-8.5
Colour	mgPt/l	55	1300	38	Max 50	Max 15
Turbidity	N.T. U	21	813	18	Max 25	Max 5
Conductivity (25° C)	µs/cm	110	112	172	Max 2500	Max 1500
Iron	mg/l	4.0	0.7	0.6	Max 0.3	Max 0.3
Manganese	mg/l	0.14	<0.01	0.2	Max 0.1	Max 0.1
Calcium	mg/l	16.2	15	12	Max 150	Max 100
Magnesium	mg/l	0.02	3.5	3.9	Max 100	Max 100
Sodium	mg/l	2	150	20	Max 200	Max 200
Potassium	mg/l	8.0	6.0	4.2	Max 50	Max 50
Total Hardness	mgCaC O <sub>3</sub> /l	47	49	46	Max 600	Max 300
Total Alkalinity	mgCaC O <sub>3</sub> /l	33	39	26	Max 500	Max 500
Chloride	mg/l	10	13	10	Max 250	Max 250
Fluoride	mg/l	0.48	0.52	0.4	Max 1.5	Max 1.5
Nitrate	mgN/l	<0.01	<0.01	1.4	Max 45	Max 10
Nitrite	mgN/l	<0.01	<0.01	<0.01	Max 0.9	Max 0.1
Sulphate	mg/l	Nil	Not Detectable	38	Max 400	Max 400
Free Carbon Dioxide	mg/l	60	66	10	-	-
Total Dissolved Solids	mg/l	90.78	120	107	Max1500	Max1000