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No. 42

REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION

STUDY ON CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM FOR GREATER NAKURU WATER SUPPLY PROJECT

FINAL REPORT

VOLUME I EXECUTIVE SUMMARY

DECEMBER 1990

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Republic of Kenya, the Japanese Government decided to conduct a study on the construction of a Dam in Malewa River System for Greater Nakuru Water Supply Project and entrusted the Cooperation Agency (JICA).

JICA sent to Kenya a study team headed by Mr. Masashi Yamaguchi, Nippon Koei Co., Ltd. and composed of members from Nippon Koei Co., Ltd. and the INA Civil Engineering Consultants Co., Ltd. three times between February 1989 and July 1990.

The team held discussions with the officials concerned of the Government of Kenya, and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Kenya for their close cooperation extended to the team.

December 1990

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International
Cooperation Agency

Mr. Keisuke Yanagiya
President, Japan Inter National Cooperation Agency
Tokyo, Japan

Dear Sir,

LETTER OF TRANSMITTAL

We have the pleasure of submitting you a Final Report for the Study for Construction of Dam in Malewa River System, Greater Nakuru Water Supply Project, Eastern Division.

The objective of the study was to formulate the optimum water supply plan for three urban centers (Nakuru Municipality and both Gilgil and Naivasha Towns) and two rural areas (Gilgil and Naivasha). For this purpose the Study Team elaborated the survey, investigation and studies on various items during the period from January, 1989 to November, 1990. The findings and results of the them are reported in six (6) volumes as per attached herewith.

It is concluded that the surface runoff of the Malewa River is a sole water source available for the project and the project is therefore vital to the success of the prosperous socio-economic development of the region and the water demand in future. However it was forecast that the project will enhance environmental impacts especially on Lake Nakuru. In this connection it is recommended that the Government of Kenya establish the counter measure best suitable to the site on natural and social environmental before implementation of this project.

All members of the Study Team wish to express grateful acknowledgement to the personnel of your agency, Advisory Committee, Ministry of Foreign Affairs, and Embassy of Japan in Nairobi as well as officials and individuals of the Government of Kenya for their assistance and cooperation extended to the Study Team.

Masashi Yamaguchi
Team Leader

December 1990

CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM
FEASIBILITY STUDY REPORT

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THE REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

