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JAPAN INTERNATIONAL COOPERATION AGENCY
THE MINISTRY OF LAND RECLAMATION, REGIONAL AND WATER DEVELOPMENT
THE REPUBLIC OF KENYA

THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA

FINAL REPORT

VOLUME I
MAIN REPORT

OCTOBER 1997

NIPPON KOEI CO., LTD.
NIHON SUIDO CONSULTANTS CO., LTD.

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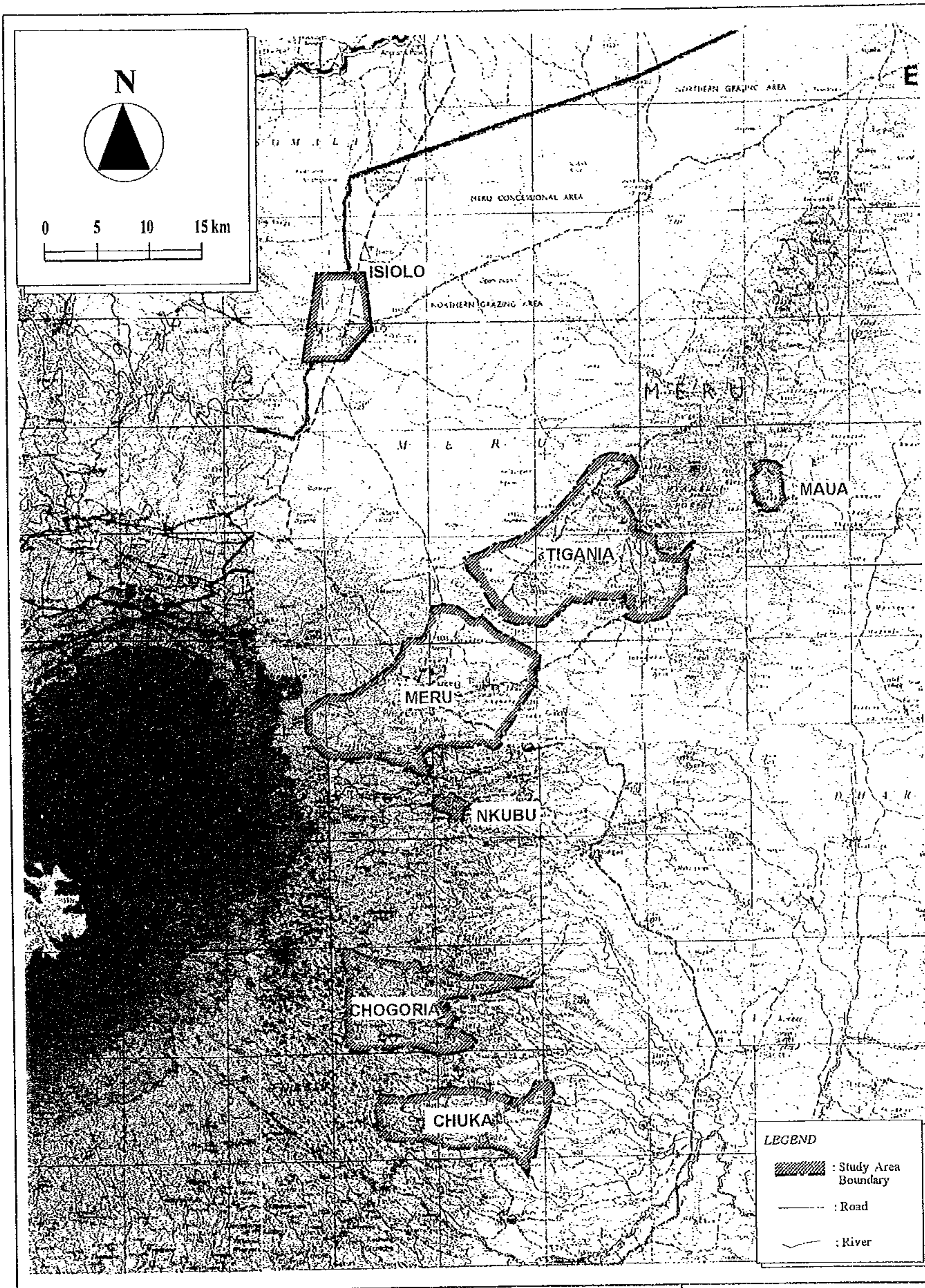
MASTER PLAN

REPORT



THE STUDY ON THE WATER SUPPLY FOR SEVEN TOWNS IN EASTERN PROVINCE IN THE REPUBLIC OF KENYA	STUDY AREA
JAPAN INTERNATIONAL COOPERATION AGENCY	

THE STUDY
ON
THE WATER SUPPLY
FOR
SEVEN TOWNS IN EASTERN PROVINCE
IN
THE REPUBLIC OF KENYA

MASTER PLAN REPORT

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ABBREVIATIONS

AC	Asbestos Cement (Pipe)
AFW	Accounted - for Water
A.I.A	Appropriation in Aid
AIC	Average incremental Cost
AIDS	Acquired Immune Deficiency Syndrome
ASK	Agricultural Society of Kenya
BHN	Basic Human Needs
BPT	Break Pressure Tank
CH1	Survey Points in Chogoria
CK2	Survey Points in Chuka
CWS	Community Water Supplies
DCO	District Commissioner's Office
dia	diameters
DTO	District Treasury Office
DWE	District Water Engineer
DWO	District Water Office
GI	Galvanized Iron
GOK	Government of Kenya
GPS	Global Positioning System
ha	Hectares
I5	Survey Points in Isiolo
ITCZ	Intertropical Convergence Zone
JICA	Japan International Cooperation Agency
KEWI	Kenya Water Institute
km	Kilometer
KNUT	Kenya National Union of Teachers
Kshs	Kenya Shillings
lcd	Litres per Capita per Day
L/sec	Litres per second
m3/day	Cubic Meters per Day
M6	Survey Points in Meru
MLRRWD	Ministry of Land Reclamation, Regional and Water Development
MOCSS	Ministry of Culture and Social Services
N1	Survey Points in Nkubu
NCCK	National Council of Churches of Kenya

NEAP	National Environmental Action Plan
NWCPC	National Water Conservation and Pipeline Corporation
NWMP	National Water Master Plan
ODA	Overseas Development Assistance
O/M	Operation and Maintenance
PE	Polyethylene Pipe
PH	Plan and Height Point
PVC	Polyvinyl Chloride
RDF	Rural Development Fund
RGS	River Gauging Station
SIDA	Swedish International Development Agency
SOI	School of Infantry
SOK	Survey of Kenya
Sq. KM	Square Kilometers
S, T, ST, TT	Trigonometric Station Points
TDS	Total Dissolved Solids
TW	Tigania Water Points
UFW	Unaccounted for Water
UNICEF	United Nations Children's Fund
US$	United States Dollar
USAID	United States Agency for International Development
UTM	Universal Transverse Mercator
VES	Vertical Electrical Sounding
WAB	Water Apportionment Board
WC	Water Closet
WHO	World Health Organization
WID	Women In Development
WQPCL	Water Quality and Pollution Control Laboratory
WRAP	Water Resources Assessment Project
WTP	Water Treatment Plant

CHAPTER I INTRODUCTION

1.1 Authorization

Based on the Scope of Work agreed between the Ministry of Land Reclamation, Regional and Water Development (hereinafter referred to as "MLRRWD") of Kenya and the Japan International Cooperation Agency (hereinafter referred to as "JICA") on March 6, 1996 in Nairobi, JICA made a contract with the joint venture of Nippon Koei Co., Ltd. and Nihon Suido Consultants Co., Ltd. on July 15, 1996 to conduct the Study on the Water Supply for Seven Towns in Eastern Province in the Republic of Kenya (hereinafter referred to as the "Study").

