CHALLENGES OF GROUNDWATER MANAGEMENT IN THE CITY OF NAIROBI

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DECLARATION

Declaration by the student

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DEDICATION

This work is dedicated to my loving husband, Simon Nyabwengi and my sons Gilbert Nyabwengi and Victor Nguyo Nyabwengi.

It is also dedicated to my hardworking parents, Boniface Nguyo Gatitu and Serah Njeri Nguyo.

ABSTRACT

Water is very important for urban development. As urban areas grow, the demand for a regular and reliable source of water supply becomes very important.

In Nairobi, the source of water supply has mainly been from rivers. The Nairobi Water and Sewerage Company has been responsible for water supply in the city. However, as the city has continued to grow both in population and the physical extent, demand for water has over stripped supply. This has resulted in water shortages. City residents have therefore resulted to alternative sources of water like groundwater.

Though groundwater is a renewable resource, there are risks to its exploitation. Unregulated exploitation of groundwater can result into overexploitation, contamination of the resource, land subsidence and overcharging. There is therefore need for groundwater management measures to be put in place to manage and regulate its exploitation and use.

The research examined trends in groundwater usage and the regulatory environment for ground water exploitation. Several study methodologies were used as outlined in the methodology section of this paper but in summary this included quantitative examination of data from boreholes drilled in Nairobi area from 1950 to 2000, literature review, interviews with key informants from the Ministry of Water and borehole owners and their agents.

The research found out that there has been increasingly reliance on ground water supply as evidenced by increase in the number of boreholes drilled in the Nairobi over the years sampled covered by the study. The predominant use of the drilled water was for domestic use.

The research also found out that the legal framework for management of groundwater resources has been set up as outlined in the Water Act of 2002, which created the Water Resource Management Authority, an autonomous body established to manage water resources in Kenya.

However, the research found that although there has been increasing use and exploitation of groundwater and although there is a regulatory mechanism in place, this regulatory mechanism is not robust enough to ensure safe and sustainable exploitation of this important resource and needs to be further strengthened and resourced.

TABLE OF CONTENTS

CHAPTER ONE - 1 -

1.1. Introduction - 1 -

1.2. Problem Statement - 4 -

1.3. The objectives of the study - 8 -

1.4. The Scope of the Study - 9 -

1.5. Research Methodology - 10 -
- 1.5.1. Review of literature - 10 -
- 1.5.2. Secondary data collection. - 11 -
- 1.5.3. Data analysis and presentation - 14 -
- 1.6. Justification for the Study - 15 -
- 1.7. Organization of the Study - 17 -

CHAPTER TWO - 19 -

LITERATURE REVIEW - 19 -
- 2.1. The Role of Water in Urban Development - 19 -
- 2. 2. Causes of Water Supply Problems in Urban Areas - 21 -
  - 2. 2.1. Rapid population growth - 21 -
  - 2. 2.2. Corruption - 23 -
  - 2. 2.3. Inadequate management - 24 -
  - 2. 2.4 Climate Change - 25 -
  - 2. 2.5. Limited financial resources - 26 -
  - 2. 2.6. Inadequate land tenure - 27 -
  - 2. 2.7. Water losses - 27 -
- 2. 3. Ground Water Resource - 28 -
  - 2.3.1. The hydrological cycle - 28 -
  - 2.3.2. Ground water quality - 29 -
  - 2.3.3 Contamination of groundwater - 30 -
  - 2. 3.4. Land subsidence - 34 -
  - 2.3.5. Over-exploitation - 35 -
  - 2. 3.6. Overcharging - 36 -
- 2. 4. Groundwater management - 37 -
  - 2.4.1 Planning - 38 -
  - 2.4.2 Public participation - 40 -
  - 2.4.3 Conjunctive use of surface and groundwater resource - 40 -
  - 2.4.4 Maintaining groundwater information system - 42 -
  - 2.4.5 Strengthening the institutions involved in groundwater management - 43 -

CHAPTER THREE - 51 -

THE LEGAL AND INSTITUTIONAL FRAMEWORK - 51 -
3.1. Legal Framework - 51 -
3.1.1. National Policy on Water Resource Management and Development. - 51 -
3.1.2. The Water Act 2002 - 53 -
3.1.3. Public Health Act Chapter 242 - 63 -
3.1.4. Environmental Management and Co-ordination Act - 64 -
3.2. Institutional framework - 71 -

CHAPTER FOUR - 73 -

4.1. INTRODUCTION - 73 -
4.2. Geography and Climate - 77 -
4.3. Population - 77 -
4.4. Land use - 79 -
4.5. Drainage basin - 83 -
4.6. Water supply - 84 -
4.7. Groundwater - 88 -
4.8. The River System - 93 -
5.1. Ground water management by MWI - 95 -
5.1.1. Strengthening of institutions - 95 -
5.1.2. Permits - 96 -
5.1.3. Licensing of borehole drilling contractors - 97 -
5.1.4. Groundwater monitoring - 99 -
5.1.5. Computerized data bank - 100 -
5.1.6. Land use planning - 100 -
5.1.7. Measures on groundwater conservation - 101 -
5.1.8. Groundwater abstraction charges - 101 -
5.1.9 Stake holders' participation - 102 -
5.1.10. Conjunctive water use - 103 -
5.1.11. Groundwater quality analysis - 103 -
5.1.12. Groundwater pollution control - 104 -
5.2. Groundwater use - 104 -
5.2.1 Trends in the number of boreholes drilled in Nairobi - 107 -
5.2.2. Average borehole water struck levels - 109 -
5.2.3. Borehole water quality - 111 -

5.3. Findings from borehole owners/ agents - 112 -

CHAPTER SIX - 115 -

6.1. Conclusions and Recommendations - 115 -

APPENDIX - 130 -

RESEARCH INSTRUMENTS - 130 -

List Of Tables ix

List Of Maps X

List Of Charts X

LIST OF TABLES

table 1: Urbanization In Africa. - 21 -

Table 2: Groundwater Quality Classification Based On Tds - 29 -

Table 3: Sources Of Ground Water Contamination - 32 -

Table 4: Who Guidelines For Minimum Concentration Of Chemical Substances In Drinking Water - 34 -

Table 5: Guidelines For Water Quality Of Domestic Water Sources - 56 -

Table 6: Fees For Assessment And Issuance Of Water Permits - 58 -

Table 7: The Roles And Responsibilities Of The Institutions Involved With Groundwater Management Under MWI - 71 -

Table 8: Nairobi: Population For Selected Years, 1906-1994 - 77 -

Table 9: Percentage Estimates Of The Country's Population Residing In Nairobi (With 750,000 Or More Inhabitants) From 1980-2015 With Five Year Interval. - 78 -

Table 10: Land Use Types Of Nairobi In 1994 - 79 -

Table 11: Drainage Basins In Kenya - 83 -

Table 12: Main Sources Of Drinking Water For Nairobi Residents- 1999. - 85 -

Table 13: Water Sources, Installed Capacity, And Normal Production For NCC - 86 -

Table 14: Nairobi Reservoir Capacity - 87 -

Table 15: Boreholes Drilled In Nairobi Area From 1997-2001 - 91 -

Table 16: Groundwater Use In Nairobi - 105 -

Table 17: Trend In The No. Of Boreholes Drilled In Nairobi - 107 -

Table 18: Average Water Struck Levels-1950-2000 - 109 -

Table 19: Borehole Fluoride Content In Nairobi (1940-2000) - 111 -

LIST OF MAPS

Map 1: Nairobi in the National Context..74

Map 2: Nairobi Administration map...75

Map 3: Nairobi Area...76

Map 4: Land Use in Nairobi..82

Map 5: Classification of Groundwater in Kenya..89

LIST OF CHARTS

Chart 1: Classification of conjunctive water use.. .45

Chart 2: The major uses of groundwater...106

Chart 3: Trends in the number of boreholes drilled in Nairobi-.......................108

Chart 4: Average borehole water struck levels...110

LIST OF ABREVIATIONS AND ACRONYMS

EMCA.............................. Environmental Management and Coordination Act

EIA....................................Environmental Impact Assessment

F.A.O.................................Food and Agricultural Organization

IEA....................................Institute of Economic Affairs

L.A....................................Local Authority

MLG..................................Ministry of Local Government

MWI..................................Ministry of Water and Irrigation

N.C.C................................Nairobi City Council

NCWSC.............................Nairobi City Water and Sewerage Company

NEMA.............................. National Environment Management Authority

G.O.K............................. Government of Kenya

SERC.............................. Standard and Enforcement Review Committee

WHO.................................World Health Organization

WRMA.............................. Water Resource Management Authority

U.N....................................United Nations

CHAPTER ONE

INTRODUCTION

1.1. Introduction

Water is a basic human need that man is entirely dependant on. It is important for life, development and environment (UNHCS-Habitat, 1990). Water is used in all productive activities of man which include domestic, commercial, industrial, agricultural, recreational, and transportation. It is therefore an important natural resource that supports urban development.

Access to water determined much of the early civilization of man. Early civilization developed and flourished on the banks of major rivers such as the Nile, Euphrates, Tigris and Indus due to the availability of water for drinking, farming and transportation (Biswas, 1998). The easy availability of water in these and other regions coupled with favourable climate led to the flourishing of human settlement. The availability of the two most essential elements for human survival, water and food, led to a more sedentary life style as opposed to a nomadic lifestyle for these populations and with settlement came the construction of permanent buildings and the development of art, culture and industry. An analysis of societies that industrialized early shows a very close relationship between the easy availability of water for both domestic use and industrial use and the emergence of industries.

In urban centers, surface water resources, including rivers and fresh water lakes, have been the main source of supply. There has been increase in the urban population due to natural population growth as well as inflows of population from the rural areas in order to benefit from the economic advantages in these urban areas. This population increase coupled with increased demand for water by industries and changes in climate lead to diminishing surface water supply and places great demand on surface water availability.

The city of Nairobi, which is the focus of this research, has experienced rapid growth since it was established as a railway camp in 1899 during the construction of the Kenya Uganda Railway. The area of Nairobi grew from 1,813 Hectares with a population of 11,512 in 1906 (Olima, 2001) to 68,945 hectares and a population of 2,143,245 in 1999 (R.O.K. 2001), and has experienced massive growth in industry and services, making it a service and industrial hub for Eastern and Central Africa.

According to Government of Kenya (2006), the Kenyan economy grew at 5.8% in year 2005. The major engines of this growth were industrialization, agriculture and service industries like tourism which are all heavy users of water. While Kenya has experienced rapid economic and population growth, all needing ever increasing volumes of clean, portable water, climate change leading to erratic rainfall and therefore inadequate recharge of surface water sources, has led to a situation where water demand is higher than supply. For example, in 2005, the short rains in Kenya were inadequate. This resulted in drought from October 2005 to early March, 2006.

There was massive water rationing by the NCWSC because the water levels of the dams that supply Nairobi with water had gone down.

Policy makers, city planners and urban residents in Nairobi have, as a result, recommended groundwater as an important source of urban water supply and a supplemental alternative to surface water sources. According to Foster and Tuinhof (2005) the use of groundwater in Nairobi will, in future, be critical in providing adequate water supply due to rapid urbanization. It will also act as a strategic reserve in times of drought.

In Nairobi, groundwater has been available, although it remains an underexploited resource. A report prepared in 1964 on the hydrogeology of Nairobi Area (Gevaerts, 1964) reported that there was adequate ground water that was also of good quality. The report also indicated that there were no signs of groundwater depletion except in the Ruaraka area and recommended further development of the resource. This study precedes on the premise that NCWSC which is the local Authority under whose jurisdiction Nairobi falls, has not exploited ground water resource as a source of urban water supply even with this recommendation.

The exploitation of the water resources in Nairobi has mainly been by private entities such as individual consumers, private companies and institutions. Groundwater is extracted through shallow wells, where the water table is high or boreholes, where the water table is low and high amount of water is required. The number of machinedrilled boreholes in Nairobi has been on the rise, from about 10 in 1940 to 2,250 in 2001 (Foster and Tuinhof, 2005).

Although there has been increasing exploitation of groundwater resources, the regulatory and managerial mechanisms have not kept pace. This study therefore examines the management of groundwater in Nairobi by looking at the regulatory and managerial measures adopted by the Ministry of Water and Irrigation and assesses the adequacy of these measures.

1.2. Problem Statement

It is widely recognized that with growing populations and industrialization, cities in developing countries like Nairobi are going to need more water supply and are faced with the challenge of extending service coverage (W.H.O, 2000).

The traditional surface water sources for the city of Nairobi have over the years been affected by changes in climate, due to prolonged droughts, which reduce the capacity of surface water sources and contribute to the unreliability of water supply.

Destruction of forests and vegetation in the catchments areas of Mount Kenya and Aberdare Ranges have also contributed to the depletion of this water source. As a result, the city of Nairobi and its environs have been experiencing acute water shortage at a time when the population has been growing.

Nairobi City Council (2001) gives the installed production capacity of the water sources of Nairobi as 560,000m³ per day. This was estimated to be adequate to meet the water demand for Nairobi up to the year 2007. However, the installed water production capacity differs from the actual production capacity, which is given as 396,000m³ per day. There is therefore a deficit in production of 164,000m³ per day which has to be met by the consumers from other alternative sources of water supply including groundwater.

Due to this deficit, Council water supply is unreliable and during periods of drought, water rationing is done. Heavy users of water like industries, hotels and high-rise office buildings have therefore resorted to drilling their own boreholes to supplement the council's unreliable water supply. With increasing industrialization and urbanization, it is expected that the number of private boreholes being drilled will increase to cope with the increasing demand.

However, groundwater, though renewable, is not a finite resource. Anton (1993) notes that groundwater level falls when the rate of extraction from an aquifer, together with its surface discharge exceeds its rate of recharge and groundwater inflow into an aquifer. A situation can therefore arise where there is increased abstraction but reduced recharge, thereby leading to rapid depletion of the water sources. FAO (2003), notes that the use of mechanized boreholes has encouraged rapid depletion of the deeper renewable groundwater resource. World Bank (2004) and UNCHS-Habitat (1990), note that over-exploitation of groundwater results in the subsequent lowering of the water table. This results in salinization of groundwater, which lowers its quality.

The increasing use of groundwater for domestic, industrial and commercial consumptions happens in an environment that poses significant pollution risk to groundwater supplies. The Nairobi City Council, (1996) notes that there is discharge of untreated or minimally treated effluents into the watercourses of Nairobi and Ngong Rivers. The development of informal settlements such as Kibera, Mathare, Mukuru and Kibarage slums along river valleys and next to water sources has also contributed to the pollution of both surface and underground water sources (NCC, 1996).

Additional contaminants of groundwater include fertilizers and pesticide (Troeh et al, 1980 and waste disposal in landfills (Kehew, 1988)

Groundwater quality has major implications on health. UNCHS-Habitat (1990) notes that over 80% of all diseases and over a third of deaths in the developing countries are caused through ingestion of contaminated water. It further notes that one tenth of each person's productive time is sacrificed to water related diseases. It is therefore important to avoid groundwater contamination in order to safe guard the health of the urban population.

Although the number of private boreholes is increasing, there does not seem to be an adequate regulatory mechanism to monitor the water abstraction from these private boreholes and to ensure the quality of the water for human consumption

The legal and regulatory mechanism that would ensure the sustainable exploitation of ground water and its continued safety for human consumption have not kept pace the rate of exploitation and usage.

Kenya does not, however, lack a regulatory framework that would ensure the sustainable use and quality and safety of groundwater. Water Act 2002 was enacted in order to address the issue of water resource management while the

National Environment Management Authority (NEMA) is a regulatory mechanism that seeks to ensure that mitigation measures are put in place to reduce environmental degradation as a result of industrial or developmental activities.

The concern that this paper seeks to address is whether the legal and regulatory mechanisms that are already in place have been adequate in addressing the challenges of sustainable groundwater management in the context of growing use of this important resource

1.3. The objectives of the study

Main Objective

- Examine the challenges of groundwater use and evaluate the groundwater management measures adapted by MWI in Nairobi.

Sub-objectives

1. Examine the trends and challenges posed by groundwater use in the city of Nairobi
2. Examine past and current practices in groundwater exploitation and management in Nairobi
3. Examine the legal and institutional frameworks and their adequacy in governing groundwater management in Nairobi
4. Suggest recommendations on ways of improving groundwater management in Nairobi.

Research Questions

The research seeks to answer the following questions:

1. What are the challenges faced in groundwater management?
2. Has there been increasing dependence and usage of groundwater sources in Nairobi?

3. What are the uses of groundwater in Nairobi?

4. Has the groundwater quality in Nairobi changed over time?

5. What are the groundwater management measures adapted by the relevant Government agencies?

6. How effective have the groundwater management agencies been in groundwater management?

7. What needs to be improved in groundwater management?

1.4. The Scope of the Study

The study examines the challenges in the management of groundwater in Nairobi. It also examines the groundwater management measures adopted by the WRMA in Nairobi and evaluates the effectiveness of these measures. The study relies on data from the MWI on the boreholes drilled in Nairobi from 1940 to 2000.

Before the enactment of the Water Act 2002, the MWI was the one charged with safeguarding the ground water resource. The measures it has taken in ground water resource management will be examined.

1.5. Research Methodology

In order to achieve the stated objectives of the research study, the methods adopted are discussed below.

1.5.1. Review of literature

Literature related to the research problem is reviewed mainly to develop a conceptual framework through a detailed study of what has been written on the research problem. The challenges of groundwater use on a global level have been examined. The best practices in groundwater management have also been studied. The researcher has used this conceptual framework to evaluate the groundwater management strategies in Nairobi.

A literature review of the legal and regulatory framework on groundwater management in Kenya has been done. The review covers the current and past regulatory and management measures that have been put in place to regulate and monitor the abstraction and usage of ground water resources. The researcher has reviewed and critiqued the mechanisms in place. This literature has been sourced from various laws of Kenya and Government documents including The Water Act, 2002, The Water Act, 19 72 (now repealed), Sessional Paper No.1 of 1999 on National Policy on Water Resource Management and Development Environmental Management and Co-ordination Act No. 8 of 1999.