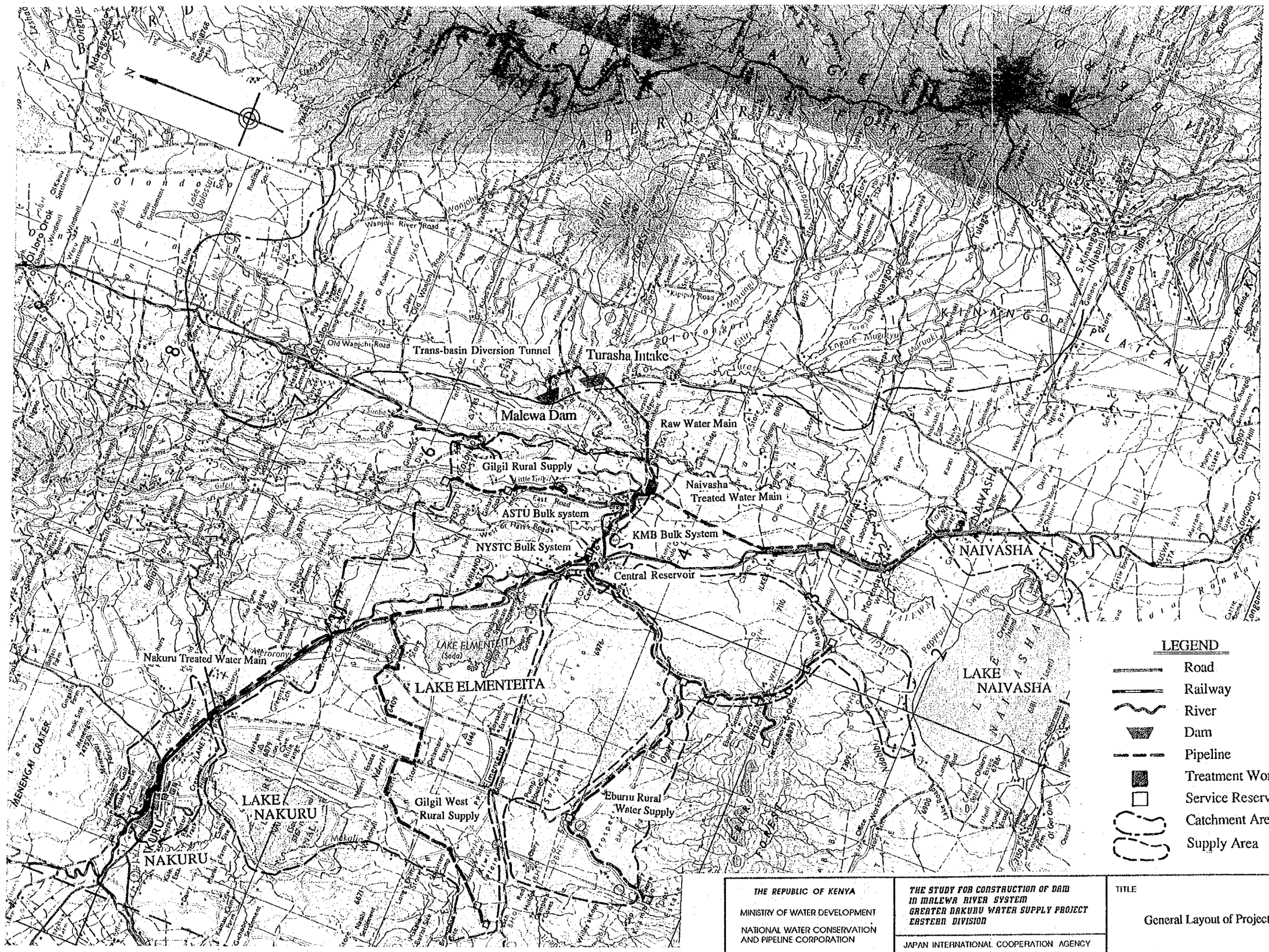
NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION

THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION

JAPAN INTERNATIONAL COOPERATION AGENCY

TITLE

Prospective View of the Proposed Dam Site



THE REPUBLIC OF KENYA

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THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION

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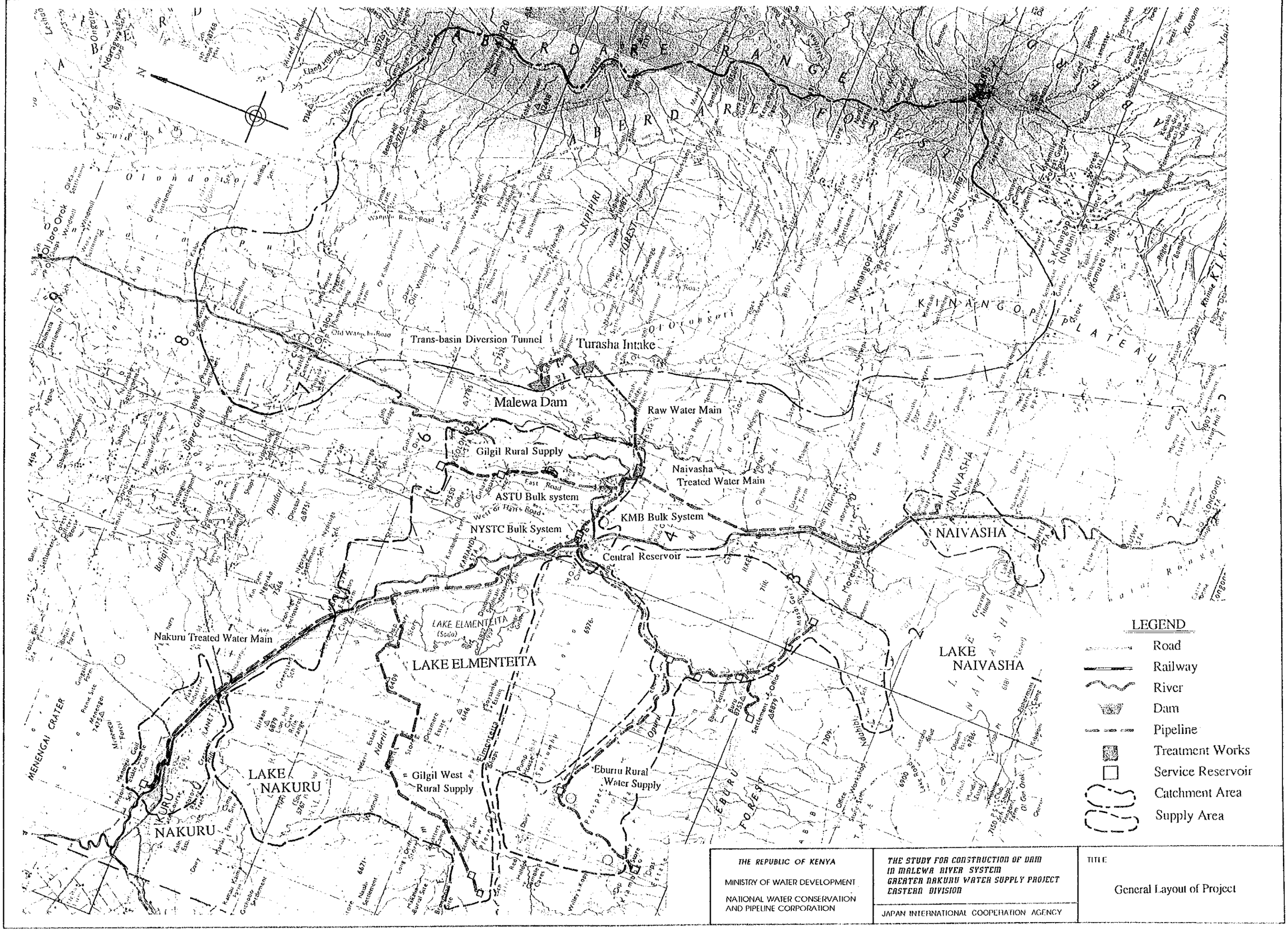
General Layout of Project



THE REPUBLIC OF KENYA

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TITLE

General Layout of Project

PRINCIPAL FEATURES OF THE PROJECT

1. Malewa Dam Scheme

1.1 Dam and Apartment Structures

(a)	Reservoir		
	Catchment area		635 sq. km
	Full supply level		El. 2,149.00 m
	Minimum supply level		El. 2,123.50 m
	Flood water level		El. 2,151.80 m
	Active storage capacity		71.80 x 10^6 cu.m
	Gross storage capacity		55.92 x 10^6 cu.m
	Dead storage capacity		15.88 x 10^6 cu.m
(b)	River diversion system		
	Design flood		240 cu.m/sec.
	Crest level of coffer dam		El. 2,115.00 m
	Volume of coffer dam,	core	16,700 cu. m
		filter	8,900 cu.m
		outer shell-1	50,200 cu.m
		outer shell-2	48,700 cu.m
	Diversion tunnel,	shape	Circular
		diameter	3.65 m
		length	342 m
	No. of rows		2
(c)	Dam		
	Type		Rockfill with center core
	Crest level		El. 2,154.00 m
	Dam height		80.0 m
	Crest length		360.0 m
	Crest width		10.0 m
	Slope, upstream		1 : 2.70
	downstream		1 : 2.20
	Embankment volume,	core	166,900 cu.m
		filter	110,900 cu.m
		inner shell	59,100 cu.m
		outer shell-1	516,200 cu.m
		outer shell-2	148,100 cu.m
(d)	Spillway		
	Type		Non-gated, fan shaped
	Crest level		El. 2,149.00 m
	Crest length		101.0 m
	Design flood		960 cu.m/sec.
	Design flood for stilling basin		460 cm.m/sec.
	Chuteway, width x length		20.0 m x 182 m
	Energy dissipator,	type	Stilling basin
		width x length	20.0 m x 80.0 m
(e)	River outlet facilities		
	Flow regulating device		Hollow jet valve, D500 mm