JICA, the official agency of the Government of Japan responsible for implementation of technical cooperation programs undertook the Study in accordance with the relevant laws and regulations in force in Japan and in close cooperation with the authorities of the Government of the Republic of Kenya. The MLRRWD acted as a counterpart agency to the Japanese Study Team and as a coordinating body in relation to other relevant organizations for smooth implementation of the Study.

1.2 Background of the Study

In the Republic of Kenya, water scarcity is a serious problem in many regional and rural areas. The Government of Kenya is committed to improve water supplies. However, financial constraints have meant that their objectives have not been fully achieved.

The water supply system in Meru Municipality utilizes surface water originating from the foot of Mt. Kenya. However, water supply coverage in the Municipality still remains at approximately 20%. There is thus an urgent need for expansion and improvement of the water supply facilities due to urban development and subsequent rapid increase in population. This situation is exacerbated by deterioration of existing water supply facilities and equipment. Isiolo Municipality, which is located in a semi-arid region, suffers from shortages due to water source constraints of the Isiolo river, during dry periods.

The National Water Master Plan implemented by JICA in 1992 proposed an index for domestic and industrial water supply schemes including provision of safe water supply to the whole population in the country by the year 2010. The detailed water supply development plan includes "provision of safe and stable water supply in urban areas with more than 5,000 population and whole rural areas in the country by the year 2000, and provision of wastewater disposal facilities in both areas by the year 2010."

Infrastructure for water supply is a prerequisite factor to sustain life and economic development. However, current development of water supply facilities in the region is far behind the national target. Therefore, in the light of the need for water, and Governmental policy of Kenya, improvement of water supplies in the eastern region of Kenya is urgently required to meet present and future demands.

In parallel with the possible increase of water supply facilities in the future, improvement of wastewater disposal facilities in the region is also required to prevent or mitigate water generated pollution and to conserve the habitat from unsanitary and hygienic problems.

Taking the above circumstance into consideration, the Government of the Republic of Kenya requested the Government of Japan to conduct the Study on the Water Supply for Seven Towns in Eastern Province in the Republic of Kenya.

1.3 Objective of the Study

The objective of the Study is to formulate a Master Plan for the target year of 2010 regarding water supply systems for the areas comprising six towns and one region in the eastern province of Kenya, to conduct a Feasibility Study for the selected project(s) in the Master Plan, and to transfer technology to Kenyan counterparts in the course of the Study.

1.4 Study Area

The study includes seven separate water supply schemes located in the Eastern Province of Kenya.

Meru, Nkubu, Chogoria and Chuka all lie on the eastern slopes of Mt.Kenya which is the second highest mountain in Africa. Although it lies on the equator, its summit contains permanent snow and ice fields. It is surrounded by a protected forest reserve which, with its associated environment and game, is a valuable tourist attraction for visitors to the area. Due to the forested catchments, surface water resources are generally plentiful in these four supply areas and, with relatively high rainfall, and well drained volcanic soils, the land has high agricultural potential. The topography in each of these areas typically slopes steeply away from the mountain with the land elevation falling by as much as 1,000 m across the supply areas, which are also divided by deep valleys and ridges that run in an easterly direction.

The Maua and Tigania schemes are both located further to the east, below the smaller Nyambene mountain range. Although also forested, the catchment areas for the streams are generally much smaller, and water resources are consequently more limited than for the Mt. Kenya catchments. The higher parts of the supply areas attract reasonably high levels of rainfall and contain areas of high land use potential. However, particularly in Tigania, there are areas of lower lying land with lower rainfall and hence lower agricultural land potential.

Isiolo is located to the north of Mt. Kenya, at the edge of a vast arid/semi arid area that stretches to the Ethiopian boarder. The land is generally of low agricultural potential. Nevertheless, to the south of Isiolo, there are areas where irrigation is being successfully practiced, using the limited surface water resources available. To the north of Isiolo cultivation is extremely limited, and the main economic activity is through nomadic pastoralism and tourism in the northern game parks. The character of the Isiolo supply area is therefore different to the other scheme areas. The surrounding permanently settled rural population is limited, and most people live within the Municipal boundaries.

District Administrative headquarters have been based in Isiolo and Meru since colonial days, and both these towns contain significant numbers of administrative staff and their dependents, and have attracted secondary service industries. Chuka and Maua have recently become the administrative headquarters for the newly formed Tharaka-Nithi District and Nyambene District respectively and it is expected that this will result in higher growth of these townships within the design horizon of this study.

With the exception of Meru and Isiolo Towns, the supply areas are strongly rural in character, except for relatively small urban centers where economic activity is concentrated on commercial trading, shops, bars, etc. Although there are a number of rural based industries such as timber, tea and coffee factories, Meru is the only town where significant industrial development has taken place.

Table 1.4-1 Study Areas

Study Area	Land Area (km2)	Population (1989)
Meru	185	125,000
Nkubu	3.5	7,000
Isiolo	45	19,000
Chuka	88	31,000
Chogoria	58	25,000
Maua	11	3,200
Tigania	93	52,000

Source: National Census, 1989

1.5 Organization of the Study

1.5.1 Japanese Organization

The Japanese organization consisted of the Study Team under JICA headquarters and the Advisory Committee set up at the JICA headquarters.

The members of the Study Team are as follows:

Mr. Keisuke Okazaki	Team Leader
Mr. Hiroyasu Yoda	Water Supply Planner
Mr. Masayuki Ogino	Water Resources Planner
Mr. Michael Douglas Allport	Design Engineer, Cost Estimator
Mr. Takehiko Oga	Organization, Institution Expert
Mr. Kenichi Ishii	Environment, Wastewater Expert
Ms. Julia Akello Kunguru	Social, Hygiene Education Expert
Mr. Kazuhiko Dobeta	Project Economist
Mr. Kiyofumi Tamari	Topographic Survey Engineer
Mr. Seikou Uchisawa	Hydrogeologist
Mr. Tadashi Hatakeyama	Geophysics Expert
Mr. Jun Wada	Assistant

The members of Advisory Committee were as follows:

Mrs. Keiko Yamamoto	Chairman of Advisory Committee
Mr. Kenji Nakanosono	Member of Advisory Committee

1.5.2 Kenyan Organization

The Kenyan organization consisted of the MLRRWD Counterpart Team and Steering Committee composed of the representatives of the organizations concerned with the Study in coordination with the MLRRWD.

The principal members of the MLRRWD Counterpart Team and Steering Committee were as follows.

MLRRWD:

Mr. E. K. Mwongera	Permanent Secretary, MLRRWD
Mr. P.N. Machiri	Director of Water Development
Mr. D.N. Stower	Senior Deputy Director, Water Resources Development
Mr. T.W. Kibaki	Deputy Director, Planning and Design
Mr. D.K. Barasa	Deputy Director, Operation and Maintenance
Mr. F.K. Mwango	Deputy Director, Groundwater
Mr. P.L. Ombogo	Deputy Director, Construction
Mr. J.R. Nyaoro	Register, Water Rights
Mr. K. Kung'u	Assistant Director, Project Planning
Mr. D.N. Nyaga	Provincial Water Engineer, North Eastern (Previously the District Water Engineer, Tharaka Nithi)
Mr. F.K. Kyengo	District Water Engineer, Isiolo
Mr. R.M. Gakubia	District Water Engineer, Meru
Mr. D.N.S. Nderi	District Water Engineer, Nyambene
Mr. R. Gathigo	Water Development, Planning Section
Mr. E. M. Chege	Superintendent Hydrologist, MLRRWD
Mr. B.I. Kasavuli	Design Engineer, Design Section
Mr. J.M. Omwenga	Assistant Director, Water Quality Surveillance
Mr. K. Kitagawa	JICA Coordinator, MLRRWD
Mr. V.Y. Jani	Assistant Director, Research Technology
Mr. O. Mbaya	Economist, Economic Planning Division
Mr. F.M. Muiruri	Assistant Director, Groundwater Supervision
Mr. C.N. Irungu	Assistant Director, Groundwater Conservasion
Mr. W. Wakaranja	Assistant Director, Groundwater Engineering Geology

Steering Committee:

Mr. J.M. Mwangi	Ministry of Local Government
Mr. J.K. Kanithi	Treasury, Ministry of Finance
Mr. W.N.K. Murage	Ministry of Lands and Settlement
Mr. N. Arap Chumo	Ministry of Environment and Natural Resources
Mr. N.N. Waweru	Ministry of Health

CHAPTER II GENERAL CONDITIONS OF THE STUDY AREA

2.1 Natural Conditions

2.1.1 Topography

The Study Area is located in the south-western part of the Eastern Province of Kenya. The locations of the seven towns concerned in the Study Area and the topography of the surrounding areas are shown in ***Figure 2.1-1***.