The source of the literature is from documents by researchers, academicians and institutions. This has been sourced from libraries and the internet.

1.5.2. Secondary data collection.

The researcher also uses quantitative data from the Ministry of Water and Irrigation to determine the major uses of groundwater in Nairobi and the average borehole water struck levels. The data is also used to determine the quality of the borehole water in the study area.

Before a borehole water use permit can be issued, the owner is required to submit a water sample from the borehole which is analysed by the MWI. The researcher has used this information to determine whether there has been any change in the water quality in the study area.

The researcher held key informant interviews with the government officers charged with the responsibilities of regulating and monitoring usage of groundwater resources. Interviews with Ministry Officials are to determine measures taken to ensure sustainable abstraction of water, and strategies for future, sustainable exploitation of groundwater resources, how effective the Ministry has been in ensuring compliance, and challenges the ministry faces in ensuring compliance.

The researcher held interviews with ten borehole owners or their agents to evaluate their compliance to the regulations governing the abstraction and usage of groundwater resources. This is also to determine whether the regulations are strictly enforced by the WRMA. It is also to gauge whether the requirements of the Water Act 2002 are being implemented. These are the people who are on the ground and the aim is to determine whether the policies that are formulated by the government are being actualized.

The target population is all boreholes in Nairobi. The study population consists of all boreholes whose owners have applied to the MWI for drilling permits. The accessible population is the boreholes that have records with the Ministry of Water and Irrigation. This is the information that is in the MWI database and it is both manual and computerized. The data for water quality is stored separately from that of the water permits. The data is for the whole of Nairobi.

Due to limitation of time and resources, the researcher has used a sample size of 100 boreholes from a total of 1030 permits whose applications were done between years 1940-2000. This is because not all the borehole applicants submitted water quality analysis results. Simple random sampling method was used to select the boreholes. The sampling units were picked randomly through use of Microsoft Excel. Land reference numbers of the sample population were keyed in order to select a random sample.

The water quality analysis of the boreholes was examined to determine whether the water quality of the chemical content in Nairobi conforms to the WHO guidelines of Minimum Standards. The researcher noted that the boreholes are not analysed for biological content by the MWI.

The following attributes of the boreholes were examined;

- Location of the borehole within Nairobi

- Purpose of water use; whether it is industrial, domestic, agricultural, commercial

- Date of application of permit.

Who drilled the borehole; are they licenses contractors or not

- Whether the details required by the Ministry were submitted.

- What was the water struck levels and the water rest levels?

- What is the water quality analysis result? This will be examined against the WHO water standards.

To evaluate how effective the MWI has been in effecting compliance with the regulatory requirements of the Water Act, 2002, questionnaires were administered to 10 borehole owner or their agents. To come up with the 10 boreholes, the researcher made enquiries through property managers, property agents and caretakers. From a population of 50 operational boreholes in Nairobi area, a sample of 10 was picked.

1.5.3. Data analysis and presentation

Kerlinger, (2004) defines data analysis as the categorizing, ordering, manipulating and summarizing of data to obtain answers to research questions.

The data collected from this study includes quantitative and qualitative data. The qualitative data came from review of literature and interviews with key informants. The data from literature review is presented in written form, with credit to the authors and key informants shown both on the main body of the research report and in the bibliography. The research instruments that were used to collect information from key informants are attached to the research report as an appendix.

The research also collected quantitative data. The data was cleaned, coded and analyzed. The coding of the data on water quality and abstraction is numerical. The data is entered and analyzed using the Microsoft excel computer package. Data is presented using tables and percentages

Data on the uses of groundwater in Nairobi is analysed using percentages and presented in the form of a pie-chart.

Data on borehole depth is analyzed using Microsoft excel computer package. The population comprise of boreholes drilled in Nairobi between 1940-2000.The data was grouped according to years. The average depth of each of the boreholes in a batch was calculated. This was used to show whether there is any change in the depth of boreholes in the study area. Descriptive statistics were used to analyze the data. This includes the mean as a measure of central tendency. The data is presented using linear graph. The data from borehole owners is presented in percentages.

1.6. Justification for the Study

There has been a rapid increase in the population of Nairobi. Population increase has been both from natural increase and rural urban migration. The increases in population and urbanization have resulted in increased demand for water for domestic, industrial and service uses. Ideally water supply is supposed to increase proportionately to the rate of population growth and urbanization which is not the case for urban Kenya known for "static institutional base, a dwindling revenue base, obsolete technology for service providers in the public domain, which translates into inadequate service in the water sector"(K'Akumu, 2004). The consumers have therefore started using other alternative water sources. This has resulted in increased use of groundwater as a source of urban water supply.

Unregulated extraction of groundwater resource poses a threat of over abstraction of the resource. Land use practices such as intensive use of fertilizers and pesticides in agricultural production, disposal of untreated sewage and industrial effluent, and dumping of toxic materials all pose a threat of pollution of the groundwater resource.

The Kenyan government has in the recent past made major policy changes in the water sector, culminating in the enactment of the 2002 Water Act. The act provides for the formation of a Water Resource Management Authority that is charged with the responsibility of managing water resources, including ground water. This research will evaluate the effectiveness of the Ministry of Water and irrigation and the current WRMA in ground water resources management. Based on the findings of this research, recommendations have been made that could provide the Water Resources Management Authority with valuable information that can be useful to it as it manages water resources, especially ground water.

The research examines the regulatory framework on groundwater use and quality in Kenya and seeks to match this with the actual practice and the likely implications. This is in regard to unregulated abstraction, quality and impact on the environment and the urban population.

The research highlights the potential of groundwater to supply expanding cities, especially in the light of diminishing surface water supply and therefore the need for a strictly enforced regulatory mechanism.

The research will also create awareness on the part of stakeholders who include the urban residents, borehole owners, the consumers, NCC and the Government. The stakeholders will therefore demand that stricter regulation standards be initiated and enforced.

The research findings may spur the formation or activation of a regulatory mechanism that will ensure that ground water use is well regulated in order to protect the resource.

1.7. Organization of the Study

This research report is in six chapters.

- Chapter one comprises of the introduction, problem statement, study objectives, research questions, Research methodology and significance of the study and scope of the study

- Chapter two comprises of the literature review done on ground water management. The literature review covers work done on the legal and institutional framework on ground water management, the significance of ground water in urban development, challenges faced in use of ground water. The review also covers the best practice of groundwater management.

- Chapter three comprises of literature review and critical analysis of the legal and regulatory framework that govern groundwater management in Kenya.
- Chapter four consists of the study area which is Nairobi.
- Chapter five comprises of the research findings
- Chapter six comprises of the conclusion and recommendations.

In addition to these six chapters, the report has a detailed bibliography, detailing the reference and research materials used.

CHAPTER TWO

LITERATURE REVIEW

2.1. The Role of Water in Urban Development

All productive sectors of the economy be they industry, commercial services or residential require water for their operation. According to World Bank (1994) adequate supply of water, as an infrastructure, is one of the prerequisites for economic growth.

Water is required for good sanitation and therefore reliable and good quality water supply has implications on health as it reduces the incidences of water borne disease caused by inadequate supply and poor quality water .The UN-Habitat (1990) reports that over 80% of all diseases and over a third of deaths in developing countries are caused by ingestion of contaminated water. About one tenth of each person's time is sacrificed to water related disease. This affects peoples' productive capacity and has negative impact in overall economic development. If the urban population is afflicted with disease, a lot of resources which would otherwise be used in service delivery are spent on treatment.

Reliable water supply ensures that growth is consistent with poverty reduction (World Bank, 1994). Access to clean water and sanitation can result in reduction in mortality rates. The poor, in particular, use a lot of their time and income in obtaining water. Funds so used can be used for income generation activities with positive reduction in poverty.

Foster and Tuinhof (2005) note that groundwater in the greater Nairobi is used for garden irrigation, commercial green houses and flower cultivation which could lead to increased demand for groundwater.

In Kenya, water is an important input in manufacturing and industrial processes (Mogaka et al, 2006).They further note that the country is currently pursuing its industrialisation policy and it is expected that increased industrial production will lead to increased water demand from 366,000m^3 per day to 491,000 m^3 per day by 2010.

Water is an important factor in tourism development. Tourism is a major foreign income earner in Kenya. A lot of water is used in the hotel industries especially for sanitation and cleaning purposes. Adequate and reliable supply of water is therefore important if the country is to continue being a competitive tourist destination.

Water is used in development of recreation facilities. The dam in Uhuru Park is man-made. A lot of water is used to maintain it. This site is a popular local recreation facility. Water is also required to grow and maintain flowers in the city especially during the dry seasons. These add to the aesthetic beauty of the city.

Water is an important requirement for the environment. This includes both the flora and fauna. Nairobi therefore requires adequate and reliable supply of water for it to be an environmentally friendly city. Growing plants act as carbon sinks and therefore helps in reduction of pollution levels in the city.

2. 2. Causes of Water Supply Problems in Urban Areas

2. 2.1. Rapid population growth

Rapid population growth has been the main cause of urban water supply problems. UN-habitat (2003), reports that between 1950 and 2000, the world urban population increased more than four fold. At present, close to fifty percent of the world population live in urban centers as indicated in the Table 1 below:-

Table 1: Urbanization in Africa.

	TOTAL POPULATION (MILLION)			AVERAGE ANNUAL % GROWTH OF TOTAL POPULATION			URBAN POPULATION AS A % OF TOTAL POPULATION		
	1980	1990	2000	1975-1979	1980-1990	1990-2002	1980	1990	2002
Kenya	16.6	23.4	31.4	3.8	3.5	2.5	16.1	24.0	35.2
All Africa	471.9	624.9	831.8	2.9	2 .9	2.4	27.1	31.7	38.4
Sub-Saharan Africa	383.5	510.9	689.3	2.9	2 .9	2.6	23.1	27.9	35.5

Source: The World Bank (2004)

Table 1 shows that though there was a decline in the average annual percent of growth of total population in Kenya and Africa as a whole from 1975 – 2002; the urban population as a percent of total population in 2002 was 35.2% almost over two times that of 1980 at 16.1%. This indicates over a double increase in the rate of urbanization in Kenya in twenty two years.

Rapid increase in urban population translates in increased demand for municipal service delivery including water supply. However additional water is often not readily available. Where it is available, new distribution networks must be built to supply the new residents (Aton, 1993). This requires financial resources, which are lacking in most developing countries including Kenya.

With increased urbanization most countries continue to rely heavily on groundwater resource. Increase in impermeable surface area reduces the opportunity for groundwater recharge and lead to the lowering of groundwater table (UN-Habitat, 1990). This results in increased saline intrusion and concentration of pollution. Cities are therefore faced with the mounting cost of water shortages, water treatment, well deepening and development of remote new resources.

Increased population in Nairobi has resulted to growth of unplanned or informal settlements (Nairobi City Council, 2007). This has greatly impacted on urban water demand .The residents of these areas rely on water vendors and shallow wells for their water supply. This has great implication on cost and health. The shallow wells are very prone to pollution. The residents are therefore under risk of being infected with water borne diseases through the use of contaminated water.

With increasing population and urbanization, urban centers have continued to increase in physical extent. Nairobi city has increased from 4480 Acres in 1901(Morgan, 1967) to 581,677 Square Kilometers in 1999 (Republic of Kenya, 2001). Therefore the area to be supplied has greatly increased with subsequent need for increased surface coverage for water supply. This implies an increase in the number of residents to be supplied with water by the utility company. This poses a challenge for the company to match water supply with the population increase. There is therefore an increasing widening gap between water demand and supply, and between consumption and potentially available safe water resources in many urban areas of the developing countries including Nairobi (UN-Habitat, 1990).

As a result, groundwater is being used to supplement the municipal water supply and also as an alternative source. However, good management measures that ensure that groundwater is abstracted sustainably and that water is of good quality have not been put in place.

2. 2.2. Corruption

Anton (1993) cites corruption as one of the causes of water supply problems in urban areas. This problem is more prevalent in the developing countries of Africa, Asia and Latin America. In Kenya, this problem has persisted even with the current World Bank driven policy of privatization of water supply and management to autonomous legal entities, separate from local authorities. In the Daily Nation of 31st January, 2005, Mr. Kingori the Chairman of Nairobi Water Services Board stated that "---we have established that a substantial amount of revenue get lost through illegal water connections, faulted meters and diversion of money payable to the company---". This happens with the collusion of the NCWSC e mployees. Such practices deny the utility company much needed revenue in form of user charges. This affects its operation and impacts negatively on the company's ability to provide reliable and adequate water supply.

2. 2.3. Inadequate management

Management failure is another cause of water supply problems in urban areas.

Government of Kenya, (2000) lists some of the management challenges faced by local authorities as inadequate institutional capacity, low service rates of individual connections and stand points leading to shortfalls in revenue collection against water sold, poor billing procedures, poor maintenance of record; water leakages; misappropriation of revenue collected and inappropriate technologies.

According to Onjala (2002) in Kenya, there is over centralization of the decision making process through the Ministry of Local Government which maintains a regulatory function over local authorities including tariff regulation. Thus, though NCC has privatized the water supply through the Nairobi Water and Sewerage Company, the company cannot make independent decisions without referring to NCC which has to consult with the Ministry of Local Government.

2. 2.4 Climate Change

Mogaka et al (2006) reports that Kenya is affected by both local droughts and floods and also widespread El nino and La nina events. They further note that the country lacks coordinated institutional structures and arrangements to mitigate the negative effects of climate variability despite there being drought monitoring centers in Kasarani.

Climate changes have resulted in long periods of drought, which have also affected the ability of local authorities to supply adequate and reliable water to the residents.

In the year 2005, most parts of Kenya, especially the catchments areas, which are the source of rivers from Nairobi gets its water, experienced inadequate rainfall. This was mostly for the short rains between October and December. There was drastic reduction in the dam levels at Ndakaini Dam where the bulk of Nairobi water supply comes from. The Nairobi Water Company had to resort to water rationing. Many parts of the city experienced inadequate water supply while others experienced dry taps for most of this period. There was booming business for water vendors and water tankers. However, this water was more expensive than the municipal water supply. It therefore increases the cost of production especially for manufacturers.

These problems have resulted in low urban water supply coverage which is estimated at 70 % (Hirji, 2000). The inadequate water supply has resulted in mushrooming of alternative water providers in the form of water tank operators, borehole water vendors, water kiosks and standpipe operators (Mohamed, 1999).

Nairobi City Council (2007), notes that in Nairobi water vendors are usually dominant in the informal settlements while water tankers supply water to the up-market neighbourhoods of the city.

According to Foster et el (2005) due to unreliability of the Council's water supply, there has been a steady increase in groundwater abstraction in Nairobi. He further notes that in 2002 groundwater supply accounted for 25% of the overall water supply for Nairobi. Most boreholes are operated by large private consumers.

2. 2.5. Limited financial resources

According to Mogaka et al (2006) in Kenya during the 1990s there was an overall decline in investments in water resource development and management. This was mainly due to decreased budget allocations due to decrease in the donor funding. He further notes that government investments in the water sector dominate surface water development and management at the expense of groundwater.

2. 2.6. Inadequate land tenure

K'Akumu and Appida (2006) pointed out that lack of land tenure discourages private developers from investing in water supply. Inadequate land tenure system, which is as a result of ineffective enforcement of development control, has led to proliferation of informal settlements in the urban areas where occupants lack security of title. Thus, these private investors fear that the land may be repossessed by the Central Government or the L.A. for their own use.

These areas are also not well served with road networks, which can be used for laying of water pipes. In the researcher's opinion inadequate land tenure would discourage private investment in groundwater abstraction.

The Kenyan government, as discussed later in this thesis uses the water permit as the instrument of groundwater allocation. The permit is issued on the basis of a title document. Therefore, with no security of title, one would not get a water permit thus raising the issue of equitable access to the groundwater resource.

2. 2.7. Water losses

Onjala (2002) notes that there are massive water losses from the pipes that connect the City of Nairobi and the dams. The pipes from Ruiru dam pass through the densely populated Kiambu area which suffers from water shortages. Thus the residents siphon water from the pipes. There is also frequent pipe bursts due to high water pressure. There are also losses due to illegal water connections.

From the above, it can be concluded that demographic pressure and climate change, coupled with inept management of surface water resources has led to an acute shortage of water. Alternative sources of water like rainwater harvesting and groundwater are being explored and exploited, but in an uncoordinated manner, as will be argued further in this study.

2. 3. Ground Water Resource

2.3.1. The hydrological cycle

According to Blyth et al (2001) groundwater is mainly derived from rainfall and melting snow. Water from rainfall or snowmelts sinks into the soil through infiltration. Soils have different rates of absorbing water (Kehew, 1998 and Blyth et al, 2001). Infiltration will occur more in ground covered by vegetation than in bare grounds. In urban areas where most of the ground is covered by buildings, concrete or tarmacked roads and pathways, the rate of infiltration of water to the ground will be low.

After water has infiltrated into the ground, it then moves downwards to the safe rated zone or the water table in a process known as percolation (Blyth et al 2001). The water then moves from the saturated zone towards rivers, lakes and seas through a process known as groundwater flow. The water from the surface sources evaporates as water vapor which precipitates as rain or snow thus completing what is known as the hydrological cycle.

2.3.2. Ground water quality

Ground water quality is a very important aspect of urban water supply and thus needs to be monitored and managed appropriately. The water quality determines whether the water can be used for industrial and domestic use including human consumption. It is affected by many factors including both natural and human activities.

According to Kehew (1998) ground water quality is affected by the soils and rocks through which the water flows as it infiltrates into the ground. These dissolves as minerals into the ground water and are measured as Total Dissolved Solids (TDS)

Table 2: Groundwater quality classification based on TDS

Water type	Total Dissolved Solids (TDS) mg/L
Fresh	0-1000
Brackish	1000-10,000
Saline	10,000 – 100,000
Brine	> 100,000

Source: Kehew (1988)

The concentration of minerals is analyzed in mg/L, which means the mass of solution in milligrams per liter of solution. Fresh water contains 0-1000TDS mg/L while saline water contains 10,000 – 100,000 TDS mg/L.