1.2 Trans-basin Diversion Tunnel

(a)	Intake	
	Type	Vertical shaft
	Design discharge	2.30 cu. m/sec.
	Sill level of inlet	El. 2,120 m
	Flow regulating device	Hollow jet valve, D750 mm
(b)	Tunnel	
	Shape	Semi-circular
	Tunnel height and width	H=1.8 m, W=1.8 m
	Length	2,420 m
	Slope	1 : 1,000
	Design discharge	2.30 cu.m/sec.
	Flow in tunnel	Free flow
(c)	Outlet	
	Type	Step-wise

2. Water Supply Scheme

2.1 Raw Water Transmission System

(a)	Intake	
	Design discharge	2.30 cu.m/sec.
	Normal intake level	El. 2,103.20 m
	Inlet sill level	El. 2,102.00 m
	No. of inlets	2
	Dimension of each inlet, width x height	2.50 m x 1.20 m
(b)	Tunnel	
	Design discharge	2.30 cu.m/sec.
	Shape,	Semi-circular
	Tunnel width x height	1.80 m x 1.80 m
	Tunnel length	190 m
	Slope	1 : 1,500
(c)	Desilting work	
	Design discharge	2.30 cu.m/sec.
	Normal water level	El. 2,102.50 m
	Sand settling basin, width x length	4.0 m x 14.0 m (2 chambers)

(d) Pipeline

	Stage 2-1	Stage 2-2
Design discharge	102,500 m^3/day	102,500 m^3/day
Flow	Gravity	Gravity
No. of rows	1	1
Pipe material	Steel	Steel
Pipeline configuration		
D 1,000 mm	6,800 m	6,800 m
D 900 mm	2,600 m	2,600 m

2.2 Treatment works

Treatment method	Stage 2-1	Stage 2-2	Full treatment Stage 2-3
Production capacity	100,000 m^3/day	50,000 m^3/day	50,000 m^3/day
No. of treatment units	50,000 m^3/day x 2	50,000 m^3/day x 1	50,000 m^3/day x 1

Principal features of the 50,000 m^3/day unit :

(a)	Rapid mixing chamber	
	Type	Hydraulic
	Number	1
(b)	Flocculating chamber	
	Type	Hydraulic, vertical flow
	Number	4
	Width and length of a chamber	10.2 m x 12.5 m
(c)	Sedimentation basin	
	Type	Conventional, horizontal flow
	Number	4
	Width and length of a basin	12.5 m x 50.0 m
(d)	Filters	
	Type	Conventional, constant rate filtration, backwash and surface wash
	No. of filter beds	8
	Width and length of a bed	8.70 m x 8.00 m
	Filter media	Sands, 600 mm thick
	Filter bed	Gravel, 350 mm thick
(e)	Clear water reservoir	
	Storage capacity	2,084 m^3
	High water level	El. 2,072.00 m
	Low water level	El. 2,069.00 m
(f)	High level tank	
	Storage capacity	1,100 m^3
	High water level	El. 2,087.0 m
	Low water level	El. 2,084.8 m
(g)	Sludge lagoon	
	Storage capacity	3,400 m^3
	Number	2
	Width x length x depth	72.4 m x 48.4 m x 1.6 m
(h)	Wash water pond	
	Storage capacity	7,400 m^3
	Number	1
	Width x length x depth	36.7 m x 102.7 m x 2.3 m

2.3 Nakuru Treated Water Transmission System

(a) Main pipeline

	Stage 2-1	Stage 2-2
Design discharge		
Treatment works - KMB	82,520 m^3/day	89,550 m^3/day
KMB - Central Reservoir	81,690 m^3/day	88,350 m^3/day
Central Reservoir - Gilgil West Branch	71,740 m^3/day	76,450 m^3/day
Gilgil West Branch - R6 in Nakuru	70,960 m^3/day	75,900 m^3/day
Flow	Gravity	Gravity
No. of rows	1	1
Pipe material	Steel	Steel
Pipeline configuration		
Treatment works - Central Reservoir		
D 1,000 mm	1,800 m	4,150 m
D 900 mm	5,600 m	3,250 m
Central Reservoir - R6 in Nakuru		
D 900 mm	-	2,170 m
D 800 mm	24,210 m	30,340 m
D 750 mm	8,300 m	-