The towns of Meru and Nkubu in Meru District and Chuka and Chogoria in Tharaka Nithi District are located on the eastern slopes of Mt. Kenya. These four towns are situated at elevations between 1,400 and 1,600 m. Owing to relatively abundant rainfall, the eastern slopes of Mt. Kenya are deeply forested and numerous streams run in an easterly direction through the Study Areas. These streams subsequently flow south-eastward before their eventual confluence with the Tana river. The terrain around the towns concerned shows a high relief comprising V-shaped deep gorges formed by streams and steep mountain ridges.

The town of Maua and the Tigania region in Nyambene District are located around the Nyambene Hills. The town of Maua and the Tigania region are located at the foot of the mountain range where the terrain changes from steep mountain to flat plain. The elevations of Maua and Tigania vary from 1,000 to 1,700 m. Water resources are more abundant along the southern slopes of the Nyambene Hills where perennial streams collect an abundant rainfall through deeply forested mountains. However, resources are more scarce along the northern slopes which adjoin the semi-arid zone to the north.

The terrain around the town of Isiolo is quite different from the other six towns. Isiolo is situated on the volcanic flat plain gently sloping towards the Ewaso Ngiro river in the north. The elevation around the town of Isiolo is approximately 1,100 m. This area is classified as a semi-arid zone and where surface water courses tend to be dry for much of the year.

2.1.2 Climate

The climate in Kenya is generally controlled by the Intertropical Convergence Zone (ITCZ) moving across the equator seasonally northward and southward, bringing two rainy and dry seasons in a year. The rainy seasons occur during middle March to May and early October to November, and called the long rains and the short rains, respectively.

The Study Area varies from humid to semi-arid zones depending on altitude. The humid zone with an average annual rainfall of more than 1,500 mm extends from the eastern slope of the Mt. Kenya to the southern slope of the Nyambene Hills where the elevation exceeds 1,500 meters. The towns in the Study Area, except Isiolo are situated in the humid or sub-humid zones. The volcanic plain extending northward is a semi-arid zone with an annual average rainfall ranging from 450 to 900 mm. The elevation of the volcanic plain is less than 1,200 meters and the town of Isiolo is located in this zone. The isohyetal map of the average annual rainfall is shown in ***Figure 2.1-2***.

The meteorological summary shown in ***Figure 2.1-3*** indicates a clear climatic contrast between Meru and Isiolo. Compared with Meru, rainfall is much less in Isiolo but evaporation is much higher. The annual rainfall and evaporation are 1,259 mm and 1,439 mm in Meru, and 619 mm and 2,682 mm in Isiolo, respectively. The temperature in Meru also varies less through a year. The annual average daily maximum and minimum temperatures are 24 °C and 13 °C in Meru, against 30 °C and 17 °C in Isiolo, respectively.

2.1.3 Regional Geology

The Study Area is located to the east of the East African Rift Valley. The surrounding region is wholly underlain by the Precambrian Basement System, but is mostly covered by volcanic rocks and sediments from the major cruption centers of Mt. Kenya and the Nyambene Hills. The rock formations are generally classified into the following three groups. The lithostratigraphic classification is given in ***Table 2.1-1***.

(1) Precambrian Basement Rocks

The Precambrian Basement Rocks form the oldest basement system underlying all the other rock units in this area. They are metamorphic rocks composed of gneisses, schists and quarizites. The basement rocks outcrop mainly around the southern part of Meru National Park and Tharaka, which are in the east and south of the low lying areas. Isolated outcrops are also observed on hilltops in the west of the Isiolo town.

(2) Tertiary Volcanic Rocks

The volcanic rocks were produced by eruption activities from the Miocene to the Middle Pliocene. The Mt. Kenya Volcanic Series outcrop on the higher part. From the summit south-eastward, the rocks comprise phonolite, kenyte lavas, tuffs and agglomerates. The middle eastern slope is mainly covered with basalt. The rocks in the higher part of the northern slope include trachytes tuffs and agglomerates. The Nyambene Series distributes on the Nyambene Hills and their surrounding slopes, and the Northern Grazing Area extending out in the east of Isiolo town. The rocks outcropping in the low lying volcanic plains are mainly composed of basalt. The rocks in the mountainous areas in the north-east include phonolite and tephrite around the summit, and olivine basalt.

(3) Quaternary Volcanic Rocks and Sediments

The upper basalt of Nyambene, composed of the basaltic phyrocastic deposits and lavas, are products of parasitic eruptions in the Pleistocene. The superficial sediments belong to the Pleistocene and recent deposits. Alluvium deposits of silt, sand and gravel exist locally along streams. Colluvium deposits of mixtures of clay, silt and rock fragment are observed on the slopes of hills around Isiolo. Lacustrine sediments with carcrete limestones are also found along water courses in the low lying areas.

2.1.4 Hydrology

The rivers in and around the Study Area originate on Mt. Kenya, and the Nyambene Hills which run from south-west to north-east demarcating the watershed between the Uaso Nyiro river system in the north and the Tana river system in the south. In Kenya, the major drainage areas are classified into five basins. The Tana and Uaso Nyiro river systems correspond to the drainage area 4 and 5, respectively. These river systems are divided into several sub-basins as seen in ***Figure 2.1-4***. A summary of the hydrological characteristics of the sub-basins concerned with the Study Area are presented below. The figures for drainage area, average annual flow and basin mean rainfall are taken from the NWMP.

Table 2.1-2 Summary of Hydrological Characteristics

Sub-basin	Area (km)	Major River	Basin Mean Rainfall (mm)	Average Runoff (mm)	Rainfall / Runoff Rate
4FA	2,181	Kathita	829	152 (10,54 m^3/sec)	0.18
4FB	-	Ura	-	-	-
4EA	743	Mutonga	857	243 (5.73 m^3/sec)	0.28
4EB	1,193	Nithi	1,048	245 (9.26 m^3/sec)	0.23
5DA	2,237	Isiolo	794	50 (3.45 m^3/sec)	0.06

2.1.5 Hydrogeology

(1) Mt. Kenya (Meru-Chuka Area)

Mt. Kenya constitutes a major hydrogeological system with water bearing layers composed of fissured and weathered volcanic deposits in the Tertiary period. These water bearing layers form an interconnected aquifer system with groundwater flow radiating from the slopes of Mt. Kenya. It is also characterised by 'perched aquifers' formed by groundwater accumulation on impervious layers which are locally formed by lava flows.

The summit area is charactarised by steep terrain with low recharging capacity because of the freezing climate and the impervious layers which predominate on the ground surface. With an abundant rainfall and a high infiltration capacity of soil which cover in the Mt. Kenya Forest, the middle slope is considered as the major recharging zone. The thickness of the aquifer decreases gradually in a downstream direction and many springs rise on the lower eastern slopes.

On the north-eastern slopes, the aquifers may be situated at greater depths, because perched aquifers are not formed in this area due to absence of impervious lava layers at shallow depth. The parasitic cones formed in the latest volcanic activity are seen in this area. These parasitic cones mainly consist of coarse pyroclastics with a high infiltration capacity. This area is therefore considered as the recharging zone for the aquifer underlying the northern volcanic plain.