According to Hammer and Hammer (2000), the main natural dissolved chemicals in groundwater include salts, irons and manganese, fluoride, arsenic, radio nuclide and trace metals. Calcium and magnesium ions cause water hardness. Though hard water is not harmful to human health it may cause scale on plumbing fixtures and boilers especially if the water is for industrial use. In domestic use, hard water causes soap not to foam. Iron concentration of above 0.3mg/L produces stains and solid precipitates on plumbing and clothing. High concentration of fluoride in ground water result to mottling of teeth or fluorosis. In extreme cases, it can cause bone damage.

2.3.3 Contamination of groundwater

Contamination of groundwater occurs when soluble materials are leached from the soil or when contaminated surface water infiltrates into the ground water.

Groundwater is contaminated through disposal of waste by sanitary landfill (Biswas, 1998). This is where liquid or solid water are spread on agricultural lands, golf-courses and other areas to serve as fertilizers and irrigation. Hamil and Bell (1986) further notes that that the disposal of domestic and commercial wastes in landfill sites is a major threat to groundwater. Where the wastes are water soluble, they infiltrate into the nearby aquifers causing groundwater contamination.

FAO (2003) reports that in Santa Cruz, Bolivia and Hat Yai, Thailand, direct discharge of untreated wastewater has led to substantial increases in pollutants including nitrate, nitrate, chloride, faecal coli forms and dissolved organic carbons in shallow aquifers. According to FAO (2003), though the groundwater quality in these cities is still good, pollution can move downwards due to extraction of groundwater from deeper wells.

Extensive use of fertilizers pesticides and insecticides has made agriculture a major source of ground water pollution (Biswas, 1998, Troeh et al, 1980). There is extensive horticultural farming in areas within close proximity of Nairobi including Kitengela, Karen and Thika. It also involves extensive irrigation. This helps in leaching the pollutants into the soil and poses threat to ground water. Thus, this puts groundwater resource in Nairobi at risk of contamination.

According to Biswas (1998) storage and disposal of wastes from poultry farms may introduce large quantities of nitrates, potassium, and phosphates in aquifers. Poultry farming is extensively practiced in Nairobi area as residents look for alternative income sources and also due to a growing demand for poultry products including eggs and meat by the growing urban population.

Groundwater aquifers can be contaminated by leakage of petroleum products from storage tanks or underground pipelines or by accidental spills (Biswas, 1998).

Table 3: Sources of ground water contamination

Waters		Non waters
Intentional discharge	Unintentional discharge	Unintentional discharge
• Spray irrigation	• Surface impoundments	• Buried – product storage tank and pipelines
• Septic systems, cesspool etc	• Landfills	• Accidental spills
• Infiltration of percolation basin	• Animal feedlots	• Highway de-icing salts stockpiles
• Water disposal wells	• Acid mine drainage	• Application of highway salts
• Brine-injection wells	• Mine spoil stock pile and tailing	• Product storage ponds
		• Agricultural activities

Source: Biswas, (1988)

Accidental spills of chemicals from manufacturing plants and on roads can also cause ground water pollution (Kehew, 1988). This is especially so if the spill is not cleaned as soon as it occurs.

Kehew, (1988) notes that in the United States there are four million underground storage tanks which mainly contain petroleum products and are mainly constructed of steel. It is estimated that one third of these tanks have caused ground water contamination either through leaks in the tanks and connecting piping or by spills and over fills occurring during refueling.

According to Obudho (1997) only about 58% of the population in Nairobi is served by the existing sewerage system. The rest of the population, 42% is served by septic tanks, conservation tanks or pit latrines, which contribute to pollution of groundwater.

World Health Organization (2006) has established drinking water quality guidelines on the minimum concentration levels of different chemical substances that are allowable for human consumption. Table 4 shows these guidelines. The table shows that high concentration of fluoride in drinking water causes dental and skeletal flourosis.

According to Nganga and Valderhaug (1982) a study was done of 513 primary school children in Nairobi with a view to assess the prevalence of severity of dental flourosis established that the degree of flourosis on children served with river water was mild.

However, in areas served with borehole water, 48% of the teeth and 48% of the children had high dental flourisis. The study therefore recommended that measures be put in place to reduce the high prevalence of dental flourisis on children who use groundwater.

The researcher has used the WHO guidelines to analyse the quality of groundwater in Nairobi.

Table 4: WHO guidelines for minimum concentration of chemical substances in drinking water

Substance	Guideline value(Mg/L	Occurrence in groundwater	Effects on human
Arsenic	0.01	Occurs naturally, also through commercial and industrial use of arsenic alloying agents in manufacturing of transistors, lasers, and semi conductors.	Carcinogen in humans. Affects the lungs, bladder andskin
Cadmium	0.003	Used in steel and plastic industries. released to ground water through waste water and fertilizers	It's a carcinogen
Chloride (Cl)	250	Natural causes	Detectable taste in water
Hardness	200	Caused by dissolved calcium carbonate	
Mercury	0.006	Used in electrolytic production of chlorine, in electrical appliances, dental amalgams.	Affects the kidney, benign tumours
Nitrate (NO3)	50	Naturally also through use of agricultural fertilizers.	Causes" blue-baby" syndrome in infants.
Nitrate (NO2)	3		
Fluoride (F)	1.5	Occurs naturally	Dental fluorosis and skeletal fluorosis
Manganese(Mn)	0.4	Occurs naturally. High levels associated with industrial pollution.	
Iron (Fe)	0.8	Occurs naturally	
Sodium (Na)	200		Concentration above minimum levels may cause unpleasant taste
Total Dissolved Solids(TDS)	1200	Natural sources and from sewage, run-off and industrial wastes	

Adapted from World Health Organization (2006)

2. 3.4. Land subsidence

Land subsidence is an environmental consequence of ground water overdraft caused by the consolidation of the soil deposits due to the lowering of the ground water level (Gupta, 1998). Land subsidence involves localized or widespread sinking of the land surface which may range from sudden collapse to slow, gradual decline in surface elevation (Kehew, 1988).

According to Gupta (1998) problems associated with large scale land subsidence include "sinking of benchmarks; collapse of well casing; reversal of gradients for drainage and sewerage systems; damage to roads, railways, storm sewer or other underground pipelines; cracks in buildings and threat of seawater flooding in coastal areas with low ground – surfaced elevation."

2.3.5. Over-exploitation

Over-exploitation of groundwater is another consequence of groundwater use. Gupta (1998) describes overexploitation as "state of pumping of groundwater when the total abstraction exceeds the long-term charge of ground water system". This results to depletion of ground water resource and lowering of the water table. According to Foster and Tuinhof (2005) there has been an increase in the number of borehole in Nairobi which has led to gradual falling of the water table. According to Mogaka et al (2006), in Nairobi the average depth of boreholes for domestic water use has increased over the years from 60 meters to 84 meters. This implies added costs to the water users in terms of increased pumping costs. F.A.O. (2003) note that widespread depletion of shallow aquifers increased in the mid-twentieth Century with the advent of mechanized pumping techniques.

Gupta (1988) and F.A.O. (2003) give the effects of groundwater over abstraction as increased pumping costs and energy use; land subsidence and damage to surface infrastructure such as roads; deterioration of groundwater quality; increases in vulnerability to urban water uses as the economically accessible buffer stock of ground water declines; reduction in access to water especially for the poor. In coastal areas over abstraction can lead to intrusion of sea water into the aquifer contaminating the freshwater resource; environmental impact on springs and wetlands where some of them disappear.

Foster and Tuinhof (2005) note that in Nairobi there has been an increase in the number of boreholes which has led to gradual fall in the water table. They further note that there has been no evidence of land subsidence in the area. However, they note that Nairobi was once a swampy area and the presence of clay and silt layers may be potential sources of subsidence.

2. 3.6. Overcharging

F.A.O (2003) notes that ground water recharge in cities is often higher than in semi-urban areas. This is mainly because many urban areas rely on imported water supplies and there is water leakage from sewers and water mains.

Rising water levels in urban areas enables the urban poor to rely on shallow wells for domestic water supply. This water has high pollution levels and therefore poses a threat to the health of the poor.

High water levels pose a problem of drainage in urban areas. FAO (2003) reports that the cities of Merida, Mexico; Hat Yai, Thailand; Santa Crux, Bolivia and Sanaa in Yemen have experienced increases in ground water recharge capacity leading to rising water levels. This poses a threat of flooding.

2. 4. Groundwater management

Gupta (1998), states that ground water management is necessary to provide safe and reliable ground water supplies. This involves planning, implementation and operation of ground water management strategies. According to Gupta (1998), the objectives of ground water management are to extend the life of the aquifer by limiting withdrawal to the safe yield; to protect the ground water basin from hazards such as pollution; to provide water supply at minimum costs and to avoid land subsidence.

F.A.O, (2003), notes that there has been neglect of groundwater management in most developing countries. In Namibia, where groundwater provides sixty percent of water supply, institutional arrangements and investments have focused on development of intermittent surface flows. In Kenya as noted earlier, Government investments in the water sector dominates surface water development and management (Mogaka et el, 2006).

In the past, ground water management has focused on development of the resource. This has resulted in serious environment consequences such as over abstraction (Gupta,1998).There is need to change the emphasis to water conservation and water demand management in order for the resources to be sustainable. In Kenya under the repealed Water Act, the emphasis was more on groundwater exploitation with little emphasis on its conservation and management.

From the literature review, various strategies are proposed for ensuring sound and sustainable ground water management: These are outlined below:

2.4.1 Planning

Burchi (1998) gives planning as one of the tools that can be used for the controlled development, use and protection of groundwater. This aims at reserving good quality water to satisfy the drinking water needs of the population. The available groundwater is apportioned to the competing user groups on a quota basis. In France, where groundwater planning has been adopted, the civil society is involved in the formation and adoption of the plans. All water permits granted on groundwater abstraction have to conform to the planning regulations.

Objectives for ground water management are often not stated and where they are, there is no clear criteria for evaluating any alternative plan. Gupta, (1998) states that ground water planning and decision-making are continuous processes, which should encompass the changing conditions and circumstances. These include changing demand due to population growth, economic development and land use, and changes in the quantity of the resources due to natural development and human activities. The objectives should therefore be constantly reviewed to reflect these changing conditions over time.

Groundwater planning should address natural factors including safe yield, geo-hydrologic regime, land use and geographic location. It should also address the technical factors including capability of wells and well fields. Social economic factors that should be addressed include the water use patterns, water demand characteristics, price elasticity and available funds. This puts focus on the water use side of water resources management.

Un-Habitat (2006) notes that Nairobi still relies on the Master plan that was developed in 1973 and which has since been overtaken by urban growth. Further, the N.C.C. and the Directorate of Physical Planning, which are mandated with overseeing development planning, are overwhelmed. Un-Habitat (2006) recommends that environmental planning be incorporated into planning of the city.

2.4.2 Public participation

Foster et al (1998) note that given the large number of small scale groundwater users, there is need to create public awareness and stakeholders' dialogue. According to Gupta (1998) and Burchi (1998) water users' participation in decisions of water resource management ensures their support of the program because they feel part of it. The public needs to be sensitized on the status of the groundwater resource and why it is important to manage it.

Bakker (1997) note that in Kenya, except for the Ministry in charge of water, other water users are not involved in decision making which makes it impossible to develop and implement planned groundwater development.

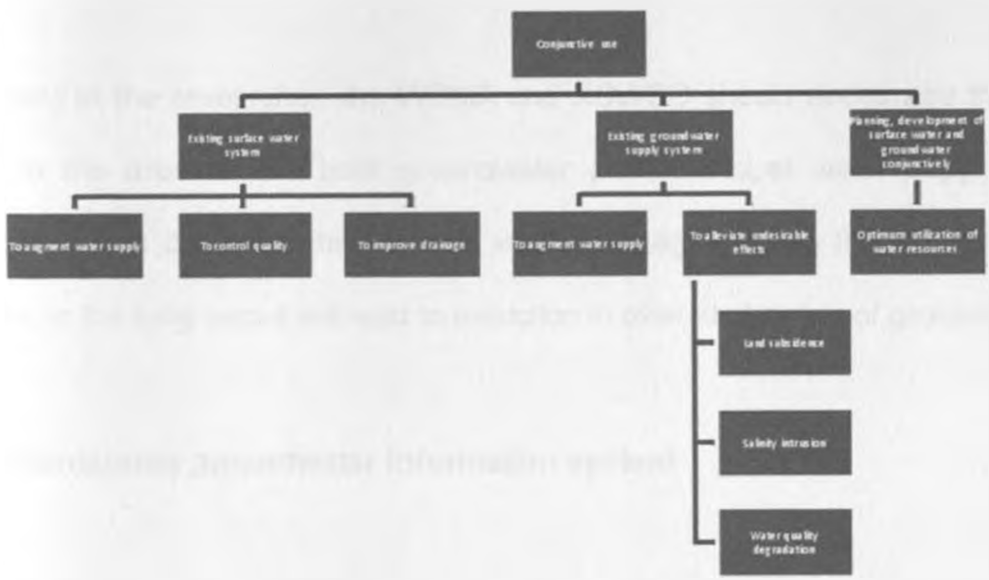
In Kenya the Water Act, 2002 as discussed in chapter 4, provides for establishment of Catchments Area Advisory Committees. This is a forum which can be developed to encourage stakeholders' participation in groundwater management in Nairobi.

2.4.3 Conjunctive use of surface and groundwater resource

Gupta (1998) and Burchi (1998) note that conjunctive use of surface and groundwater resource is one of the approaches to groundwater management.

Gupta defines conjunctive use as the coordinated and planned utilization of surface water and groundwater resources in an integrated manner. In most cases conjunctive use has developed where there is high water demand and where the quality of groundwater is relatively poor necessitating mixing of groundwater with surface water. It can be used to alleviate environmental consequences of over exploitation of groundwater as depicted in the Chart 1.

Chart 1: Classification of conjunctive water use.



Source: Gupta (1998)

Gupta notes that ground water is often considered as inexhaustible resource. This results in over estimation of the resources potential leading to over abstraction.

According to FAO (2003), management of surface water greatly impacts on ground water quality and quantity. Integrated management of both surface and ground water resources should therefore be adapted.

According to Foster and Tuinhof (2005) the use of groundwater in Nairobi is mainly for domestic use and complementary to the NCWSC water supply. They note that the availability of groundwater as a backup resource for emergency situations will contribute greatly to the reliability of the overall water supply.

According to the researcher, the WRMA and NCWSC should encourage the water users in the area to use both groundwater and municipal water supply where applicable. This can ease the frequent water shortages during the water rationing periods. In the long term it will lead to reduction in over abstraction of groundwater.

2.4.4 Maintaining groundwater information system

There is lack of reliable and adequate data on the quantity and quality of ground water recharge and safe yield (Gupta, 1998). Though the cost of collecting information on the ground water is relatively higher than for surface water, there is need to develop and maintain information system on the ground water quality (World Bank, 1998).

According to Mogaka et al (2005) in Kenya, there has been a reduction in groundwater quality monitoring which hinders the country's ability to determine extent of pollution, the sources of pollution and also to enforce permit procedures.

He further notes that there has been a decline in the water quality monitoring by the Central Water Testing Laboratory in Nairobi. This has in turn affected the Ministry of Water and Irrigation ability to determine the extent of water resources pollution, identify the sources of pollution and enforce permit procedures.

Bakker (1997) notes that in Kenya, groundwater levels are rarely monitored .A huge gap therefore exists between the stored information on water resources and the real field data.

2.4.5 Strengthening the institutions involved in groundwater management

Management of ground water faces various challenges. According to Biswas (1998), and World Bank (2005) inadequate and a weak regulatory framework has resulted in environmental degradation of the ground water resources.

There is need to strengthen the institutions involved in the ground water management through the review of laws and regulations that govern them, their organization and decision making and co-ordination and communication between them.

World Bank (2005) recommended that a strong program to regulate and license ownership and use of well-drilling equipment, with criteria for new construction should be put into place to control ground water abstraction.

Foster et al (1998) gives the following as measures of improving ground water resource management:

- The Institutional framework should include legislation that clearly defines water use rights. This is through the granting of licenses and levying charges for ground water exploitation. As shall be discussed in Chapter 3, this has already been put in place through the Water Act 2002 which is the legal framework through which groundwater is exploited. Under the Act, an institutional framework has been created with the WRMA as the lead agency charged with groundwater management. It grants licenses or groundwater drilling and abstraction permits and also levies charges.

- Legal consent or planning approval should be given for activities that are likely to pollute groundwater such as discharge of liquid affluent, land disposal of solid wastes.

- A national or local regulatory or administrative agency should be created to supervise the licensing processes and enforce them. This agency should have technical expertise, financial resources and legal backing to perform its duties. This agency will face the challenge of how to exert control over large numbers of small resource abstraction and polluting discharge. This can be achieved through public awareness and stakeholder dialogue on the status of ground water resources and need for introducing management measures.

NEMA, through EMCA is the agency, charged with the supervision and coordination of environmental matters. This is further discussed in Chapter 3 of this thesis.

Foster et al (1998) further note that water resource managers need to achieve the following targets:-

- Constrain ground water levels in aquifer underlying urban areas within a tolerable range by controlling the magnitude and end use of ground water abstraction.

- Moderate the sub-surface contaminant load to acceptable levels by considering the vulnerability of local aquifer to pollution, land use planning to reduce potential pollution sources and selective controls over effluent discharges and other existing pollution controls.

According to Foster et al (1998), groundwater management targets can be achieved by regulating aquifer development. Ground water exploitation can be better regulated through control of water well drilling than licensing pumping after drilling.

The control of water well drilling can include well depth, diameter and screen intake levels.