(d) Service reservoirs

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
Gilgil					
– Central	2,051.70	2,047.00	1 x 4,100	1 x 2,940	1 x 2,940
Nakuru					
– R1	1,983.03	1,979.03	1 x 1,200	1 x 800	1 x 800
– R2	1,935.20	1,932.20	1 x 300	1 x 150	1 x 150
– R3	1,903.00	1,898.80	2 x 4,410	1 x 2,520	2 x 2,520
– R4	1,888.46	1,884.46	1 x 1,600	1 x 2,400	1 x 2,400
– R5	1,850.96	1,846.96	2 x 4,800	1 x 5,400	1 x 5,400
– R6	1,915.90	1,911.70	2 x 2,625	1 x 3,675	1 x 3,675
– R7	1,871.01	1,866.51	2 x 3,600	1 x 6,300	1 x 6,300

2.4 Naivasha Treated Water Transmission System

(a) Main pipeline

	Stage 2-1	Stage 2-2
Design discharge	16,700 m^3/day	9,900 m^3/day
Flow	Gravity	Gravity
No. of rows	1	1
Pipe material	Steel	Steel
Pipeline configuration		
D 500 mm	25,700 m	-
D 450 mm	3,000 m	4,000 m
D 400 mm	-	24,700 m

(b) Service reservoirs

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
R1	1,994.0	1,990.0	1 x 1,600	1 x 600	1 x 600
R2	1,962.0	1,958.0	2 x 4,200	1 x 2,400	1 x 2,400

2.5 Gilgil East Rural Supply System

(a) Boosting facilities

Type of pump: Multi-stage volute pump

	Treatment works	Reservoir No. 1	Reservoir No.2
No. of pumps	2	2	2
Pump capacity	0.596 m^3/min.	0.374 m^3/min.	0.225 m^3/min.
Pump height	171 m	136 m	149 m

(b) Pumping main

Design discharge	Stage 2-1	Stage 2-2
Treatment works - Reservoir No.1	780 m^3/day	550 m^3/day
Reservoir No.1 - No.2	490 m^3/day	340 m^3/day
Reservoir No.2 - No.3	295 m^3/day	205 m^3/day
No. of rows	1	1
Pipe material	UPVC	UPVC

Pipeline configulation

Treatment works - Reservoir No.1	D150 mm, L = 7,100 m
Reservoir No.1 - No.2	D125 mm, L = 4,300 m
Reservoir No.2 - No.3	D100 mm, L = 4,600 m

(c) Service reservoirs

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
No.1	2,210.0	2,207.8	1 x 660	1 x 500	–
No.2	2,335.0	2,332.8	1 x 440	1 x 330	–
No.3	2,460.0	2,458.0	1 x 300	1 x 200	–

2.6 Gilgil West Rural Supply System

(a) Distribution main (each stage)

Design discharge Nakuru treated water main - Reservoir No.1	Stage 2-1	Stge 2-2
D150 mm, L = 15,000 m	780 m^3/day	550 m^3/day
D100 mm, L = 11,700 m	480 m^3/day	280 m^3/day
D80 mm, L = 2,200 m	170 m^3/day	160 m^3/day

(b) Boosting facility (each stage)

Type of pump	Multi-stage volute pump
No. of pumps	2
Pump capacity	0.114 m^3/min.
Pump height	104 m

(c) Pumping main (each stage)

	Stage 2-1	Stge 2-2
Design discharge (Reservoir No.1 - No.2)	150 m^3/day	100 m^3/day
No. of raws	1	1
Pipe material	Steel pipe	Steel pipe
Pipeline	D100 mm, L = 2,100 m	D100 mm,L = 2,100 m

(d) Service reservoirs

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
No.1	1,860.0	1,858.0	1 x 50	1 x 50	–
No.2	1,960.0	1,956.4	1 x 180	1 x 90	–

2.7 Eburru Rural Supply System

(a) Distribution main (each stage)