(2) Nyambene Hills (Tigania-Maua Area)

The hydrogeological features of the Nyambene Hills are similar to those of Mt. Kenya. The subsoil consists of Tertiary volcanic deposits with massive lava flows. Perched aquifers are formed mainly at shallow depth. The southern slope is a spring yielding area because of abundant rainfall and a high infiltration capacity of the ground surface. Springs are the result of overflowing groundwater accumulated on the perched aquifers.

On the northern slopes, only a few springs are observed. The upper layers are covered by the recent coarse pyroclasitic deposits with a high infiltration capacity. The rain water may percolate to greater depth possibly recharging an aquifer underlying the Northern Grazing Area. The existence of this aquifer can be explained by the occurrence of the springs along the Usao Nyiro river. The same hydrogeological features are probable in the low-lying plain to the north-east, as suggested by the major springs along the eastern boundary between the volcanic plain and the basement area.

(3) Volcanic Plains (Isiolo Area)

The volcanic plain covers the Northern Grazing Area in the north and the Nyambene Plain in the south-east. These areas are mainly covered by basaltic rocks of the Lower Nyambene Series. Recharge from rainfall is limited because the areas generally belong to the semi-arid zone. According to geophysical surveys and exploratory drillings carried out by WRAP, the existence of productive aquifers recharged from the Nyambene Hills is expected in the volcanic plains.

(4) Basement Area

The basement area is located further south to east from the watershed. The area is composed of metamorphic rocks of the Precambrian Basement System. The major part of this area is covered by impervious rocks. Consequently, the aquifer is formed locally by fractured or weathered deposits and alluvial deposits along the streams. Recharge from rainfall in this area is expected to be limited due to the semi-arid climate. Due to these hydrogeological conditions, the groundwater is generally shallow and its yield is low.

2.2 Water Resources

2.2.1 Existing and Ongoing Development Plan

(1) National Water Master Plan (NWMP)

The NWMP Study was carried out from 1990 to 1992. Its planning horizon was established for the year 2010. The national action plan aimed for the target year

2000 was subsequently provided in compliance with the NWMP for implementation of regional water resources development programs providing the necessary information and guidelines for specific development plans for each district.

(2) Water Resources Assessment Project (WRAP)

The project was carried out by the former Ministry of Water Development in cooperation with the TNO-DGV Institute of Applied Geoscience of the Netherlands. WRAP carried out water resources assessment and water development studies for a number of districts in Kenya. The water resources assessment study provides an evaluation of water resources potential on a district by district basis, and the results of this study contributed in formulation and preparation of guidelines and recommendations for investment packages in district water development plans. These WRAP studies for Meru and Isiolo were conducted between 1987 and 1991.

2.2.2 General Description of Water Resources

(1) Surface Water

1) General

a) Mt. Kenya Slopes (Meru-Chuka Area)

On the eastern slopes of Mt. Kenya, surface water in the form of numerous streams and springs is abundant. No restrictions are presently reported on water use of the rivers in the sub-basins 4FA, 4EA and 4EB pertinent to the Study Area, and a large number of water projects are currently being implemented and proposed. Further water development projects, however, should be executed on the basis of comprehensive water resources study and water management of the rivers.

b) Nyambene Hills (Tigania, Maua Area)

There are also numerous perennial springs around the Nyambene Hills. In this area, unlike the slopes of Mt. Kenya, there are few major streams, and these are not found in the vicinity of population centers. Thus, the water supply for inhabitants is mostly dependent upon nearby springs. Spring yields are assessed to be sufficient for the current water demand but not assured for future increase of water demand. In order to successfully meet the future water demand, the combination of river water, groundwater and springs shall be taken into account in establishing the future water supply plan.

c) Isiolo

There are few perennial streams in the northern side of Mt. Kenya. One of these is the Isiolo river. However, due to the absence of alternative water sources, water from the river is abstracted intensively largely for irrigation, by unregistered users as well as legally registered users. As a result, the river flow decreases drastically and almost no water reaches downstream of the Isiolo water intake in the dry season.

Isiolo town currently experiences quite serious domestic water shortages, while surface water is abstracted extensively mostly for irrigation. Coordination of water use between domestic and irrigation needs should therefore be undertaken urgently to reduce these water shortages. For this purpose, a comprehensive investigation needs to be conducted to clarify the actual flow rate of the Isiolo River and present water abstraction required for irrigation.

2) Low Flow Rate

A network of river gauging stations (RGSs) has been installed on the river basins in and around the Study Area, namely, the catchment areas of the Tana and the Ewaso Ngiro river tributaries. The number of stations in each sub-basin is listed below. The figures include the number of stations both operational and non-operational.

Table 2.2-1 Number of River Gauging Stations

Sub-basin No.	Major Streams	Number of RGS
4EA	Mutonga, Kithenu	7
4EB	Nithi, Mara, Ruguti, Thuchi	16
4FA / 4FB	Kathita, Thingithu, Thanantu, Thangatha, Ura, Rojiwero	37
5D	Isiolo, Ngare Ndare, Ngare Nything	14

Source : NWMP

The results of flow analyses based on these gauging stations carried out by WRAP and NWMP are relevant to this Study. The analyses provides:

1) average flow, 2) daily low flow with 95 % probability 3) minimum monthly flow, and 4) minimum daily flow as given in ***Table 2.2-2***.

(2) Groundwater

According to the hydrogeological evaluation by WRAP, the following high potential groundwater zones were identified. A summary of these hydrological zones is given in ***Table 2.2-3***. Groundwater level contours and flow directions estimated by WRAP are shown in ***Figure 2.2-1***.

1) Volcanic Plains (Isiolo Area)

This zone covers the Northern Grazing Area and the southern and eastern foot of the Nyambene Hills. Of 75 boreholes, approximately 85% were successfully drilled with an average depth of 66 m. An average yield was reported of 10.5 m^3/hour, or 2.9 liter/sec. The average groundwater struck and rest levels were at a depth of 40 and 30 m from the ground surface. Groundwater quality in the volcanic deposits was generally good, however, saline water was identified in some boreholes in the Northern Grazing Area. Approximate transmissivity and groundwater flows were estimated as follows.

Table 2.2-4 Approximate Groundwater Flow Amount

Area	Transmissivity (m^2/day)	Groundwater flow (m^3/day)
Northern foot hills	1,000	542,000
Lower south-eastern slope	500	420,000
Lower southern slope	200	77,000

Source : WRAP

45 springs were identified during the inventory survey. The average yield was found to be 9.4 liter/sec.

2) The Lower Slopes of Mt. Kenya (Meru-Chuka Area)

There are only 11 boreholes listed in this area. This low number can be explained by the abundant perennial streams and springs which have provided satisfactory water supplies to this area. On average, the depth of the boreholes was 129 m with a yield of 9.6 m^3/hour or 2.7 liter/sec. The average groundwater struck and rest levels were almost same at a depth of

53 m from the ground surface. Groundwater quality was reported to be excellent. There are 307 springs and the average yield was 7.4 liter/sec.

3) Nyambene Hills (Tigania, Maua Area)

The prevalence of groundwater is similar to the Meru-Chuka area, namely, many springs and small number of boreholes listed in the high relief terrain. Out of 13 boreholes, 69% were successfully drilled with an average depth of 55 m. The groundwater struck and rest levels for the aquifer were 40 m and 30 m from the ground surface, respectively. An average yield of 5.1 m^3/hour or 1.4 liter/sec was recorded with an excellent quality. 125 springs were identified with an average yield of 11.3 liter/sec.