Licensing of water well drilling companies exerts control over ground water abstraction. It also improves the standards of water well constructions. Through control of well construction; the water managers can be able to reserve good ground water for potable and sensitive uses. Poorer groundwater can be used for non-sensitive industrial processes. It can also reduce over-exploitation of ground water in local areas which can cause yield failure or excessive inefficiency.
Foster et al (1998) further adds that there should be provision for an adequate sanitary seal for production boreholes to prevent contamination from the well-head. This will reduce ground water supply pollution.

A register of licensed drilling contractors operating within the regulator's jurisdiction should be maintained. The contractors should provide the program for each of their drilling machines so as to maintain contact with operations and to maximize data collection. Sanctions should be imposed on drilling companies who do not conform to such requirement.

After a well is constructed, applicants can then request for an abstraction license from the regulator. Most domestic users are exempt from the licensing. However, they should also be controlled in order for the regulator to have overall control of exploitation and avoid irrational development.

A capital levy or annual fee should be charged for ground water abstraction. This can be based on the quantity licensed for abstraction or on actual annual abstraction. Actual abstraction can be measured through metering.

To ensure efficient water use, an incremental scheme for charging for large abstraction can be introduced. Charges should be economically realistic and should cover administration costs. They should be based on the criteria of recovery of the full cost of administrative activities of the regulatory body; the shadow cost of alternative raw water supplies to the users and the full economic value including cost of environmental externalities.

The charge should be per unit volume based on the quality and location, the environmental sensitivity of the abstraction and the quality of the ground water supply obtained. A higher weighing factor could be assigned if abstraction occurs in the dry season or if the borehole is located in coastal areas or near environmentally sensitive features fed by groundwater. A lower weighing factor could be assigned if poor water is abstracted, thereby, providing an element of additional protection for neighboring ground water resources of high quality. Raising raw water abstraction charges may provide some incentive for more effective demand management in urban areas.

Foster et al (1998) recommends that for the abstraction policy to be effective, sanctions should be imposed on those who construct wells without a permit or exceed the licensed abstraction. Monetary fines are not the best option. There should be temporary prohibition of the use of the well by removing the pumping plants or sealing the wellhead. Well maintenance should be monitored to diagnose maintenance requirements such as routine pump servicing and intermittent well cleaning and rehabilitation.

Where there are over exploited aquifers Foster et al (1998) recommends that abstraction controls should include measures to prohibit construction of new water wells and to reduce abstraction from the existing wells. Specific areas should be denoted where ground water resources need to be protected for public interest.

Over regulation of groundwater resource abstraction should be avoided. Ground water levels should be observed in observation boreholes as opposed to production boreholes. Production boreholes are a far less consistent and sensitive guide to the state of ground water resource exploitation. Groundwater levels can be used to guide resource exploitation policy.

Foster et al (1998) suggests that introduction of tradable abstraction rights may serve as a supplementary economic instrument to control groundwater exploitation. Many existing abstraction licenses are transferable of title provided there is no change in location, pumping rate, and use of ground water. However, tradable permits allow change of use and variation of location thereby creating a water market. The system can only work effectively where water rights are clearly registered and guaranteed.

According to Foster et al (1998) the benefits of introducing a system of tradable ground water abstraction rights are: stimulates the registration of all abstraction, establishes a process for realistic valuation of the resource, encourages increased efficiency of water use, provides a mechanism through which proportional reduction in abstraction can be introduced when technically justified. He further notes that most groundwater originates as excess rainfall that infiltrates the land surface. Therefore, many activities on the land surface threaten groundwater quality and the availability of the resource. There is therefore need to control the sub-surface contaminant load.

In groundwater management, the objective should be to strike a balance between maintaining water supply availability (Foster et al, 1998) and quality, preserving the urban infrastructure and ensuring safe disposal of wastes. The goals of ground water management should therefore be: improving the sustainability of groundwater resource exploitation and making more efficient use of the available resource. The benefits of constraining groundwater abstraction and moderating the sub-surface contaminant load may only be realized in the long term.

Hirji (2000) reports that in the last two decades, the Kenyan government has not accorded water resources management a high priority compared to water development. This has resulted in poor hydrological and climate data collection and analysis; water resources assessment, monitoring, apportionment and allocation, enforcement, catchments management and pollution control. There were also drastic staff cuts of hydrologists and hydro geologists to almost 32% for each through the recently done retrenchment. This does not augur well for ground water resource management.

Mogaka et al (2006) further notes that though the exploitation of groundwater is well regulated in principle, in practice the regulations are largely ineffective. This has resulted to permits being issued on other grounds other than on the basis of assessment of sustainable yields and boreholes being drilled with disregard of procedures due to cumbersome procedures and corruption.

CHAPTER THREE

THE LEGAL AND INSTITUTIONAL FRAMEWORK

3.1. Legal Framework

In a bid to strengthen water resources management for the economic development of the country, the Kenyan government has developed policies and passed laws that seek to regulate sustainable development and usage of water resources.

As part of the research objective, the researcher examined and critiqued the current regulatory and management structures for groundwater management .This was done through a desk analysis of current laws and policies governing groundwater management. Interviews were also done with key personnel in the Ministry of Water and Irrigation, Water Development department.

In this section, the researcher will outline and critique the current regulatory and management structures for groundwater management:

3.1.1. National Policy on Water Resource Management and Development.

Sessional Paper No. 1 of 1999 on National Policy on water resource management and development was developed to guide the utilization of the water resource in the country through promoting sustainable development and management of the water sector.

The policy acknowledges that in the past, the enforcement of the Water Act 372 had been inadequate due to constraint of resources needed to monitor operations of the water users. The Water Act 372 did not also have stiff penalties for non-adherence to its requirements.

The policy provides that a comprehensive environmental impact assessment should be carried out on every major water project. Project development should aim at enhancing the environment rather than degrading it.

The policy acknowledges that pollution of water resources including surface and ground water has been a major problem. Land use activities have affected both the quality and quantity of water resource. It proposes to make the water abstraction and waste disposal permits dynamic and economic instruments for water pollution control. It provides for water quality monitoring of all water bodies and pollution control inspection of potential polluting sources. The policy seeks to control the discharge to the standards set by law.

The policy acknowledges that the database and information flow in the water sector is characterized by data gaps due to discontinuous water resource assessment programmes, weak monitoring systems and an inadequate database. Such a situation could lead to production of unreliable reports, wrong conclusions and more risks in planning hence inappropriate plans and poor resource utilization.

To deal with these problems, the policy proposes to strengthen the institutional capacity of the responsible agencies. Databases for hydrologic, hydro-geologic, water quality, water permits and socio-economic data bases should be established at all water resource management levels. The ministry in charge of water is given this mandate. The policy provides for the increase of funding for procurement and establishment of water resource assessment tools.

The policy mandates the Ministry of Water and Irrigation to set up a research institute on water matters. It is also supposed to monitor and give guidelines on groundwater extraction and utilization.

3.1.2. The Water Act 2002

This is the Act of parliament that provides for the management and regulation of water resources in Kenya. It forms a framework for effecting Sessional Paper No.1 on National Policy on Water Resource Management and Development. The Act separates policy formulation, regulation and service provision and defines clear roles for sector actors and a decentralized institutional framework.

Previously, the Water Act, Chapter 372 of the Laws of Kenya which had been operational since 1962(GOK 1972) was the one that governed the management and regulation of the water resource in Kenya. This Act was operational until 2003. The Act had weaknesses that adversely affected its effective operation. M.W.I. (2005) gives its weaknesses as neglect of the water resource at the expense of water services; weak apportionment and allocation practices for water resource; lack of centralized co-ordination of water use among different sectors; lack of the recognition of the role of communities in water management; lack of standards for services.

The Water Act 2002 separates water resource management from water service provision. It puts the drilling of boreholes and extraction and use of groundwater under the control of the Government through the M.W.I.

Just like in the repealed Water Act Cap 372 of the laws of Kenya, groundwater is defined as the water of underground streams, channels, artesian basins, reservoirs, lakes and other bodies of water in the ground. It also includes water in interfaces below the water table.

Section 3 of the Act vests the ownership of every water resource including groundwater resource in the state. This empowers the state through the Minister for Water to control the use of groundwater. A landowner may hold the title to the land on which there is groundwater. However, s/he has to apply for a permit from the Minister if s/he wants to use the groundwater resource on his/her land. Section 26 of the Act gives exception where a permit may not be required. This includes where the abstraction of water is for domestic purposes in a shallow well, where abstraction is in a groundwater conservation area and abstraction of water which has been gazetted.

According to Foster et al (1998) regulation of groundwater exploitation is achieved more through control of water well drilling including well depth, diameter and screen intake levels rather than licensing pumping after drilling as it happens in Kenya. He further notes that borehole diameter and depth especially for domestic groundwater use should be used to control abstraction rates. This will control overall exploitation and avoid irrational groundwater development. Nairobi area was declared a water conservation area. Therefore a permit is required for any abstraction of groundwater except for domestic use. A permit is also required for any discharge of a pollutant into any groundwater resource.

The Water Resources Management Authority (WRMA) is established by section 7 of the Act. This is a body corporate with the following functions: - to set guidelines for water resource management, to monitor and evaluate water resources, to enforce the requirement of the Water Act, to regulate and protect water resources quality, manage and protect catchments area, maintain a water resources database, advise the Minister on water resource management.

Section 11 requires the Minister to formulate a national water resource management strategy order to manage, protect, use, develop, conserve and control the water resources. This is supposed to be reviewed periodically. However, the Act does not set a time frame within which the strategy should be reviewed. According to Section 18, the strategy shall provide for national monitoring and information system on water resources. Therefore the water resources are to be regularly monitored for water quality and data well maintained and reviewed.

Section 12 requires the Minister to establish water resource quality objectives based on the type, location and geographical factors. In line with this, The Water Resource Management Draft Rules (R.O.K, 2006) gives the guideline standards for water quality of domestic water sources as follows;

Table 5: Guidelines for water quality of domestic water sources

Parameter	Guide Value(max allowable)
Ph	6.5-8.5
Suspended solids	30(mg/L)
Nitrate-	10(mg/L)
Ammonia	0.5(mg/L)
Nitrite	3(mg/L)
Total dissolved solids	1200(mg/L)
Scientific name(E.coli)	Nil/100ml
Fluoride	1.5(mg/L)
Phenols	Nil
Arsenic	0.01(mg/L)
Cadmium	0.01(mg/L)
Lead	0.05(mg/L)
Selenium	0.01(mg/L)
Copper	0.05(mg/L)
Zinc	1.5(mg/L)
Alkyl benzyl sulphonates	0.5(mg/L)
Permanganate value	1.0(mg/L)

Source: GOK (2006)

Section 25 of the Act requires that the application for a permit be made to the authority that may provide approval subject to conditions in the Act or those it may set. A permit is required for use of any water resource or discharge of a pollutant to a water resource.

However, the exemption to seek a permit for shallow wells poses a major risk to users. T he water quality is not tested. There is a risk of the resident drinking contaminated water leading to the spread of water- borne diseases. This problem is further compounded by the fact that that have shallow wells (in Nairobi these are the low income areas of Dagoretti, Riruta, Waithaka, Kinoo and Wangige) are by the sewerage network and drainage is usually to shallow dug pit latrines and soak-pits. This poses a threat of groundwater contamination.

The Water Resource Management draft Rules (G.O.K, 2006) gives the maximum duration of a permit as five years for all type of water use. The draft has proposals of the fees to be charged for different types of permits depending on the water use. It categorizes water use activities from A-D.

Table 6: Fees for assessment and issuance of water permits

Water use and/effluent discharge application	Assessment of application (Kshs.)	Issuance of approval or permits (Kshs)
Category A	1,000	1,000
Category B	5,000	5,000
Category C	20,000	20,000
Category D	40,000	40,000

Source: G.O.K. (2006)

Category A is where the water use is deemed to be of low risk to the water resource. Category B consists of water use activity deemed to make a significant impact on the water resource. Category D deals with international waters, two different catchments areas or large scale projects.

However the Draft does not specify which impacts the water use activities may have on the groundwater resource. Impacts can either be positive or negative and therefore the Draft should be more specific on this. Water for industrial use should attract more fees than that for domestic use. WRMA should liaise closely with NEMA in order to establish the uses which would pose more threats to the groundwater resource. Uses that discharge possible pollutants of groundwater should be heavily penalized.

It is the opinion of the researcher that the proposed fees for the permits are relatively low given the economic status in the country. A fee of Ksh. 2000/= is to be charged for the assessment of application and issuance of a permit under category A.

Adequate fees should be charged to enable the WRMA to raise money which can be used to manage the groundwater resource and adequately cover the administrative cost of WRMA. Alternatively, the permits can be renewed yearly. The fees charged should depend on the location, quality and quantity of the groundwater resource. Groundwater in some areas may be more prone to pollution than others depending on the land use activities being carried out and the underlying rocks.

Foster et al (1998) notes that individual annual groundwater charges should be based on a weighting factor per unit volume. This should depend on: the proportion of consumed water use; the quality and location of the effluence generated; the overall environmental sensitivity of the abstraction in terms of its location and timing, the quality of groundwater supply obtained.

The Water Resource Management Draft Rules 2006 proposes to adopt a uniform rate of water use irrespective of whether the abstracted water is of good or poor quality. It does not also take into consideration whether the abstracted water is in areas where there is a risk of groundwater pollution such as coastal areas, or not.

Though the strategy of the Water Act 2002 is to make the WRMA autonomous and independent from the parent ministry, Section 81 requires the Minister of Water to provide financial subsidies. Therefore the WRMA is still financially dependent on the ministry and the Minister can therefore influence the decisions of the authority .The authority can be affected if the ministry does not allocate enough funds for it to carry out its operations.

Section 44 empowers WRMA to declare some areas ground water conservation areas for the protection of water supplies used by the public, industry, agriculture or other private purposes. The authority may also regulate any use of ground water in this area.

Section 45 provides for the procedures to be followed for abstraction of all ground water, whether a permit is required or not. This is provided for in the fourth schedule which provides for the procedures to be followed in abstraction of groundwater. A person constructing a well or bore-hole contractor is required to notify the authority of his/her intention to construct a well. One is required to keep records of measurements of strata passed through, water struck levels, quantity of water obtained at each level and also at the rest level.

The person drilling the well is required to allow personnel from the authority to have free access to the well and inspect and take copies of any records kept.

However part 2(5) of the fourth schedule allows the authority to exempt a person from the above requirements. This leaves a loop- hole in the enforcement of this regulation.

The provision of water samples is not mandatory as provided by part 3(d). This depends on whether the Authority asks for them. This is a major weakness in the Act.

Provision of water samples should be made mandatory and the Ministry should have processes and mechanisms for testing the samples so presented and certify them or refuse to certify them for use by would be consumers.

Ground water can contain harmful pollutants, especially in heavily build up areas or in boreholes drilled in industrial zones. The concentration of natural occurring chemicals in certain boreholes may be higher than is allowable for human consumption and may be detrimental to human health. Collection and testing of samples should therefore be made mandatory to ascertain quality and suitability of the water for domestic or industrial use.

Part 6 allows a contractor or plot owner to ask for the Authority to treat the records from any well as confidential. No firm reason is provided for treating well records confidentially. This negates the spirit of transparency. It is the researcher's opinion that such information should be unconditionally accessible to the public through appropriate forums, including websites accessible to the public. This will allow people to make informed decision on whether to use water from any borehole. It would also enhance public participation in the management of groundwater.

Part 7 prohibits any waste of ground water. No person is allowed to waste ground water; abstract more than what he/she requires; allow water to leak from pipes. This requirement is supposed to ensure that there is no waste of the groundwater. It also prevents pollution of the water from other sources.

Part 8 provides that any well which encounters salt water shall be sealed off. This is referred to as a defective well. Permission is required for re-casing or unplugging of a defective well. The owner of the well or his agent is the one supposed to do the sealing. This is prone to abuse especially where a person is in desperate need of water. He might use this water, which is a health hazard especially when used for human consumption. The salt water may also seep to the neighboring wells causing pollution of fresh groundwater. The authority needs to carry out random inspections of the defective wells to ensure that they are not unplugged. The researcher recommends that punitive fines should also be charged to those who do not adhere to the requirements of WRMA.

Part 12 allows the WRMA to inspect any wells suspected to contain salty water. This may be out of WRMA own initiative or from complaints from any source. This implies that if there is no complaint, the WRMA will not inspect such a well. The well may continue to be used posing a threat of pollution to the groundwater resource by the salt water infiltrating into the other aquifers which may be of good quality. This also poses a threat to the water consumers.

Part 15 provides for the prevention of contamination of the groundwater resource. The person abstracting the groundwater is required to: seal off any contaminated water; seal off the top of the well; ensure that waste water does not return to the well; extend the well casing twenty centimeters above the pump house; use welded or screw type joints on well casing; dispose domestic, industrial, or any other effluent in a manner that does not pollute the well; carry out any work as the WRMA may order. Effective enforcement of these requirements may prevent groundwater pollution.

Section 16 of the Act provides for the WRMA to set up Catchments Area Advisory Committees (CAAC). The members of the committee are to be drawn from various sectors including public bodies, local authorities, the community, non-governmental organizations and any other competent person. This creates a forum for the stakeholders to participate in groundwater management as discussed in section 2.4.2.

3.1.3. Public Health Act Chapter 242

Section 130 of the Act empowers the Minister for Health to impose rules on Local Authorities (L.A) and others requiring them to protect water supplies in defined areas. The L.A. is supposed to help prevent pollution of water supplies within its jurisdiction which the public uses for drinking or domestic purposes. The L.A. is also required to purify any water supply that has become polluted and to prevent the pollution of streams that might pose a threat to public health.

Section 129 states that it is the duty of every Local Authority to take all lawfully, necessary, and reasonably practicable measures to prevent pollution of any public water supply within its area of jurisdiction. The L.A. is required to take necessary measures to purify polluted water supply within its jurisdiction. They are also empowered to sue any person that causes such pollution of public water supply.