Design discharge Central reservoir		Stage 2-1 (m^3/day)	Stage 2-2 (m^3/day)
- Reservoir No.1	D250 mm, L = 10,200 m	3,700	2,220
Reservoir No.1 - No.2	D250 mm, L = 14,300 m	1,900	1,110
Reservoir No.2 - No.3	D200 mm, L = 8,700 m	1,900	1,110
Reservoir No.1 - No.4	D200 mm, L = 3,400 m	1,900	1,110
Reservoir No.4 - No.5	D200 mm, L = 3,700 m	1,900	1,110
Reservoir No.5 - No.6	D150 mm, L = 4,600 m	950	555
Reservoir No.5 - No.7	D100 mm, L = 1,700 m	950	555
Reservoir No.7 - No.8	D100 mm, L = 1,800 m	950	555
Reservoir No.8 - No.9	D100 mm, L = 2,300 m	950	555

(b) Boosting facilities

Type of pump	Multi-stage volute pump

	Reservoir No.3	Reservoir No.4	Reservoir No.5	Reservoir No.6
No. of pumps	2	2	2	2
Pump capacity	1.450 m^3/min.	1.450 m^3/min.	1.450 m^3/min.	0.726m^3/min.
Pump height	297 m	134 m	199 m	294 m

(c) Service reservoirs

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
No.1	2,014.0	2,010.4	1 x 90	1 x 90	–
No.2	1,890.0	1,886.4	1 x 90	1 x 9	–
No.3	1,955.0	1,953.0	1 x 1,200	1 x 800	–
No.4	2,170.0	2,166.4	1 x 90	1 x 90	–
No.5	2,350.0	2,346.4	1 x 90	1 x 90	–
No.6	2,620.0	2,617.8	1 x 660	1 x 330	–
No.7	2,260.0	2,256.4	1 x 90	1 x 90	–
No.8	2,100.0	2,096.4	1 x 90	1 x 90	–
No.9	2,020.0	2,017.8	1 x 660	1 x 330	–

2.8 Bulk Supply System in Gilgil

Scheduled phase of construction

KMB, GMB - NYSTC	Stage 2-1
ASTU	Stage 2-2

	GMB-NYSTC	KMB	ASTU
Design discharge	7,060 m^3/day	2,030 m^3/day	1,140 m^3/day
(a) Boosting facilities			
Type of pump	-	-	Multi-stage volute pump
No. of pumps	-	-	2
Capacity of pump	-	-	0.825 m^3/min.
Pumping height	-	-	25 m
(b) Distribution main			
Flow	Gravity	Gravity	Pumping
No. of rows	1	1	1
Pipe material	UPVC	UPVC	UPVC
Pipeline configuration			
D 100 mm	-	130 m	-
D 150 mm	-	-	2,530 m
D 300 mm	260 m	-	-

(c) Service reservoir

Reservoir	Water Level (El.m)		Number and Storage Capacity (m^3)		
	HWL	LWL	Stage 2-1	Stage 2-2	Stage 2-3
KMB	2,029.1	2,025.5	1 x 760	–	–
ASTU	2,063.6	2,060.0	–	1 x 720	–

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Abbreviation and Local Terms

1. Abbreviation of Measures

1.1 Length

mm	=	millimeter
cm	=	centimeter
m	=	meter
km	=	kilometer

1.2 Area

m^2, sq.m	=	square meter
ha	=	hectare
km^2, sq.km	=	square kilometer

1.3 Volume

lit, l	=	liter
lcd	=	liter per capita per day
cu.m, m^3	=	cubic meter
cu.m/day, m^3/day	=	cubic meter per day
MCM	=	million cubic meter

1.4 Weight

mg	=	milligram
mg/l	=	milligram per liter
g	=	gramme
kg	=	kilogram
t	=	ton

1.5 Time

s, sec	=	second
min	=	minute
h, hr	=	hour
d	=	day
yr	=	year

1.6 Money

Kshs.	=	Kenya Shilling(unit of Kenya currency, US$1.00 = Ksh 23.0 = ¥ 150)
US$, $	=	US dollar
¥	=	Japanese Yen

1.7 Electric Measures

kV	=	kilovolt
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt hour
kVA	=	kilovolt ampere