2.2.3 Investigation of Water Sources

(1) Surface Water

1) Intake Sites Proposed by MLRRWD

The following new intake sites were originally proposed by MLRRWD for the seven water supply schemes. Locations of the proposed sites are shown in ***Figures 2.2-2 to 2.2-8***. The Study Team carried out investigations for these sites during the first field work from July to November, 1996. General topographic and hydrologic conditions were confirmed during field reconnaissance surveys. In addition, topographic surveys, flow measurements, initial environmental examinations and water quality tests were also conducted to determine the feasibility of these sites.

Table 2.2-5 Intake Site Proposed by MLRRWD

Town	Water Source	Description
Meru	Kathita River	Located in Mt. Kenya Forest about 15 km west from Meru town. Approximate elevation of the site is 2,340 m. The river channel runs through the bottom of a U-shaped deep rocky gorge.
Nkubu	Kiguandegwa River	Located on a tributary of the Thingithu River about 4 km west from Nkubu town. Approximate elevation of the site is 1,660 m. Cultivated lands for coffee farming are observed along the river bank.
Chuka	Ruguti River	Located in Mt. Kenya Forest about 15 km north-west from Chuka town. Approximate elevation at the site is 1,960 m. The river follows the bottom of a deep V-shaped gorge.
Chogoria	Mara Manyi Stream	Located on a tributary of the North Mara River about 5 km north-west from Chogoria town. Approximate elevation of the site is 2,015 m. The location of the site is deep in the forest close to the origin of the river. The stream flows through the bottom of a V-shaped gorge.
Maua	Mboone Stream	Located upstream of the existing water supply intake on the stream, about 1.5 km north-west of the town center. Approximate elevation of the site is 1,700 m.
Tigania	Thangatha Stream	Located on the stream originating from the Nyambene Forest, about 5 km east from Tigania. Approximate elevation of the site is 1,720 m.
Isiolo	Isiolo River	Located about 6 km south of Isiolo town, at an approximate elevation of 1,240 m. The surrounding area is gently sloping volcanic plain. Vegetation is poor due to the semi-arid climate. The river runs through a shallow valley formed by water flow erosion. A storage dam is proposed at this site.
	Kithima Spring	Located about 10 km south of Isiolo town at an approximate elevation of 1,340 m. Several springs issue water from the outcrops of weathered volcanic deposit. Water from these springs come together forming a tributary of the Isiolo river,

2) Alternatives

In the course of the initial evaluation, the following alternatives were also identified. Locations of the alternative sites / water sources are shown in ***Figures 2.2-2 to 2.2-8***.

Table 2.2-6 Alternative Intake Sites

Town	Water Source	Description
Meru	Kathita River	Located in Mt. Kenya Forest about 5 km upstream of the intake site originally proposed.
Nkubu	Kiguandegwa River	Located about 8 km upstream of the intake site originally proposed.
Maua	Ura River	Located about 4 km south from the center of Maua town, as proposed by NWMP.
Tigania	Thangatha Stream	Located downstream of the intake site originally proposed.
Isiolo	Rugusu Spring	Located on the Eastern Marania river, about 10 km south from Isiolo town.
	Groundwater	The Northern Grazing Area is identified as a groundwater potential zone. Referring to the borehole data around Isiolo town, an average yield is 10.5 m^3/hour

The alternatives were also incorporated with the initial evaluation. As a result, the following alternatives appear to be more advantageous than the originally proposed intake sites or water sources.

a) Kathita River Intake Site (Meru)

Concerning the Kathita river intake site originally proposed by MLRRWD, the topographic survey of the raw water pipeline revealed problems with difficult terrain for water transmission by gravity. An alternative site was therefore identified at a sufficient elevation further upstream. The upstream catchment characteristics suggest that this site will also be satisfactory in terms of both quantity and quality of water.

b) Thangatha Stream Intake Site (Tigania)

The originally proposed intake site gauged during the initial stage of this Study did not have sufficient yield for the Tigania supply area. In the course of the site reconnaissance, it was found that the Thangatha stream has a much larger flow rate about 1 km downstream of the original site after joining with some tributaries. Taking this into account, it is recommended the intake site be shifted downstream at a sufficient elevation for raw water transmission by gravity.

c) Groundwater Development in Isiolo

The hydrological assessment for the Isiolo river concluded that further surface water development is not feasible under current conditions. According to the hydrogeological assessment, groundwater appears to be a short term solution for the water shortage. Detail groundwater investigations by exploratory drilling were therefore recommended.

The following alternatives were not considered viable:

Table 2.2-7 Evaluation of Alternatives

Alternatives	Evaluation
Kiguandegwa River Intake Site (Nkubu)	Better water quality is expected, but much longer raw water pipelines will result in a significant increase of construction costs.
Ura River Intake Site (Maua)	Quantity of water seems to be sufficient, but pumping will be required for water transmission to the supply area.
Rugusu Spring (Isiolo)	Constraints remain on water rights.

3) Additional Investigations for Intake Sites

In compliance with the initial evaluation of water sources, additional investigations were carried out during the second field work from January to March, 1997. The groundwater investigations in Isiolo are described in ***Section (2).*** The investigations conducted on the alternative surface water intakes for Meru and Tigania are summarized below.

a) Kathita River Intake Site (Meru)

The alternative site is located approximately 5 km upstream of the site originally proposed. Approximate elevation of this site is 2,450 m. The river flows through the bottom of a U-shaped deep rocky gorge in the Mt. Kenya Forest. The bottom width of the gorge is about 25 m. The river bed material is mainly composed of gravel and boulders.

Around this site, the Italian NGO group named CEFA has been implementing the Kathita-Kirua Water Project and has constructed an intake weir on the river. A small intake for two community water supplies is also found about 100 m upstream of the CEFA intake, but these community water supplies are not in operation.

b) Thangatha Stream Intake Site (Tigania)

The alternative site is located about 1 km downstream of the site originally proposed. Approximate elevation of this site is 1,760 m which is about 40 m lower than the original site but is still sufficient for supplying water by gravity. One major tributary flows into the mainstream just upstream of this site so that the flow rate is much larger than the original site.

4) Flow Rates at Intake Sites

a) Reliability

The safe yield at each intake site was estimated on the basis of its 95 % daily low flow, calculated by correlation of catchment characteristics with existing gauging stations in the vicinity, and supported by flow measurement at the intake sites.

b) River Maintenance Flow

Minimum maintenance flow in perennial rivers is not mentioned in the Design Manual for Water Supply in Kenya. However, it is necessary to maintain a certain amount of water for conservation of the natural river environment as recommended by NWMP. The same concept of river maintenance flow is therefore proposed for the estimation of safe yield for this Study.

The NWMP recommended that river maintenance flow be assumed to be equivalent to the minimum daily flow. NWMP applied a ratio of the minimum daily flow to the average flow which was estimated at 6.2 % on average for the representative 15 rivers in the whole country. Whereas, a corresponding average ratio of 14.8 % was calculated for the sub-basins within the Study Area based on runoff records. This higher ratio reflects the hydrologic characteristics of more abundant water resources in the eastern slope of Mt. Kenya. The value of 14.8 % was applied as a regional factor for estimating river maintenance flow in the Study Area.

c) Safe Yield for River Intakes

The safe yield of surface water sources were obtained from the balance between the 95 % daily low flow and the river maintenance flow. The estimated safe yields are shown in ***Table 2.2-8***.

d) Safe Yield for Stream/Spring Intakes

Periodical flow measurements are the most practical way to determine the safe yield of small streams or springs. However, due to the short duration of this study, sufficient flow measurements at the stream/spring intakes were not available. For the purpose of this Study, the safe yield for stream/spring intakes was taken as the minimum flow obtained from the available results of flow measurements. Since this period coincided with one of the worst droughts in the area, this is not an unreasonable assumption.