The Act does not however specify the sources of water supply. It is the opinion of the researcher that when it was formulated the Act may have been referring to surface water supply such as rivers and streams .The Act is silent on groundwater supply.

Section 111 of the new Water Act allows anybody with powers to perform duties related to water to continue doing so until such a time this sub-section is revoked.

3.1.4. Environmental Management and Co-ordination Act

The Environmental Management and Coordination Act (EMCA) is an Act of Parliament that provides for the establishment of an appropriate legal and institutional framework for the management of the environment. The Act establishes the National Environmental Managements Authority (NEMA). It gives NEMA the powers of supervision and co-ordination on matters relating to the environment.

The Act defines effluent as any gaseous waste water or liquid or other fluid of domestic, agriculture, trade or industrial origin treated or untreated and discharged directly or indirectly into the aquatic environment.

Environmental monitoring is defined as the continuous periodic determination of the actual and potential effects of any activity or phenomenon on the environment whether short-term or long term.

Section 68 requires the Authority to carry out Environmental audit of all activities that are likely to have significant effect on the environment. In this regard, the Environmental (Impact Assessment and Audit) Regulations, 2002 were established. EIA are conducted to determine whether or not a programme, activity or project will have any impact on the environment.

The Water Act 2002 does not require an EIA to be carried out before a permit to drill a borehole is given. The Water Act 2002 therefore needs to be amended in order to include this provision. NEMA and WRMA need to work in collaboration in order to identify the threat to groundwater in Nairobi and the mitigating measures that can be taken to minimize the effects of these threats to groundwater.

The Second Schedule of the Regulations highlights what is to be considered when carrying out an EIA. These include ecological considerations, sustainable use, maintenance of the ecosystem, social considerations, landscape and land uses. The issues to be considered on water include the water sources such as groundwater, and the drainage patterns. An EIA of any planned activity should therefore highlight what impacts, if any the activity would have on the groundwater resource.

Section 69 requires the Authority to carryout environmental monitoring in consultation with the relevant agencies. This is to be done on industrial projects or any activity to determine the immediate and long-term effects on the environment. Monitoring of all environmental phenomena is supposed to be done with a view to making an assessment of any possible changes in the environment and their possible impacts. Industrial activities are also supposed to be monitored with a view of determining their long term effects on the environment.

An environmental inspector appointed under this Act may enter upon any land or premises for the purposes of monitoring the effects upon the environment of any activities carried on that land or premises.

Section 70 establishes the Standard and Enforcement Review Committee (SERC), which is a committee of NEMA. The SERC is supposed to advice NEMA on how to establish criteria for measurements of water quality. It is supposed to recommend minimum water quality standards for different uses of water including drinking, industrial, agricultural, recreational, fisheries and wildlife.

It is supposed to set guidelines for effluent discharge into the environment and preservation of water resources; advise NEMA to carry out research on water pollution, collect data from local authorities and industries on levels of effluents; recommend on measures to treat effluents and make recommendations on monitoring and control of water pollution.

Section 72 prohibits the discharging or application of any poison, toxic, noxious or obstructing matter, radioactive waste or other pollutants into the aquatic environment. If a person does this he/she is liable to imprisonment or fine.

Section 73 requires all owners of irrigation project schemes, sewerage system, industrial production workshop etc to submit to the Authority accurate information about the quantity and quality of such effluent or other pollutants produced.

Section 74 requires that effluents be discharged only into sewerage system. Industrial owners or traders or workshops which produce pollutants and effluents are supposed to discharge them into existing sewerage systems and the relevant L.A. shall issue them with a license at the prescribed fee.

The industrial owners are supposed to install an appropriate plant for the treatment of such affluent before it is discharged into the environment. This is prior to being granted a license by the L.A. the Act does not specify the standards to which the effluents should be treated.

According to Section 75 L.A. are supposed to obtain a license from NEMA before operating a sewerage system. All industries that discharge effluents are required to obtain effluent discharge license from the Authority.

NEMA is supposed to issue a license after consultation with the concerned L.A. and the organization. It is supposed to take considerations of any possible effects of the effluents or pollutants to be discharged on the quality of an affected watercourse or other source of water.

Section 77 requires the Authority to maintain a register of the effluent discharge licenses issued. This register can be inspected by members of the public at a fee.

Section 85 requires NEMA through SERC to identify wastes that are harmful to the human and environment and set standards for the disposal of these wastes.

Section 86 prohibits the discharge of waste that may cause pollution to the environment and affect human health.

In section 94, the SERC is supposed to recommend measures for monitoring the effects of pesticides and substances on the environment.

The Act sets environment quality standards for air, hazardous waste, noise and water. All types of water sources are lumped together. There are no specific guidelines on how to manage groundwater in particular.

The NEMA act is very comprehensive and very broad and addresses potential and actual threats to ground water quality and exploitation. There is need to integrate the NEMA act with the WRMA and require any persons wishing to drill and supply groundwater to adhere to the provisions of the NEMA Act.

The major weakness the researcher sees is in the enforcement of the relevant sections of the NEMA act in ground water management and recommends that an enforcement mechanism be developed to ensure that groundwater exploitation adheres to good environmental protection principles that the NEMA Act seeks to enforce

The Public Health Act empowers the L.A. to take the necessary measures to prevent pollution within their areas of jurisdiction. At the same time, EMCA 1999 appoints NEMA as the body charged to do the same in the country. There is therefore conflict that may put at risk pollution control measures.

It is the opinion of the researcher that the WRMA should be at the forefront in identifying the potential risk to the groundwater resource in Nairobi. The WRMA should then work closely with NEMA and the NCC to ensure that activities that pose a threat to the groundwater resource are curtailed. In setting up the minimum water quality especially for drinking water, the WRMA should consult the Ministry of Public Health. Regular monitoring of the groundwater should be done to ensure that there is no pollution.

3.2. Institutional framework

Table 7: The roles and responsibilities of the institutions involved with groundwater management under MWI.

Institution		Roles and responsibilities
1.	Ministry of Water and Irrigation (MWI)	• Development of legislation, policy formulation, sector coordination and guidance, and monitoring and evaluation.
2.	Water Resources Management Authority (WRMA)	• Planning, management, protection and conservation of water resources. • Planning, allocation, apportionment, assessment and monitoring of water resources. • Issuance of water permits. • Water rights and enforcement of permit conditions. • Regulation of conservation and abstraction structures. • Catchments and water quality management. • Regulation and control of water use. • Coordination of the IWRM Plan.
3.	Catchments Area Advisory Committees (CAACs)	• Advising WRMA on water resources issues at catchment level.
4.	Water Resource Users Associations (WRUAs)	• Involvement in decision-making process to identify and register water user. • Collaboration in water allocation and catchments management. • Assisting in water monitoring and information gathering. • Conflict resolution and co-operative management of water resources
5.	Water Services Regulatory Board (WSRB)	• Regulation and monitoring of Water Services Boards. • Issuance of licenses to Water Services Boards. • Setting standards for provision of water services. • Developing guidelines for water tariffs.
		•
6.	The Water Appeals Board (WAB)	• Arbitration of water related disputes and conflicts.
7.	Kenya Water Institute (KEWI)	• Training and Applied Research in water.

Source: MWI (2007)

The institutions involved with groundwater management under the Water Act (2000) are MWI, WRMA, CAAs, WRUAs, Consumers and users. Other institutions are

NEMA. NCC and the Ministry of Environment. These institutions need to be well coordinated in order to manage the groundwater resource in Nairobi. As discussed earlier. WRMA work under the Water Act, 2002 while NEMA works under EMCA

CHAPTER FOUR

THE STUDY AREA

4.1. INTRODUCTION

The study area for this research is the city of Nairobi which is the Capital City of Kenya and the headquarters of Government administration located to the south-east of Kenya.

Nairobi was established in 1899 as a railway camp during the construction of Mombasa-Uganda railway line (Morgan, 1967). The site was chosen for its level topographical nature as well as availability of water from the Nairobi River, which gives the city its name. Before the establishment of the railway camp, Nairobi used to be the dry season grazing and watering ground for the Maasai people.

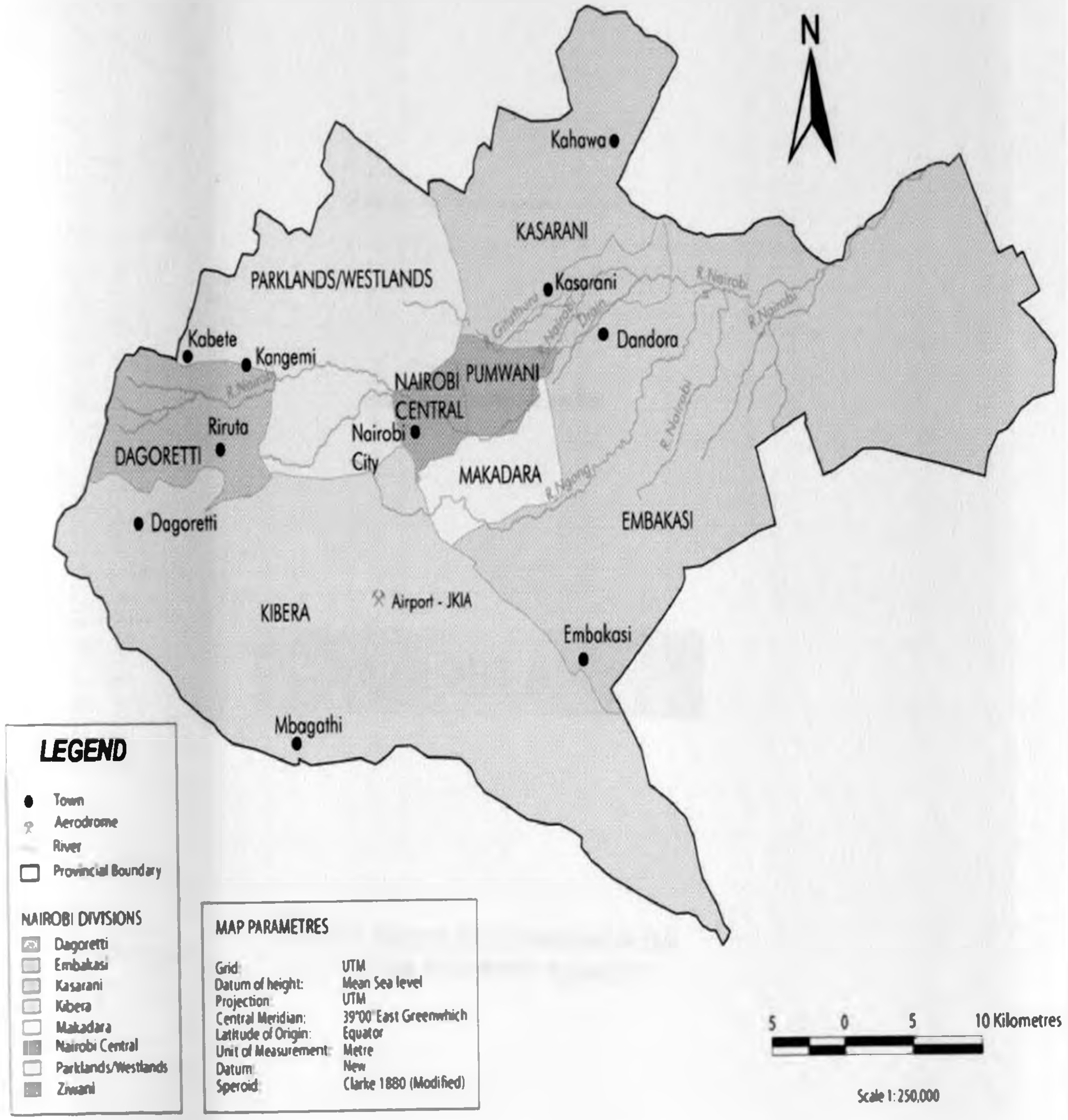
Nairobi later became the government headquarters after government administration was moved from Machakos (Morgan, 1967). According to NCC et al (2007) the construction of the Kenya-Uganda Railway led to the growth of Nairobi as a commercial business hub of the British East Africa Protectorate. Nairobi has since grown from a railway camp to a bustling city with the population approaching of 3 million people (NCC et al 2007).

According to Un-Habitat (2006) Nairobi is an international, regional, national and local hub for commerce, transport, regional co-operation and economic development. The city has therefore grown from a small railway post to an international center. It has experienced increased population growth from rural-urban migration and also natural growth.

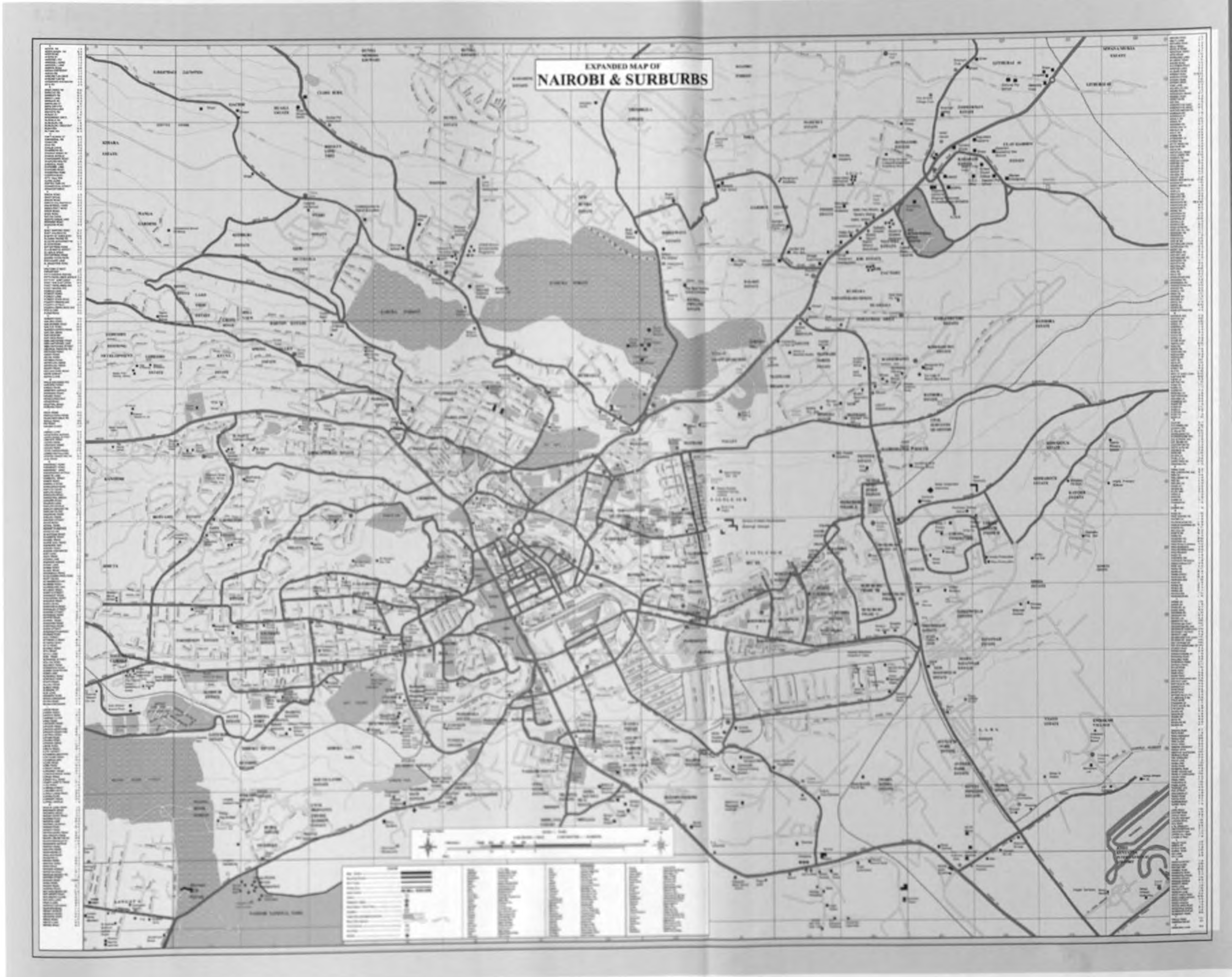
Map 1: Nairobi in the National context

Adapted from Ministry of Lands (2007)

Map 2: Nairobi administrative map



Adapted from Nairobi River Basin Programme (UNEP)



NAIROBI AREA

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4.2. Geography and Climate

According to NCC (2007) the altitude of Nairobi varies with the eastern side being 1600 meters above sea level. The western side is 1700-1800 meters above sea level.

Kenya experiences bimodal rainfall which occurs in two seasons of March-April – May and October- November- December (NCC, 1996). The mean annual rainfall is 1080mm. This falls during the long rains from March to May and the short rains from mid-October to December. The mean annual temperature is 19 degrees centigrade and the mean daily maximum and minimum temperatures are 25 degrees centigrade and 14 degrees centigrade respectively. (Moss, 1981)

4.3. Population

Table 8: **Nairobi: Population for selected years, 1906-1994**

Year	Area (ha)	Population	% increase p.a.
1906	1,813	10,512	4.4
1928	2,537	29,864	17.1
1931	2,537	47,944	6.5
1936	2,537	49,606	6.5
1944	2,537	108,900	6.5
1948	2,537	118,976	2.2
1962	2,537	266,795	5.9
1969	68,945	509,286	9.8
1979	68,945	827,775	5.1
1989	68,945	1,324,570	4.8[a]
1994[a]	68,945	1,690,000	5

Adapted from Obudho (1997)

According to UN (2001) estimates shown in Table 8, there has been a steady increase in the population of Nairobi from 10,512 in 1906 to 1,690,000 in 1994.

The 1999 population census report indicate that Nairobi had a total population of 2.143,245 residing in an area of 696 Square Kilometers giving population density of 3079 persons per square Kilometer placing the total population. Given that the population of Kenya then was 28,689,607, 7% of the Kenyan population was residing in Nairobi.

It is estimated that the population of Nairobi will be 3,750,000 by the year 2010 (UN-Habitat, 2006).