5) Preliminary Study for Isiolo Dam Alternative

a) Reservoir Storage from Topographic Conditions

The proposed dam site is located about 0.5 km upstream of the existing intake. The topographic map showing the proposed dam site and its upstream area is given in ***Figure 2.2-9***. A relationship between elevation and reservoir storage was derived from this map as shown in ***Figure 2.2-10***. The optimum elevation of the dam crest will be approximately EL. 1,218 m based on topographic constrains around the dam site. The high water level of reservoir was taken as EL. 1,216 m providing 2 m freeboard from the crest level. The low water level was taken as approximate EL. 1,210 m for the construction of a raw water intake. The approximate effective reservoir storage was 400,000 m^3 as a storage between EL. 1,210 and EL. 1,216 m.

b) Estimation of Long Term Runoff

Long term runoff data for River Gauging Station (RGS) 5D08 was estimated using a rainfall-runoff simulation model. The tank model, which is a serial storage type, was applied. The long term naturalized runoff was simulated on a monthly basis for the period of 20 years (1969-1988). The average flow, the 95% low flow, and the minimum flow for the 20 years were obtained at 0.143 m^3/sec, 0.080 m^3/sec and 0.075 m^3/sec, respectively.

c) Development Yield and Required Storage

Required reservoir storage was analyzed based on the simulated long term runoff. A mass curve analysis was applied for estimating the required reservoir storage to maintain a constantly regulated reservoir outflow for downstream use. The analysis was carried out using several different reservoir outflow rates in order to establish a draft-storage curve indicating a relationship between reservoir outflow and required storage.

Reservoir inflow was defined to be a balance between the simulated runoff and the amount of upstream water requirements. The amount of upstream water use was estimated based on the following assumptions.

- Domestic

The amount of domestic water requirements upstream of the dam site was estimated at 245 m^3/day from the existing water permit data. The domestic water requirement in 2010 was estimated at 417 m3/day, providing the same growth rate for the water demand projections in Isiolo (rural)

- Irrigation

The amount of irrigation water requirements upstream of the dam site was estimated at 3,772 m^3/day from the existing water permit data. Alternative cases were also provided for irrigation water requirements decreasing to 75, 50 and 25%, respectively.

With an effective reservoir storage of 400,000 m^3, possible development yield (regulated outflow) for downstream water use can be derived from the draft-storage curves, as shown in ***Figure 2.2-11***.

Table 2.2-9 Possible Development Yield

Case	Development Yield
1	0.065 m^3/sec (5,616 m^3/day)
2 (Irrigation decreasing in 75%)	0.076 m^3/sec (6,566 m^3/day)
3 (Irrigation decreasing in 50%)	0.087 m^3/sec (7,517 m^3/day)
4 (Irrigation decreasing in 25%)	0.098 m^3/sec (8,467 m^3/day)

d) Water Balance

The amount of downstream water requirements were estimated based on the following assumptions.

- Domestic

Downstream of the dam site, the amount of domestic water requirements other than the Isiolo water supply was estimated at 179 m^3/day from the existing water permit data. The domestic water requirement in 2010 was estimated at 242 m3/day, providing the same growth rate for the water demand projections in Isiolo (rural). The raw water demand for the Isiolo water supply in 2010 was estimated at 10,671 m³/day. The total amount of domestic water requirements downstream of the dam site therefore becomes 10,913 m³/day.

- Irrigation

The amount of irrigation water requirements was estimated at 4,557 m³/day from the existing water permit data. Alternative cases were also provided for irrigation water requirements decreasing to 75, 50 and 25%, respectively.

The water balance between possible development yield and downstream water requirements is shown in ***Table 2.2-10*** and summarized below, suggesting limited storage potential.

Table 2.2-11 Water Balance

(Unit : m³/day)

Case	Development Yield	Downstream Water Use	Balance
1	5,616	15,470	-9,854
2 (Irrigation decreasing by 75%)	6,566	14,331	-7,765
3 (Irrigation decreasing by 50%)	7,517	13,692	-6,175
4 (Irrigation decreasing by 25%)	8,467	12,052	-3,585

e) Sediment

Sediment inflow to the Isiolo dam site with a catchment area of 230 km² was estimated at 80,500 m³/year, based on the regional denudation rate of 350 m³/km²/year as given by NWMP. When the low water level is set at EL. 1,210 m, the corresponding dead storage of the reservoir is only 135,000 m³ which is less than the amount of sediment inflow for two years. Such dead storage is so small that measures for preventing sediment inflow in combination with removal of sediment deposits, from the reservoir would be necessary. The following measures should therefore be taken into account for the dam construction.

- Installation of sediment flushing gate
- Construction of upstream check dam(s)
- Introduction of dredging facilities

6) Surface Water Quality

Water quality standards for drinking water in Kenya follow closely to those established by the World Health Organization (WHO). The Design Manual for Water Supplies in Kenya stipulates bacteriological and chemical water quality requirements. Water quality analysis is performed by the Water Quality and Pollution Control Laboratory. Chemical quality testing is performed on approximately 27 constituents, in addition to bacteriological examination.

A water quality survey for the proposed water resources was conducted during September 1996 and March 1997. Twenty seven (27) chemical quality parameters and two bacteriological quality parameters were assessed. The water quality results are attached in ***Table 2.2-12***, and selected parameters are summarized below. Although high coliform counts were recorded in Nkubu, and Isiolo, the raw water quality results at the intake sites show that they are suitable for water supplies.

Table 2.2-13 Water Quality Summary at Intake Site

Dry Season

Parameters	Meru	Nkubu	Isiolo	Chuka	Chogoria	Maua	Tigania
Turbidity (FTU)	0.4	1.4	1.3	1.2	0.5	0.6	0.2
BOD (mg/l)	5	5	3	2	10	6	5
Coliform (/100ml)	0	300	50	20	10	25	10

Wet Season

Parameters	Meru	Nkubu	Isiolo	Chuka	Chogoria	Maua	Tigania
Turbidity (FTU)	1.1	1.4	1.1	1.7	1.5	2.5	1.2
BOD (mg/l)	4	0	4	8	6	0	2
Coliform (/100ml)	410	320	520	15	90	170	20

Source: Summarized from table 5-7 or Appendix J

(2) Groundwater

1) Preliminary Groundwater Assessment

The results of the preliminary quantitative hydrological analysis, indicate that the potential for surface water development is limited due to climatic conditions in the area around the town of Isiolo. Development of groundwater sources may therefore be a more suitable short-term alternative to meet the projected water demands for the near future.

A number of boreholes have been constructed by the private sector and public organizations since the 1940s. The available borehole data around the town of Isiolo is shown in ***Table 2.2-14***. The depth of these boreholes vary from 37 m to 213 m depending on the topographic configuration and extraction. The practical yields vary from 10 to 30 m^3/hour.

The groundwater quality data for these boreholes are summarized in ***Table 2.2-15***. From this table it can be seen that the parameters obtained in the Northern Grazing Area reveals moderately satisfactory results compared to the potable water standards in Kenya. Some of the boreholes monitored, however, contain comparatively high contents of chloride, and electric conductivity is very high as a whole. This suggests that the groundwater in these areas is saline.

It would therefore appear that there is potential for groundwater development around the town of Isiolo. However, the long-term development potential at a wellfield to supply Isiolo township, requires more detail investigations and analysis. Nevertheless, the future use of groundwater will undoubtedly be much larger than that at present. Such extraction should be managed based on a more detailed evaluation of the groundwater potential and the calculated safe development yield of the area.

2) Geophysical Prospecting

The locations for electrical resistivity surveys was selected south of Isiolo town, since water quality in the immediate vicinity of the town and the northern area, where the alluvial plain prevails, is mainly saline. Vertical Electrical Sounding (VES) points were mainly established along the existing roads due to ease of accessibility. The location of VES points are shown in ***Figure 2.2-12***. According to the analysis of the p-a curves obtained from the surveys, the underground strata at each VES point consists of three to four layers. The apparent resistivity at the VES points is tabulated for each profile line as given in ***Table 2.2-16***. The third layer is interpreted as an aquifer extending over the fourth layer which is identified as an impermeable layer. This aquifer tends to decrease in thickness towards Isiolo.