Table 9: Percentage estimates of the country's population residing in Nairobi (with 750,000 or more inhabitants) from 1980-2015 with five year interval.

Year	1980	1985	1990	1995	2000	2005	2010	2015
Percentage	5.2	5.5	6.0	6.7	7.7	8.7	9.5	10.0

Source: United Nations (2001)

Increased population growth has resulted in increased demand for urban services including water.

4.4. Land use

Nairobi has experienced changes in land use from a small railway camp to a capital city with residential, commercial, industrial, institutional and recreational land uses.

This has greatly impacted on the water demand and supply.

Table 10: Land use types of Nairobi in 1994

Land use type	**Area (km2)**	**Over (%)**
Residential areas	175.6	25.22
Industrial/commercial/service centers	31.8	4.57
Infrastructure	15.9	2.28
Recreation	12	1.72
Water bodies and riverine areas	11.8	1.69
Urban agriculture	96.8	13.9
Open lands	198 8	28.55
Others (including protected areas)	153.6	22.06

Adapted from: NCC et al (2007)

There has also been an increase in the spatial extent of Nairobi from 3.84 square Kilometers in 1910 (NCC, 1996) to 587,677 square Kilometers in 1999 (Government of Kenya, 2001). Therefore the area to be supplied with water has greatly increased, with the subsequent need for increased surface coverage for water supply. This has great cost implications for the city water utility company, which faces problems of underfunding and cost recovery.

NCC (1996) reports that the first land use plan of Nairobi, made in 1910, mainly consisted of railway yard, commercial center and residential areas occupied by Europeans and Asians. In 1948, due to increase in population, a zoning plan was made which consisted of industrial, residential, open spaces, public land use and recreational sites.

However, according to NCC (1996) the current major land use types in Nairobi are residential, industrial, commercial, forest, recreational, agricultural and open spaces. Other types of land uses are given as infrastructure, quarrying, sewage, hospitals, drive-in cinemas and water bodies.

NCC (1996) gives the categories of residential land uses as high, low and very low habitation areas. The very high-density areas have population densities of over 15,000 persons per square kilometer. They are areas to the North East, South East and South West of Nairobi. The high-density areas are populated by the low-income residents of the city. They form the Eastland part of Nairobi and include Dandora, Kayole, Kariobangi and Mathare areas. There are also informal settlements including Kibera and Mathare.

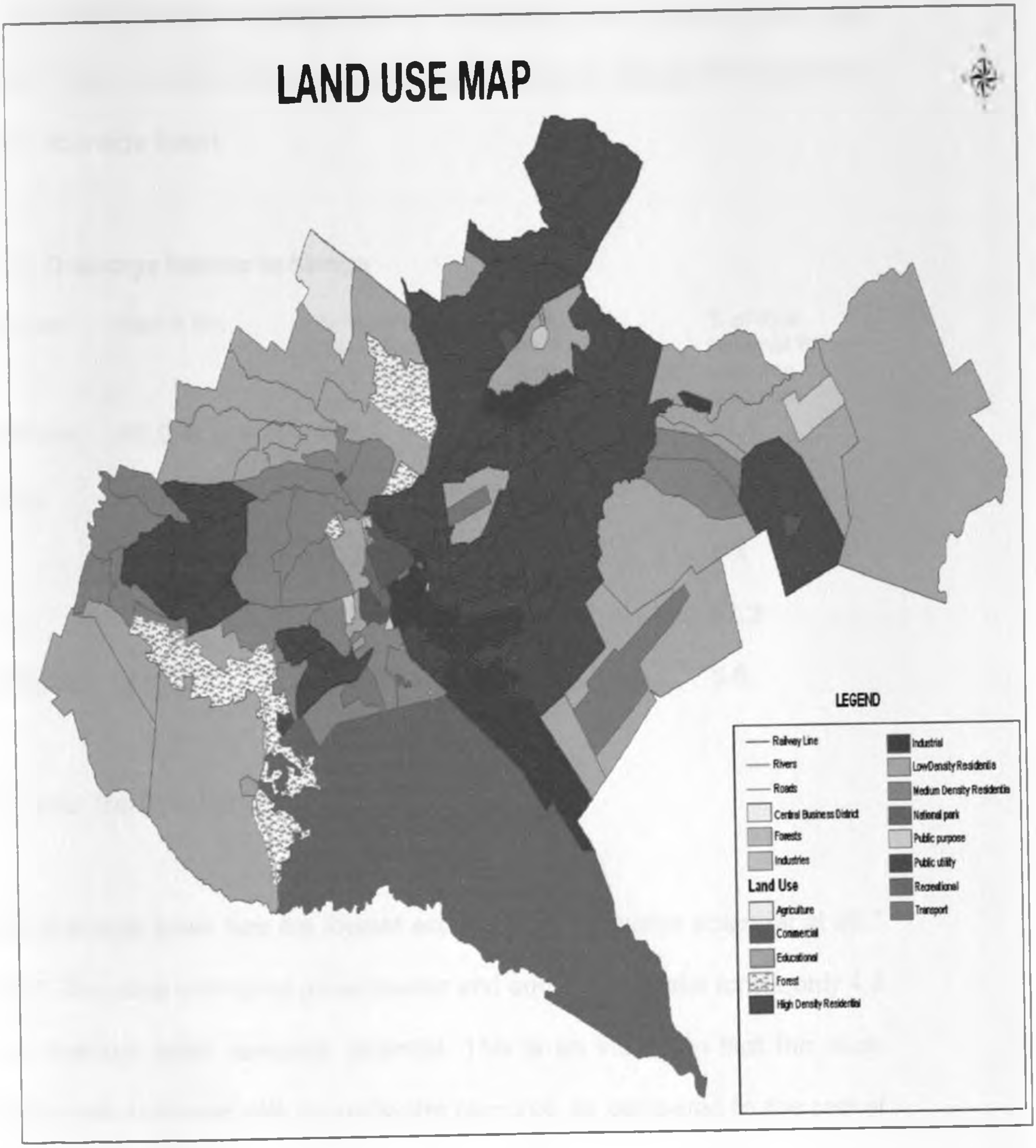
The low density areas have 6,000-15,000 persons per square kilometer. They are areas around the city and include Nairobi south. They are also middle income areas.

The high income areas are in the suburbs of Karen-Langata, Kitisuru, and the former coffee estates of Runda, Kitisuru and Ridgeways.

The researcher has observed that the residential pattern in Nairobi is highly influenced by the historical background of the city. During the colonial period, the high density areas were occupied by indigenous Africans. The medium density areas were occupied mainly by the Asians while the low density areas were occupied by the Europeans.

The map below show the different types of land use in Nairobi

Map No.4: Land use in Nairobi



Adapted from Ministry of Lands (2007)

4.5. Drainage basin

Kenya is divided into five drainage basins. These are Lake Victoria, Rift Valley, Athi River, Tana River and Ewaso Ngiro drainage basins. Nairobi falls under the Athi River drainage basin.

Table 11: Drainage basins in Kenya

Drainage basin	Size in Km	Estimated groundwater potential in Million m^3	Estimated surface water potential in billion m^3	% of total National Water resource potential
Lake Victoria	46,000	115.7	11.672	54.1
Rift Valley	130,000	125.7	2.784	3.4
Athi	67,000	86.7	1.152	4.3
Tana	127,000	147.3	3.744	32.3
Ewaso Ngiro	210,000	142.4	0.339	5.8

Adapted from National Water Master Plan 1992(2005)

The Athi drainage basin has the lowest estimated groundwater potential at 86.7 million m^3. The total estimated groundwater and surface potential forms only 4.3 % of the national water resource potential. This is an indication that the study area is not well endowed with groundwater resource as compared to the rest of the country.

4.6. Water supply

The main source of water supply in Nairobi is piped water supplied by the NCWSC.

According to the Government of Kenya (2001) domestic piped water supply forms 92.67% of the total water supply serving 649,426 of the households in Nairobi while groundwater forms only 2.01% serving 13,049 residents.

However, most residents in Nairobi use groundwater to supplement the unreliable City Council water supply. This is not captured in the census results. Borehole water can also be supplied to consumers through pipes. Table 12 shows the main drinking water sources for Nairobi residents.

Table 12: Main Sources of drinking water for Nairobi residents- 1999.

Source	Number of Households	Percentage
Pond	19,792	3.05
Dam	1,577	0.24
Lake	2,119	0.33
Stream/river	1,940	0.30
Spring	2,506	0.39
Well	2,654	0.41
Borehole	10,395	1.60
Piped	601,809	92.67
Jabias/Tank	6,637	1.02
TOTAL	649,426	100.00

Source: Government of Kenya (2001)

Nairobi City Council (2001) gives the installed production capacity of the water sources of Nairobi as 560,000m^3/d. This was estimated to be adequate to meet the water demand for Nairobi up to the year 2007. However, the installed water production capacity differs from the actual production capacity, which is 396,000 M^3/d.

Table 13: Water sources, installed capacity, and normal production for NCC

Source	Installed Capacity (m3/d)	Normal production m3/d
Kikuyu springs	4000	4000
Rural	22,700	12,000
Sasumua Dam	59,000	44,000
Ngethu Treatment Works (including water from Ndakaini Dam)	440,000	336,000
Total	525,700	396,000

Source: Nairobi City Council (2001)

The bulk of the water supply from Nairobi comes from Ngethu treatment works. N.C.C. has reservoirs in Kikuyu springs, Dagorreti, Uthiru, Karen, Loresho, Kyuna, Kabete,Hill Tank, Gigiri and Karura .Table 14 below gives their capacities.

Table 14: Nairobi Reservoir Capacity

Area	Capacity (m3)
Kikuyu spring	2,200
Dagoretti	11,000
Uthiru	11,000
Karen	5,000
Loresho	450
Kyuna	900
Kabete	59,000
Hill Tank	18,000
Gigiri	61,000
Karura	9,000

Source: Nairobi City Council (2001)

A lot of water is lost through leakages and this affects the total volume available to the consumers. Unreliability of water supply by the NCWSC and extreme climatic changes leading to drought has made the water consumers look for alternative water sources. Ground water has been a readily available water source.

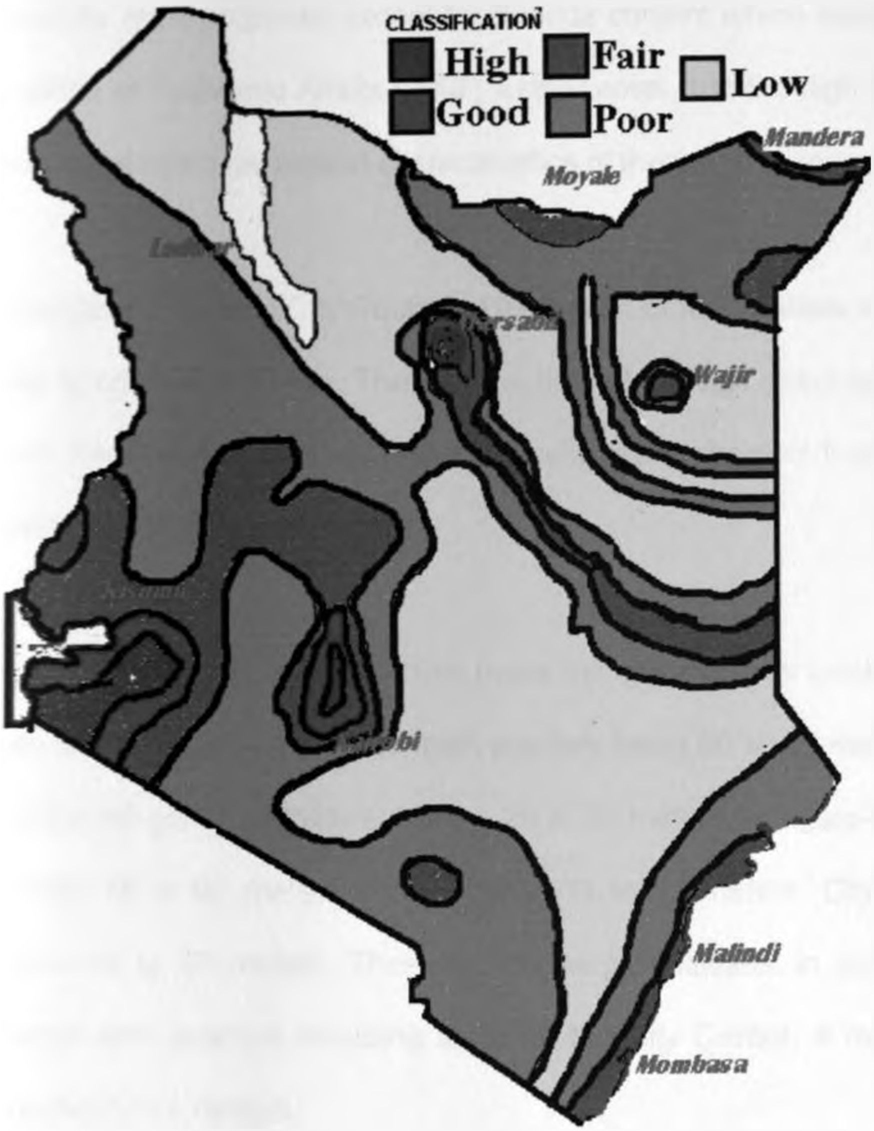
Nairobi City Council (1996) notes that the densely populated informal settlements of Kibera, Mathare, Kibarage and Mukuru in Nairobi face the problem of unavailable, unreliable and inadequate water supply. About 86% of the population obtains its water from kiosks while only about 12% have water supply into their plots. The other main sources of water are roof catchments, boreholes and river water.

4.7. Groundwater

According to NCC et el (2007), the groundwater basin in Nairobi extends from the west of the City to the Athi flood plains east of the City. The geology of the study area is mainly made up of volcanic lavas and ashes. The groundwater aquifers mainly comprise of Kerishwa valley series and Upper Athi series.

Institute of Economic Affairs (2007) note that the Kerishwa valley series and Upper Athi series are porous and permeable allowing for water percolation and therefore making the rocks favourable for recharge of aquifers. The lower Athi series has more clay and therefore forms a sub-surface rock that does not yield sufficient water quantities.

Map No. 5: Classification of groundwater quality in Kenya



Adapted from Ministry of Water and Irrigation (2007)

According to Ministry of Water and Irrigation (2007), the groundwater quality in Nairobi area is generally of good quality compared to other parts of Kenya. Onjala, (2007) notes that groundwater in Nairobi contains little dissolved solids and has low electrical conductivity. It is therefore suitable for all types of domestic use. Foster et al (2005) further notes that the groundwater quality in Nairobi is good for most purposes except for fluoride content which exceeds 1 mg/1. The Institute of Economic Affairs (2007) further notes that the high fluoride content is due to the hydro-geological characteristics of the volcanic rocks in the area.

According to Nairobi City Council (1996) most of the aquifers in Nairobi area are free or confined aquifers. They are recharged through direct precipitation mainly from the Kikuyu Highlands. Shallow wells are recharged from streams, rivers, springs or direct precipitation.

Nairobi City Council (1996) further notes that groundwater level is generally deep with the average depth of the main aquifers being 60 to 90 meters. The average depths are given as follows; Karen- 20 to 35 meters, Langata-70 to 100 meters, Kamiti- 15 to 60 meters, Spring Valley-11 to 25 meters, City Centre and Athi Plains-15 to 90 meters. There is shallow groundwater in areas close to river valleys and swamps including areas in the City Center, 4 meters and Adams Arcade, 6 to 8 meters.

There has been increased abstraction of groundwater in Nairobi area as shown in Table 15 below.

Table 15: Boreholes drilled in Nairobi Area from 1997-2001

YEAR	1997	1998	1999	2000	2001
Number of water wells	32	32	44	61	97
Average depth(m)	221	209	218	227	238
Average static groundwater level(m)	96	86	97	109	106
Average initial pumping yield(m^3/hr)	8	9	8	11	12

Source: Foster et al (2005)

Table 15 above shows that the number of boreholes has increased from 32 in 1997 to 97 in 2001.This represents a 67% increase in the number of boreholes drilled in Nairobi in a 5 year period.

Though the average depth of borehole decreased in 1998 and 1999, it increased from 218 meters in year 1999 to 238 meters in year 2001. Mogaka et al (2002) notes that increase in the average depth of boreholes in Nairobi has resulted in increase in the drilling and pumping costs.

According to Central Bureau of Statistics, 2006 the total number of boreholes drilled in Kenya excluding Nairobi in 2001 was 151.Therefore about 40% of the boreholes drilled in the country were in Nairobi.

The major sources of groundwater pollution in Nairobi are domestic and industrial wastewater (Nairobi City Council, 1996). According to Nairobi City Council (1996) about 90% of the population in informal settlements does not have access to adequate sanitary facilities. Due to lack of water borne sewerage system, pit latrines are the major method of excreta disposal. The pit latrines mainly drain into rivers and adjacent drains. There is also dumping of garbage into the nearby rivers. This pollutes the surface and groundwater sources.

Nairobi City Council (1996) further notes that discharge of effluents without treatment or with minimum treatment directly into the water courses of Nairobi and Ngong rivers poses a serious threat to groundwater quality. There are industries such as textiles, metal processing and tanneries which discharge their effluents directly into the soils without site treatment. Such practices can lead to leaching of arsenic and cadmium chemical substances into the groundwater. As shown in Table 4 these are carcinogens and can be harmful to human beings.

4.8. The River System

The land use Map No. 5 shows the river system in the study area. Nairobi and its environs lie within the Athi river Basin (NCC, 1996). Nairobi River which rises near Kikuyu springs, and its tributaries of Ngong and Mathare rivers are the natural drainage of Nairobi and also the outlet of the man-made drainage system.

The source of Ngong River is the Mutu-ini swamps at Dagoretti Market. It flows through Ngong forest and into Nairobi Dam. Sewage from Kibera slum is disposed into this river and it eventually drains into the Nairobi Dam. Drainage systems from estates along Ngong road, Nairobi Hill, Mombasa and Langata Roads and the industrial area also flow into the Nairobi dam.