Table 2.2-16 Apparent Resistivity on the Profile Line

Profile Line	Apparent Resistivity $(\Omega - m)$			
	1st Layer	2nd Layer	3rd layer	4th Layer
No. 1 - No. 22	4 ~ 460	162 ~1360	90 ~ 390	11 ~ 83
No. 24 - No. 13	3 ~ 690	200 ~ 1380	100 ~ 630	18 ~ 190
No. 25- No. 20	4 ~ 310	75 ~ 900	54 ~ 300	30 ~ 190

3) Exploratory Drilling and Pumping Test

Exploratory drilling sites were selected at the locations shown in ***Figure 2.2-13***. Details of the drilling are shown in ***Table 2.2-17***.

Table 2.2-17 List of Test Wells

Well No.	Unit	TW1	TW2	TE3
Location		Ruisi Meru	Ruisi Meru	Ruisi Meru
Elevation	m	1254.74	1280.00	1262.51
Well Completed Date		7-Mar-93	16-Mar-97	23-Mar-97
Drilling Rig		Drill TECH	Drill TECH	Drill TECH
Diameter	mm	155	155	155
Depth	m	109.70	96.00 (122.00)	83.00 (120.00)
Screen Position	m	67.00 – 79.00 85.00 – 109.00	82.00 – 94.00 (100.00) – (118.00)	30.00 – 36.00 42.00 – 54.00 60.00 – 78.00
Screen Length	m	12.00 24.00	12.00 18.00	6.00 12.00 18.00
Static Length	m	24.71	0.90	2.53
Pumping Water Level	m	38.17	13.33	6.25
Pumping Test Yield	l/sec	5.28	4.90	5.38

Three types of tests were involved in the pumping test: 1) the step drawdown test, 2) the time drawdown test, and 3) recovery test. The results are summarized in ***Table 2.2-18***.

4) Groundwater Quality

Water quality was analyzed for TW1, TW2 and sample close to TW3 well. These results are similar to existing water quality data and contain a high rate of Total Dissolved Solids (TDS). Aeration will be required to remove high iron content.

(3) Evaluation and Selection of Water Sources

1) Evaluation of Water Sources

Selection of water sources was carried out to formulate the water supply master plans for the respective seven towns. Water sources were evaluated based on the following engineering parameters.

a) Quantity of water is sufficiently reliable for satisfying raw water requirements.

b) Water transmission by gravity.

c) Cost effectiveness.

d) Water quality is acceptable for the purpose of water supply.

The main points of the evaluation of water sources are described below.

a) Meru

As discussed above, problems with difficult terrain for water transmission by gravity were encountered on the Kathita river intake site proposed by MLRRWD. The intake site was therefore relocated to an alternative site located 5 km upstream. The safe yield was estimated at 0.409 m^3/sec (35,300 m^3/day). Whereas, the raw water requirements for Meru town in 2010 are estimated at 22,000 m^3/day. In addition, there are three other projects having water permits on the Kathita river in the vicinity of the alternative site. Water requirements for Meru town, the CEFA's project and the two community water supplies are given below. The safe yield is still sufficient for the total water requirements for all the projects concerned.

Table 2.2-19 Water Requirements for Projects Concerned

Scheme	Water Permit Authorization No.	Water Requirements
Meru Town	-	22,000 m^3/day
Kathita-Kirua Water Project (CEFA)	P26616	4,109 m^3/day
Kiamigo Water Project (Community Water Supply)	P25596	472 m^3/day
Kimuri Water Project (Community Water Supply)	P24999	63 m^3/day
Total		26,644 m^3/day

b) Nkubu

The intake site proposed by MLRRWD on the Kiguandegwa river has ample capacity to supply water for Nkubu town in 2010. The safe yield is estimated at 0.163 m^3/sec (14,100 m^3/day), whereas the estimated raw water requirements are 2,200 m^3/day.

c) Chuka

The intake site proposed by MLRRWD on the Ruguti river has ample capacity to provide raw water for Chuka town in 2010. The safe yield is estimated at 0.149 m^3/sec (12,800 m^3/day), whereas the estimated raw water requirements are 4,400 m^3/day.

d) Chogoria

The intake site proposed by MLRRWD is on the Mara Manyi river which is a tributary of the North Mara river. Flow measurements carried out at the end of dry season in 1996 resulted in 0.153 m^3/sec (13,200 m^3/sec). Whereas the raw water requirements for Chogoria town in 2010 are estimated at 3,300 m^3/day. The raw water requirements represent about 25 % of the measured yield during the dry season, which should therefore prove adequate.

e) Maua

The intake site proposed by the MLRRWD is on the Mboone stream. The yield of the site, however, measured during the dry season of 1996 came to only 0.022 m^3/sec (1,900 m^3/day), which is below the requirements of the originally identified supply area.

There are no other sources of comparable size in the area except the Ura River to the south of Maua, however pumping would be required to transmit water to the supply area. It is therefore suggested that the northern areas, including the town center, be supplied from the Mboone stream, and the southern areas be supplied from the Ura river.

f) Tigania

As discussed above, flow measurements conducted during the dry season in 1996 revealed that the flow rate at the intake site proposed by MLRRWD on the Thangatha stream was not sufficient for the Tigania supply area. The intake site was therefore relocated at an alternative site about 1 km downstream of the original site. Flow measurements carried out during the dry season in February 1997 recorded 0.053 m^3/sec (4,500 m^3/day). The measured flow rate is insufficient to satisfy the estimated raw water requirements of 4,400 m^3/day.

g) Isiolo

Taking the limited water resources of Isiolo into account, the following alternative water development plans were considered for the purpose of the water supply master plan for the town of Isiolo. The evaluation of the respective alternative plans are summarized below.

- Dam Construction on the Isiolo River

The preliminary study concluded that the construction of a storage dam at the proposed location is not viable for water development of the Isiolo river due to the following reasons:

The effective storage capacity at the proposed site is not sufficient for flow regulation. As a very general rule, the storage capacity required for regulating seasonal fluctuation of river flows should be more than 30 % of the average annual runoff. This implies, a required effective storage of at least 1,350,000 m^3 from the average annual runoff of 4,500,000 m^3 at the dam site. However, the computed effective storage capacity is only 400,000 m^3, derived from the topographic configuration at the dam site.

In addition, the dead storage is about 135,000 m^3 which is too small to cope with the sediment yield estimated at 80,500 m^3/year (equivalent to 0.35 mm/km^2/year). Sedimentation in the reservoir should therefore be minimized in order to secure effective storage. For this purpose, countermeasures such as provision of sediment flushing gates, dredging facilities and upstream check dams would be essential. However, provision of these countermeasures is not feasible due to various technical constraints and financial considerations.

The Isiolo river is a limited surface water source for the town of Isiolo and the surrounding area. Water development by dam construction should therefore be beneficial not only for Isiolo water supply but also other uses. However, the water balance study revealed that the estimated flow rate to be developed by the storage dam will not be sufficient to meet water requirements downstream of the dam site.

- Springs on the Isiolo River

The Kithima and the Rugsu springs are a major source of water to the Isiolo river in the dry season. Water development of these springs is expected to be a possible alternative for supplying water to Isiolo town.

An advantage of this alternative is that the present loss of water between the springs and the existing intake is minimized by direct introduction of water from the sources. As far as the measured minimum flow rates, in the order of 6,800 m^3/day of water in total may be utilized from these springs. However, there are a number of existing users of the water mainly for irrigation. This alternative cannot be recommended without coordinating water use between the Isiolo water supply and other water users.