Gitathuru River is a tributary of Nairobi River. Its source is from Limuru and Kikuyu. The river passes through Kariobangi treatment works where waste water from nearby factories flows into it. Mathare River which is a tributary of Gitathuru River receives domestic effluent as it flows through the slum in Mathare Valley.

Nairobi River and other tributaries flow into the Athi River. Athi River receives a lot of industrial effluent from industries along Mombasa Road and Athi River town, which lack proper mechanisms for collecting and treating of effluents (Nairobi City Council, 1996).

Other rivers flowing through Nairobi are small streams – Kiu, Ruaraka, and Kamiti Rivers. These mainly receive wastes from coffee processing factories near their courses (NCC, 1996).

According to Nairobi City Council (1996) the Nairobi river receive pollution from the following sources: industrial effluents from factories, godowns, business premises; raw sewage from blocked, broken or overloaded NCC sewers; sewage from the informal settlements and sectors such as slums, markets and Jua Kali premises; effluents from public and private sewage treatment works; effluents from petrol stations and garages; surface run off; soil wastes and garbage dumped in the rivers by NCC, squatters and Jua Kali premises.

Nairobi City Council (1996) notes that data collected in1995 on the pollution of Nairobi and Ngong Rivers shows that the rivers are very much polluted and they carry contamination loads way above those accepted for domestic, industrial and agricultural purposes.

Since the rivers also recharge the underground aquifers, the pollutants infiltrate into the underground water and further compromises the quality of the water.

CHAPTER FIVE

RESEARCH FINDINGS

5.1. Ground water management by MWI

The researcher held interviews with key informants in the Ministry of Water and Irrigation. These are under the Department of Water Development in the MWI. The officers are geologists by profession. This department is the one charged with dealing with groundwater in Nairobi before the implementation of the Water Act, 2002.

From the interviews, it emerged that the MWI has implemented the legal and policy frameworks as follows:

5.1.1. Strengthening of institutions

The enactment of the Water Act 2002 led to the establishment of WRMA. This started operating in 2006. The WRMA licenses borehole drilling contractors. It is also responsible for issuing groundwater drilling licenses, abstraction licenses and levying of water use charges. Before one can drill a borehole, s/he has to apply to the WRMA for a drilling permit. The drilling should be done by a licensed drilling contractor. The abstraction permit is issued for one to start using the borehole water. This is after the water quality is analyzed to ensure that it is suitable for the use it is intend for.

5.1.2. Permits

The MWI admitted that most of the existing borehole permits were issued under the repealed Water Act, 372. The terms under which the permits were issued are therefore in conflict with the Water Act, 2002. There is therefore need to review the borehole permits to conform with the requirements of the Water Act, 2002

The MWI also admitted that there may be permits which are issued and the owners do not drill the boreholes. There is potential for confusion if the Ministry records each permit issued as a borehole drilled. There is need to tie the issuance of permits to actual drilling and regular reconciliation of the number of permits issued against actual boreholes drilled and as necessary, revoking permits whose owners have not drilled within a specified time period.

The Ministry also informed this researcher that there are many incidences where drilled boreholes are no longer in use due to lack of water, probably due to lowering of the water table and/or to lack of adequate recharge of the boreholes.

The Ministry does not seem to have a mechanism for monitoring and updating their databases on boreholes that are active and boreholes that no longer have water. The Ministry does not also have up to date data on the actual discharge of boreholes once drilled. They rely on the borehole owners to provide this information. As a result, the data the Ministry has on the number of active boreholes and actual discharge may be inaccurate. The implications of this are that the Ministry is not in a position to determine the rate of usage of groundwater resources and the continued sustainability of this resource.

The Ministry does therefore need, as a matter of urgency, to come up with policies and processes that would enable it to monitor on a continuous basis the drilling and abstraction of groundwater resources of all approved boreholes. This will facilitate in formulation of policies and guidelines that protects the groundwater resource.

5.1.3. Licensing of borehole drilling contractors

The contractors are the ones authorized to drill boreholes by WRMA.

Before a borehole is drilled, the property owner applies for a borehole drilling permit and introduces the contractor who is to drill. The contractor is supposed to provide information to the WRMA on the location of the borehole, purpose of water use, borehole depth, water struck levels, water rest levels. Once the borehole is drilled, a sample of water is taken to the government for a chemical analysis. Where the fluoride levels of the water are higher than the recommended minimum, the client is asked to mix the water with the Nairobi City Council water supply in order to minimize the fluoride content.

The taking of the water samples for testing seems to rest on the goodwill of the borehole owner. There is no system in place that ensures that the water taken for testing is from that particular borehole and crooked borehole owners can easily substitute the sample with samples from other boreholes or even with NCC water.

The borehole owner is also the one required to take the sample for testing. As noted above, the trust bestowed on the borehole owner is prone to abuse. There is need to change the procedure and have the WRMA take the sample and test it themselves and certify that the water is safe or not safe for its intended use.

However the officials admitted that there is a likelihood of boreholes being drilled in the study area without the approval of the government. The WRMA is therefore not able to determine key parameters like the depth at which the water was reached, the chemical composition of the struck water, the proximity of boreholes to one another, the risks of over abstraction and ground subsidence etc.

There is urgent need therefore for stiff penalties to be meted to contractors or persons who drill boreholes without the required approval. This necessitates the financing of the WRMA to be able to undertake policing activities. Alternatively, a mechanism should be put in place that informs local chiefs under the provincial administration, of approved drillings in their areas and empowers them to report and take the necessary legal actions if they find illegal drilling taking place in their areas of jurisdiction. Where the property has sewer system, the NCWSC usually takes the meter reading of the borehole. This is in order to charge for the use of the sewer services because it is assumed that the water eventually discharges into the sewer system .The WRMA should therefore work in collaboration with the NCC.

5.1.4. Groundwater monitoring

Before July 2005, there was virtually no monitoring of groundwater in Nairobi. However, with the establishment and operation of WRMA, this has changed. Since July 2005, WRMA has been monitoring an average of twenty boreholes in Nairobi. The boreholes are owned by individuals or by institutions.

The main objective of groundwater monitoring is to monitor the water rest levels in order to observe if there is any excessive abstraction of groundwater.

In carrying out the groundwater monitoring, WRMA has not faced any major resource challenges. It has adequate resources and well trained personnel. However WRMA faces the challenge of accessing the boreholes. Most of the boreholes are privately owned. The owners are suspicious of anything to do with the government. Monitoring also involves switching off the boreholes for 48 hours. Most borehole owners are not therefore willing to give access to WRMA for their boreholes to be monitored.

There is need to entrench the monitoring of boreholes into an amended Water Management Act and make it illegal to bar or deny WRMA Officials access to any borehole.

5.1.5. Computerized data bank

There is a computerized data bank in the MWI. This has all applications for borehole drillings in Kenya. It also has information on analysis of chemical content of groundwater. This information is supplied by the applicant who is the landowner or the drilling company, on his/her behalf. WRMA officials are now verifying it. It was noted that the data bank is not up to date due to lack of regular updating as a result of shortage of personnel in this area.

The researcher also noted that the data on chemical analysis is kept separate from that on borehole drilling. All the data concerning one borehole should be stored together. This makes retrieval of information very easy.

The data from all areas in Kenya is lumped together. There are no separate databanks for different areas in Kenya.

5.1.6. Land use planning

The MWI does not incorporate land use planning in groundwater management.

5.1.7. Measures on groundwater conservation

Every borehole is required to be fitted with a water meter. WRMA usually carries out field inspection to ensure that this is done.

The borehole drilling permit is issued on the basis of the volume of water to be abstracted.

Nairobi is still a groundwater conservation area. Therefore drilling of boreholes is closely monitored. Permits are only issued on exceptional cases especially where the borehole will serve the public good.

According to the Water Act, no permit is given for boreholes within a radius of 800 Meters.

WRMA encourages borehole owners to supply water to their immediate neighbors instead of their neighbours drilling additional boreholes.

5.1.8. Groundwater abstraction charges

Once a groundwater abstraction permit is issued, it is renewed every five years after payment of fees. The fees are as shown in Table 14. In the opinion of the researcher the fees should be reviewed annually. In a five year period, the use of the water can change from low risk to high risk. Therefore having short period of review would help in monitoring the water use category.

Groundwater permits are charged on the basis of the volume of abstracted water. The use for which the water is to be put and its quality are not taken into consideration. The location of the borehole is also not factored in. The charge is uniform across the board. The permit has a limit of the volume of water that should be abstracted. Penalties are charged for over abstraction of groundwater.

As discussed in Chapter 2, charges for water use should be realistic and should cover administrative costs. The charges should also be based on quality and location of the borehole. It is noted that the WRMA does not use these parameters for purposes of charging.

There is also a penalty for over abstracting. The WRMA visit the site and if they find that one is using the water above the permitted limits, then s/he is fined.

5.1.9 Stake holders' participation

Though the Water Act 2002 provides for involvement of the water resource user in the management and development of the resource the WRMA has not yet started involving the public in ground water management.

5.1.10. Conjunctive water use

The borehole water extraction permit sets the limit of water which should be abstracted from the borehole in a day. If the borehole owner water demand is above the set limit, one is supposed to top up the water from the municipal water supply. Where the fluoride content in the borehole is above the WHO recommended limit, WRMA advices that the water is mixed with the council water so that the fluoride content is diluted. However there is no follow up to ensure that this recommendation is implemented.

5.1.11. Groundwater quality analysis

The MWI has a laboratory which is used to analyse the chemical content of the drilled borehole water. It is not mandatory to give a sample of the water for testing.

The water is mainly analysed for such contents as iron, zinc, manganese, nitrate, nitrite, calcium, fluoride and Total Dissolved Solids. The analysis does not include chemicals whose source can be from manufacturing industries and are carcinogens. These include arsenic and cadmium. According to the MWI, groundwater is generally of good quality unless it has high iron content. Where the fluoride quality is high, the Ministry usually advices the users to use the water in conjunction with water from NCC in order to dilute the fluoride content.

5.1.12. Groundwater pollution control

The enactment of EMCA and the establishment of NEMA is envisaged to ensure that no activities that are likely to pollute ground water are allowed to take place.

However, there is no evidence of an EIA that has been done on borehole drilling. NEMA should work in collaboration with WRMA to ensure the protection of groundwater in Nairobi.

5.2. Groundwater use

To determine usage of groundwater use, data on boreholes permits issued and boreholes drilled was collected from the Water Department of the Ministry of Water and Irrigation. The data is computerized and covers the period from 1940 to 2000.

The borehole drillers provide the MWI with samples of the water from the borehole. Tests are done on water in order to determine whether the quality is suitable for the intended purpose. The various levels where water is struck when the drilling is done are also recorded and provided to the Ministry. This data is then computerized by the MWI personnel.

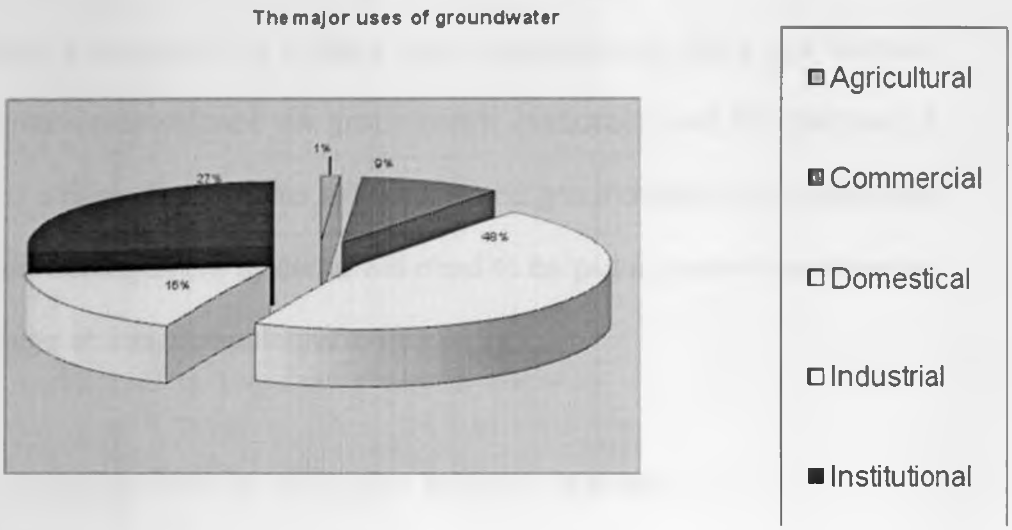
This data was analyzed using Microsoft Excel to determine the major uses of borehole water in Nairobi. The uses are categorized into domestic, commercial, industrial institutional and agricultural uses.

To establish the major uses of boreholes in the study area, a sample of 100 boreholes was randomly selected. This was based on the purpose for which a permit for drilling of boreholes is applied for.

Table 16: Groundwater use in Nairobi

User of the borehole	Number of boreholes	Percentage
Agricultural	2	2%
Commercial	9	9%
Domestic	47	47%
Industrial	16	16%
Institutional	27	27%
Total	100	100%

Chart 2: Major uses of groundwater



The pie chart shows that borehole applications for water for domestic use forms the bulk of water permit application at 47%.This is followed by institutional use at 27%, industrial use at 16%, and commercial use at 9%. Agricultural use is the lowest at 1%.

As mentioned in chapter three, the growing population of Nairobi is putting tremendous pressure on available water resources. From the data above, the researcher concludes that residents of the city are beginning to rely more on groundwater resources. Institutions, industries and commercial entities are also feeling the shortcomings of piped water supply, hence the increasing number of applications from these users.

With global warming becoming a reality, it is widely expected that countries in the African continent will experience more frequent droughts and erratic rainfall, thereby reducing the amount of surface water available for cities like Nairobi. There will be more dependence on groundwater resources and the number of applications for drilling of boreholes will rise. Since groundwater is a renewable resource, sound management systems will need to be put in place to ensure the sustainable usage of this increasing vital resource.

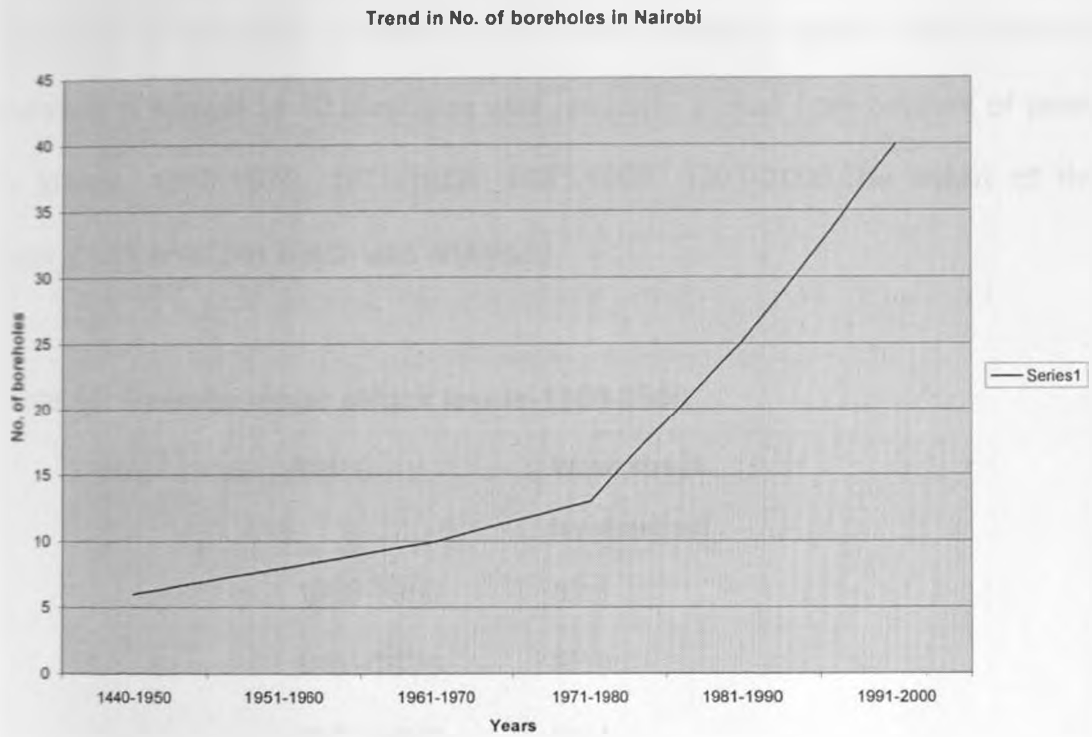
5.2.1 Trends in the number of boreholes drilled in Nairobi

This data was obtained from boreholes drilled in Nairobi from 1940-2000. The boreholes were grouped in years as follows; 1940-1950, 1951-1960, 1961-1970, 1971-1980, 1981-1990, and 1991-2000.

Table 17: Trend in the No. of boreholes drilled in Nairobi

Year	No. of boreholes
1940-1950	6
1951-1960	8
1961-1970	10
1971-1980	13
1981-1990	25
1991-2000	40
Total	102

Chart 3: Trend in the No. of boreholes drilled in Nairobi



The sample of boreholes in Nairobi indicates that the number of boreholes have increased from 6 in the year 1940-1950 to 40 in the years 1990-2000.This is about 85% increase.

This can be attributed to increased water demand in the City, unreliability of Nairobi City Council water supply and changes in climatic conditions resulting from reduction in rainfall which lowers the dam levels of the supply for the Nairobi City Council. All these factors have made surface water unreliable hence the increased reliance on borehole water.

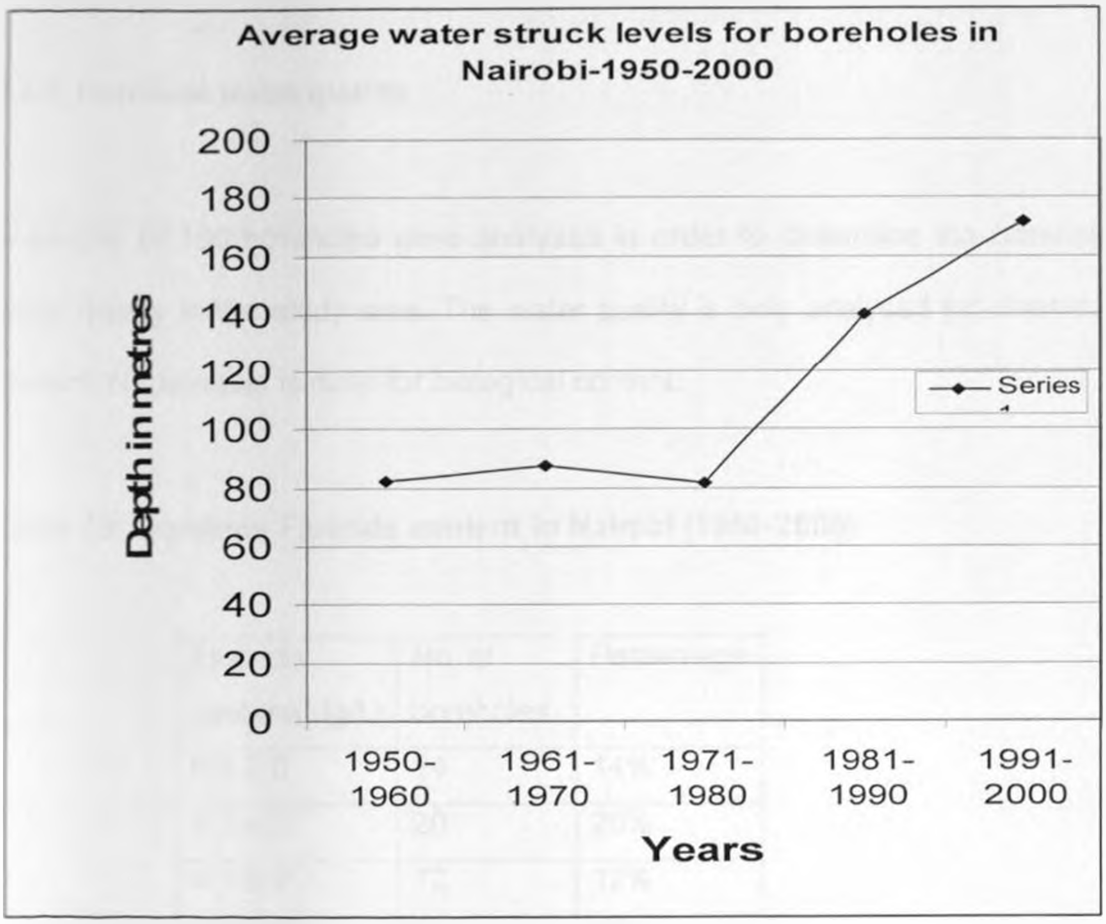
5.2.2. Average borehole water struck levels

The water struck levels of boreholes in Nairobi between years 1960-2000 was analyzed. A sample of 10 boreholes was randomly picked from batches of years as follows, 1960-1970, 1971-1980, 1981-1990, 1991-2000.The mean of the water struck level per batch was analysed.

Table 18: Average water struck levels-1950-2000

Years	Water struck level(metres)
1950-1960	82.1
1961-1970	87.9
1971-1980	81.4
1981-1990	139.8
1991-2000	171.7

Chart 4: Average borehole water struck levels



The table and chart 3 shows that there has been an increase in the water struck levels in Nairobi over the years. The depth increased from 82.1 meters in 1950 to an average of 171.7 meters in 2000.

This is about a double increase in the depth at which water level is struck when drilling boreholes in Nairobi. This may be an indication of lowering of the water table in the study area as a result of over exploitation of groundwater. As discussed in Chapter 2.3.5 lowering of the water table can lead to increased pumping of the water which increases the water cost to the consumer.

5.2.3. Borehole water quality

A sample of 100 boreholes were analysed in order to determine the borehole water quality in the study area. The water quality is only analysed for chemical content. No analysis is done for biological content.

Table 19: Borehole Fluoride content in Nairobi (1940-2000)

Fluoride content(Mg/L)	No. of boreholes	Percentage
0.0-2.0	14	14%
2.1-4.0	20	20%
4.1-6.0	12	12%
6.1-10.0	40	40%
10.1-14.1	14	14%
Total	100	100%

The table shows that 14 % of the boreholes had fluoride content of below 2.0 Mg/L. Over 86% of the sampled boreholes have fluoride levels above the WHO guideline of 1.5Mg/L.

As highlighted in Chapter 2 high fluoride content in drinking water causes dental and skeletal flourisis. There is therefore need to ensure that drinking water has low fluoride content to minimize its effect on the health of the residents in Nairobi.

5.3. Findings from borehole owners/ agents

Questionnaires were administered to property managers where there are boreholes within Nairobi. The borehole locations are as follows:

Location	Number
Karen	2
Kilimani	2
Upper Hill	2
City Center	2
Dagorretti	2

The boreholes were drilled from1995-2006. All the boreholes were drilled by contractors who are licensed by the Ministry of Water. Of the 10 boreholes, 3 are under institutional use, 4 have high rise commercial properties and 3 are under residential use. All the boreholes were drilled due to constant water shortages in their areas. The water supply from NCWSC in all the areas is unreliable and flows on some specific days in the week. The borehole owners obtained permits from the government before drilling. Fourty percent (40%) of the borehole owners had obtained water abstraction permit from the WRMA.

Sixty percent (60%) of the borehole owners are not paying any water abstraction charges to WRMA. They have not received any communication from WRMA. They are therefore not aware of the maximum amount of water they are supposed to abstract.

Eighty-Five percent (85%) of the boreholes have a meter from Nairobi City Water and Sewerage Co. The Water Company takes monthly readings which are used to bill the owners for discharging water into the sewerage system.

Forty percent (40%) of the properties have water connection from NCWSC but they do not use it. The main reason is that the meter has been disconnected due to non-payment over disputed amounts. The property managers however noted that borehole water is relatively cheaper compared to NCWSC water supply. The properties sorely rely on borehole water. However, none of the property managers is aware of the daily maximum amount of borehole water they are supposed to abstract as per the WRMA regulations.

Thirty five (35%) of the properties use both borehole and NCWSC water supply concurrently. The WRMA staff have visited the premises and informed the owners that they are abstracting water beyond the permitted amounts. They were informed that they will be charged for over abstraction of borehole water.

None of the property managers had been sensitized on groundwater management by WRMA or by any other source.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1. Conclusions and Recommendations

The government has set up the legal framework for groundwater management in Kenya through the enactment of the Water Act, 2002.This has culminated in establishment on WRMA which is now responsible for the management of the water resources in Kenya.

However, the WRMA is yet to establish itself as an effective regulatory body and, although on paper there is a legal framework, ground water exploitation in Kenya is still largely unregulated. The researcher recommends the following measures that, if implemented, will ensure that sound management mechanisms are in place and ground water is sustainably exploited:

- The emphasis in the past has been on groundwater development which was done through licensing of the drilling of boreholes by the Water Department of the Ministry of Water and Irrigation. There is need for a change of emphasis from development of the ground water resource to the management of this resources and WRMA should seek to strike balance between development of the groundwater resource and its management for quality and sustainability.

- The WRMA only gathers data from boreholes drilled by licensed contractors. The officials admitted that there is a likelihood of boreholes being drilled illegally in Nairobi. The authority does not have details of such boreholes. This poses a challenge of regulating the activities of such operators. The authority therefore needs to gather information on these boreholes and introduce legally sanctioned punitive measures for persons who drill boreholes without the express approval of the WRMA.

- The WRMA does not also have data on shallow wells drilled in the study area. Though shallow wells were not studied in this research, it is noted that they pose a greater threat as a source of groundwater contamination. Contaminants can easily seep through them if they are not sealed. Shallow wells should be brought under the same regulatory mechanism as boreholes

WRMA should charge for water at a rate that is comparative to the one by NCWSC. The groundwater permit and abstraction fees should be realistic in view of the inflation rate in the country. The fees can be used to supplement other sources of funding for WRMA. The charges should also take into consideration the location and water quality of the borehole.

- The study noted that none of the 10 property managers who were interviewed had been sensitized on the importance of groundwater management either by the WRMA or any other institution.

The interview with MWI officials also indicated that no sensitization on groundwater management has been done in the past by the Ministry. WRMA therefore needs to sensitize the public on the importance of groundwater management. This can be done through the media and holding of stakeholders meetings. The stakeholders in Nairobi are the neighbourhood associations, property owners and consultants, the NCBDA and NCC.

The WRMA needs to raise the profile of groundwater use and management. The public need to be sensitized on the importance of conserving the resource, the danger of groundwater pollution and over abstraction. This will encourage their participation in groundwater management.

- WRMA also has to intensify its field visits. Of the 10 property managers interviewed, only 30 % had had a visit by the WRMA officials. The visits would act as a deterrent to over-abstraction of the water. The officials will also ensure that the groundwater is used for the purpose it has been licensed. Thus this would ensure monitoring of the groundwater use.

- As noted in 4.3., the permit issued for groundwater abstraction has a limit of the volume to be abstracted. When one exceeds the limit, they are penalized. However, as noted in 5.2., 60% of the borehole owners are not paying any water abstraction charges because they have not received any communication from the WRMA. Though they have permits, they could be over abstracting the borehole water.

The researcher recommends that groundwater use be charged per unit volume used instead of having a flat rate. WRMA therefore needs to work closely with NEMA and NCC. The WRMA can rely on NCWSC water meter readings in order to charge for the water use. This can be done where there is sewerage system.

However, in areas which are not covered by sewer, the WRMA has to use their personnel to take the meter readings. In this way the use of groundwater in Nairobi will be regulated. Where borehole owners are over abstracting, stiff penalties should be charged.

The current rate of 50 cents per cubic meter is very low. The users might choose to over abstract and then pay the low fees. The water use charges should also be competitive to those of NCWSC. This will ensure that groundwater management by the authority is self sustaining.

- There is need to incorporate groundwater management in the land use plans of Nairobi. This can be done in collaboration with NCC and Ministry of Lands. Land uses that pose a threat to groundwater resource should be regulated.

- Strict enforcement of the requirement of the Water Act, 2002 need to be done. The WRMA should explore ways of ensuring that the boreholes that were drilled under the old Water Act are compliant with the regulations of the current Act.

- The WRMA currently gather data on all boreholes drilled by licensed contractors. The challenge is that the borehole owners are the ones who supply the data. The WRMA should set up independent borehole which should be used for monitoring the ground water quality and water levels. The data should be regularly analysed to establish if there is any change in the water quality or any incidence of over abstraction.

- Currently, borehole water is only analysed for chemical content. Detailed chemical analyses should be done and should include new threats to groundwater pollution such as arsenic and cadmium. WRMA should make it mandatory for water quality analysis to be done before issuing an abstraction license. This information would assist in monitoring the groundwater quality of the boreholes in the area. Biological analyses should also be done since there is danger of contamination especially from shallow wells.

- The fluoride content of the groundwater in Nairobi is very high. 86% of the borehole data that was analysed had fluoride content above 1.5Mg/L which is the WHO recommended minimum fluoride content in drinking water.

  The Ministry of Health together with the NCC and the MWI should work together to ensure that drinking water in the City has the recommended fluoride content in order to prevent adverse health problems for the City residents. Before an applicant is allowed to abstract the water especially for drinking purposes, they should show which measures they will to take to reduce the fluoride content where the content is above the recommended minimum. Implementation of such measures should be constantly monitored by the WRMA

- The study has noted that the monitoring of groundwater use in Nairobi need to be enhanced. The WRA relies on private boreholes to carry out the monitoring. The WRMA therefore needs to drill observational borehole which are to be used for groundwater monitoring only. This will provide more accurate and objective data that would inform policies that would ensure sustainable use of the resource.

- There has been a marked increase in the borehole depth over the years. This could be an indication of lowering of the water table. The WRMA should therefore strictly control borehole licensing and abstraction licenses.

This will ensure that the requirements are well enforced and would regulate over abstraction. Nairobi was declared a groundwater conservation area in the 1960s. Therefore there should be strict enforcement of the groundwater regulations. This will ensure sustainable use of the groundwater resources.

- The Water Act, 2002 does not incorporate an EIA audit when drilling a borehole. The Act needs to be amended in line with EMCA to provide for carrying out of EIA reports.
- The stakeholders involved in groundwater development and use should be actively engaged to ensure their participation in sound ground water management

  The WRMA and NEMA should work closely together to protect the groundwater resource and ensure its proper management

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APPENDIX

RESEARCH INSTRUMENTS

Letter to the. Permanent Secretary, Ministry of Water and Irrigation

Permanent Secretary,

Ministry of Water and Irrigation,

P.O. BOX 49720,

NAIROBI

REF: REQUEST FOR INFORMATION.

I am a post graduate student at the University of Nairobi doing a degree in Master of Urban Management. As part of the course I am undertaking a research on challenges of groundwater use in urban areas with Nairobi as the study area.

I am therefore requesting for the following information on groundwater in Nairobi:

- Total number of boreholes
- Number of application borehole drilling since 2000 to 2006
- Number of accepted and rejected borehole drilling application
- Number of defective wells in the area and their location
- Number of borehole contractors in the area and their qualification
- Revenue collected from the borehole permits from 2000 -2006
- Number of staff in the Department of Water Development and their designations. The shortfalls in staffing levels in this department

My study is based on a sample of 100 boreholes in Nairobi. I will require the following information:

- The land reference Number and location of the boreholes
- Date of application of permit
- Date of approval or rejection of the application and the reasons given
- Date of completion of well drilling
- Who drilled the well, are the licensed.
- Purpose of the water use whether domestic ,commercial, industrial or agricultural
- Details on water quality analysis, water struck levels and water rest levels
- When did your officer visit the site and what did he ascertain.

I also intend to administer the following questionnaire to one of your officer in the department of water development.

I hope you will give favorable consideration to my request.

Thank you.

Lucy Nyabwengi

Questionnaire to the Ministry of Water and Irrigation

1. What is the groundwater potential of Nairobi area?

- How has it changed over time?

2. Do you carry out groundwater monitoring?

    - If the answer to above is yes how often is this done?
    - When was the last time ground water monitoring was done in Nairobi area?
    - What are the main objectives for groundwater monitoring?
    - What are the parameters you use in carrying out groundwater monitoring?

3. Are there obstacles that you face in the office that hinder you from carrying out groundwater monitoring?

    - Are there obstacles that you face in the field that hinder you from carrying groundwater monitoring?
    - How do you propose these obstacles can be handled?

4. Which are the groundwater pollution sources you have identified in Nairobi area?

    - What measures have you adopted to prevent groundwater pollution in Nairobi?

5. What is the criteria for licensing borehole drillers?

    - What are their qualifications?
    - Do you monitor their work and how?
    - What is the licensing fee?
    - How often is it reviewed?

6. Are there observation boreholes in Nairobi?

- If there are, where are they located?
- What type of data is gathered from them?
- How regularly is this data collected?
- How is this data stored and analyzed?
- Is there a computerized data bank on groundwater resource in Nairobi?

7. How much is a permit to drill a borehole?

- What is the basis for this charge?
- How often are the charges reviewed?
- In your opinion is this charge fair and why?
- How many applications for borehole permit have you received for Nairobi area?

8. The fourth schedule part 5 allows the WRMA to exempt an applicant from providing information on the progress of work when drilling a borehole.

- What have been the criteria for exemption?
- How many exemptions have been given in the last five years?

9. Nairobi was declared a water conservation area in 1958.

- Is it still a water conservation area?
- What are the implications of this in terms of groundwater use in this area?

10. Is there threat of groundwater abstraction in Nairobi?

- If yes which areas are under risk?
- What measures have you undertaken to reduce the risk of groundwater abstraction?

11. Do you carry out public awareness campaigns on groundwater management?

- If yes, how often is this done
- Who are your target population
- How is the campaign carried out?

12. Are the current board members of WRMA qualified in groundwater or environmental management?

13. What measures have you been carrying out to for sustainable use of ground water in Nairobi?

14. Which are the agencies you partner with in groundwater management?

- Which are the areas you partner in?

REQUEST FOR INFORMATION FROM BOREHOLE OWNERS

To whom it may concern

<u>REF: REQUEST FOR INFORMATION.</u>

I am a post graduate student at the University of Nairobi doing a degree in Master of Urban Management. As part of the course I am undertaking a research on challenges of groundwater use in urban area with Nairobi as the study area. I therefore request you to provide the information in the following questionnaire.

Questionnaire to the borehole owners

1. In which area is the borehole located.

2. Which year was the borehole drilled.

3. Did you get a permit from the ministry of water and irrigation before drilling the borehole?

4. Who drilled the borehole licensed contractor or not.

5. What do you use the borehole water for?
    - Domestic use
    - Industrial use
    - Institutional use

- Agricultural use

6. What is the average amount of water you abstract from the borehole per day?

7. What is the average water consumption/demand for your premises?

8. Do you have NWC water supply?

- If the answer to the question above is yes, how often do you get this water in a week?

- What is the average amount of water from NWC do you consume per day?

9. Do you have a water abstraction permit from water resource management authority (WRMA)?

- If the answer to the above is yes, what is the volume of water in cubic meters you are allowed to abstract in a day?

10. Have you been paying charges to WRMA for the use of water? IF so how often have you been paying?

11. What is the fluoride content of the water?

- If is above the allowable content, which process do you use for reducing the content?

- Do you get visits from Water Resource Management Authority (WRMA)?

- If yes how often and when did they start?

- What do the officials check during these visits?

12. Have you been invited in any forum to discuss ground water management?

    - If the answer to the above is yes, which forum is that and when was it?

13. Have you been called upon for a stakeholders meeting by the WRMA?

    - If yes how often has this been?

14. Have you received any sensitization on use of borehole water?

    - If yes, from which source?

Thank you for the information.