- Groundwater

The optimum pumping ratio is calculated from permissible maximum drawdown in a borehole. The permissible maximum pumping determined from the tests was 5.0 lit./sec for TW1,TW3 and 3.0 lit./sec for TW2.

Table 2.2-20 Summary Results of Pumping Tests

Well	Permissible Maximum Discharge (l/sec)		Recommended Pumping Rate (l/sec)
	Estimated from Entrance Velocity	Estimated from Total Drawdown	
TW1	10	10	5
TW2	3	16	3
TW3	10	23	5

2) Conclusions

As a result of the evaluations above, the resultant raw water requirements and the safe yields for the selected water sources for the different schemes are given below:

Table 2.2-21 Source Requirements and Flow Rates

Scheme	Raw Water Requirement (m^3/day)	Selected Water Source	Flow Rate applied as Safe Yield (m^3/day)
Meru	22,000	Kathita River	35,300
Nkubu	2,200	Kiguandegwa River	14,100
Chuka	4,400	Ruguti River	12,900
Chogoria	3,300	Mara Manyi Stream	13,200
Maua	1,650 [1)]	Mboone Stream	1,900
Tigania	4,400	Thangatha Stream	4,500
Isiolo	8,800	Groundwater	-

Note : Northern supply area only.

2.3 Socio - economic Conditions

2.3.1 Administration

All the supply areas are located in Eastern Province which, in terms of both area and population, is the second largest of Kenya's eight Provinces.

Eastern Province has its Provincial Headquarters in Embu and is divided into eight Districts. Meru and Nkubu are located in Meru District with the District Headquarters in Meru. Isiolo is the District Headquarters for Isiolo District, Chuka and Chogoria lie in Thraka Nithi District, with the newly formed headquarters located at Chuka and, Maua and Tigania are located in Nyambene District, with the District Headquarters located just north of Maua.

District Development Plans are prepared at District level and it is significant to note that all current plans place a high priority on the improvement of water supplies.

2.3.2 Population

Baseline population levels and current growth rates were obtained from an analysis of past population census results, as summarised below:

Table 2.3-1 1989 Scheme Populations, and 1969-1989 Inter-Census Growth Rates for Identified Supply Areas

Project	Kenya	Eastern Province	Meru	Nkubu	Isiolo	Chuka (1)	Chogoria	Maua (2)	Tigania
1989 population	21,443,636	3,768,677	125,191	6,881	18,658	62,784	25,148	3,223	51,826
1969-1989annual growth rate	3.4%	3.65%	3.6%	3.5%	4.2%	2.7%	3.4%	3.4%	2.4%
1997 population	28,000,000	5,020,000	165,980	9,471	25,679	81,034	32,134	5,537	63,891

Notes (1) Chuka population includes for additional area outside supply area, for which water will be delivered from the proposed treatment plant.
(2) Maua supply area is limited to the urban areas within Amwathi sub-lcation. A higher growth rate than that for the full sub-location has therefore been applied.

These figures indicate that population growth rates during the twenty years between 1969 and 1989 were among the highest in the world. Since the 1989 census, there has been no similar widescale and detailed population survey, although a number of local population estimates have been made. These however do not give sufficient justification for adopting alternative growth characteristics. Therefore, the above current (1997) population levels have been estimated using the average 1969-1989 annual growth rates. The exception being Maua where, due to raw water source constraints, the supply area is limited to the urban areas of Amwathi sub-location only. Since the growth characteristic of urban areas is different from rural areas, the growth rate for the whole sub-location cannot be applied in this instance. A higher growth rate has been assumed in this case to allow for the higher level of urbanisation and also due to the location of the new District Offices close to the supply area.

2.3.3 Land Use and Economic Activities

The supply areas lie within the high agricultural potential zone that exists between the mountainous forested areas of Mount Kenya and Nyambene, and the lower arid areas, where rainfall, and hence agricultural potential is limited.

With the exception of Meru and Isiolo towns and some urban centres, the region is rural in character, and the economy is dependent on agriculture.

Land potential increases with elevation, and high income generating crops, such as tea and coffee are grown in the higher areas, whereas livestock and subsistence cropping become more predominant at lower elevations, as at Isiolo. Other cash crops include miraa, grown principally in the Maua area, maize, horticultural products, cotton and sunflower. Subsistence crops include Irish potatoes, beans, sorghum, millet, cow peas, green grams, cassava and sweet potatoes

Family farming activities, income and socio economic status is therefore predominantly determined by the area and location of land the household controls. The socio economic survey indicated that 60% of households lived on plots of less than 2 acres, with an average family size of 7.4. The average plot size tended to be higher in Chogoria and Chuka but lower in areas with higher levels of urbanization, particularly Isiolo.

Existing livestock ownership levels have been estimated at approximately 1.5 livestock units per household. This is roughly equivalent to 3 indigenous cattle and 8 sheep or goats. The socio economic survey indicated a similar figure for the permanent residents of Isiolo, but a much higher number of cattle seasonally migrate to the town due to the nomadic nature of the area surrounding Isiolo.

The main industries in the area such as coffee and tea processing, maize milling, dairy factories, textiles and timber yards are all based on agricultural production. Tea and coffee factories tend to be located in rural areas close to the production areas, but there is a growing industrial presence in Meru.

There are no industries located in Isiolo although one livestock factory is under construction.

There is a significant tourism industry in surrounding areas which provides employment and economic impact to adjacent communities. Samburu Game Reserve is located 30 km north of Isiolo. Meru Game Reserve is 15 km east of Maua, and Mount Kenya Forest Reserve forms the western boundary of Meru, Chogoria and Chuka supply areas. However, although Samburu is quite highly utilised, there is considerable potential for increase in the utilisation of Meru Reserve and of Mount Kenya.

2.3.4 Existing Infrastructure

(1) Roads

All weather surfaced roads are limited to the main Embu - Meru - Isiolo road, the secondary Meru - Maua road, and other limited lengths of access roads. These provide good access to the centre of all supply areas. However all other roads are unsurfaced, and access to remoter parts of the supply areas during rainy periods is problematical. The road network density is high in the more populated high potential areas, but is low in the semi arid areas around Isiolo. Maintenance of the existing road network system is constrained by the available resources.

(2) Electricity

Government policy towards rural electrification has resulted in an extensive electricity grid, connecting all large towns and most rural centres. The main consumers are commercial, institutional and industrial. As shown by the socio-economic survey, less than 10% of the population have electricity connections.

(3) Telephones

The telephone infrastructure coverage is similar to electricity, with most rural centres being connected. In this case however, only 5% of the surveyed population had telephone connections.

(4) Water

As described elsewhere, water supply services are less than adequate. Only 15% of the population are served by Ministry supplies, 23% are supplied from untreated community water supply schemes, and the remainder obtain water from traditional sources such as surface water sources (30%) and hand dug wells (8%).

(5) Sanitation

Pit latrines are used by the majority of people (88%), many of which however are poorly constructed and maintained.

Septic tanks are used by approximately 7% of the population.

Sewer reticulation systems exist only in Meru and Isiolo Townships where they serve approximately 30% of the urban population.

The low sewer reticulation coverage in urban areas, and the poor condition of sanitary facilities, especially in urban areas, gives cause for concern over the spread of water related diseases.

(6) Health

There are currently an average of 5 hospital beds available per 1,000 population, and 17 outpatients are treated daily, per 1,000 population, Nkubu having the highest coverage and Chuka the lowest.

Malaria is the most frequent disease reported as affecting people in the supply areas. This is surprising, since these high elevations had previously been considered free of malaria. Typhoid, dysentry and cholera, (all of which are also water related diseases), together with respiratory diseases, are amongst the most common diseases reported by Ministry of Health statistics.

(7) Education

In accordance with Government Policy of encouraging school attendance and, with a high percentage of population at school going age, the number of pupils represent more than 30 % of the population. To accommodate this high number, there are 59 primary, 26 secondary and 15 technical schools within the supply areas.