1.8 Other Measures

mmho	=	micromho = conductance
ppm	=	parts per million
ppb	=	parts per billion
MPN	=	most probable number
‰	=	mill
%	=	per cent
PS	=	0.736 kW
°	=	degree
'	=	minute
"	=	second
℃	=	degree centigrade
n.a.	=	not available
COD	=	Chemical Oxygen Demand
T-N	=	Total Nitrogen
I -	=	Inorganic -
O -	=	Organic -
T-P	=	Total - Phosphorus
DO	=	Dissolved Oxygen
pH	=	Exponent of hydrogen ion concentration

1.9 Derived Measures Based on the Same Symbols

cu.m/sec, m^3/s	=	cubic meter per second
cu.m/day, m^3/day	=	cubic meter per day
t/ha	=	ton per hectare
lpcd	=	liter per capita per day

2. Other Abbreviations

BS	=	British Standards
JIS	=	Japanese Industrial Standards
ASTM	=	American Society for Testing and Material
GNP	=	gross national products

GDP	=	gross domestic product
GRDP	=	gross regional domestic product
El.	=	elevation
FWL	=	flood water level
FSL	=	full supply level
MSL	=	minimum supply level
HWL	=	normal operation level
LWL	=	minimum operation level
f.o.b	=	free on board
c.i.f.	=	cost, insurance and freight
ICB	=	international competitive bid
LCB	=	local competitive bid

3. Abbreviation of Organizations

MOA	=	Ministry of Agriculture
MENR	=	Ministry of Environment & Natural Resources
MOF	=	Ministry of Finance
MOLD	=	Ministry of Livestock Development
MOLG	=	Ministry of Local Government
MOTW	=	Ministry of Tourism & Wildlife
MOTC	=	Ministry of Transport & Communication
MORD	=	Ministry of Regional Development
MOWD	=	Ministry of Water Development
NES	=	National Environmental Secretariat
NWCPC	=	National Water Conservation & Pipeline Corporation
SOK	=	Survey of Kenya
KWS	=	Kenya Wildlife Service
NMC	=	Nakuru Municipal Council
NTC	=	Naivasha Town Council

ASTU	=	Anti-Stock Theft Unit
KYSTC	=	National Youth Service Training Center
GMB	=	Gilgil Military Barracks
KMB	=	Kenyatta Military Barracks
WWF	=	World Wide Fund for Nature
JICA	=	Japan International Cooperation Agency
OECF	=	Overseas Economic Cooperation Fund, Japan

I. INTRODUCTION

1.1 Historical Background

The contemplated project is an integral part of the Greater Nakuru Water Supply Project, Eastern Division, in the Rift Valley Province, and its primary purpose is to secure and augment safe water supply to three urban areas (Nakuru municipality and both Gilgil and Naivasha towns) and two rural areas (Gilgil and Eburru). The Nakuru municipality is the capital of the Rift Valley Province and is ranked as the fourth largest urban center within Kenya.

In order to achieve the prosperous regional development in the target area and to ameliorate the lives of its inhabitants, the Government of Kenya is giving serious attention to the need to establishing a long term water supply plan. Through various elaborations, the Ministry of Water Development finally endorsed a plan to develop the surface runoff of the Malewa river basin in two stages. The Stage 1 Project will use the unregulated runoff of the Turasha river, the main tributary of the Malewa river, to supply treated water amounting to 18,000 cu.m/day to both the Nakuru municipality and Gilgil town to solve their acute water shortages. This project is currently under construction and is programmed to be completed in 1992. The Stage 2 Project (the Project) contemplates to expansion of the source by construction of a dam/reservoir in the Malewa river basin in order to fully accomplish the initial objective as a whole.

1.2 Organization and Management of the Study

In response to a request made by the Government of Kenya, JICA carried out a feasibility study on Construction of Dam in Malewa River System, Eastern Division, Greater Nakuru Water Supply Project (the Study) during the period from January, 1989 to October, 1990. The Study was carried out in three phases : Phase 1 Study - selection of the most promising dam site ; the Phase 2 Study - feasibility study of the Project ; and Phase 3 Study - preliminary environmental study.

During execution of the Study, MOWD was represented by NWCPC. JICA organized an Advisory Committee to furnish the Study Team with technical assistance and advice throughout the period of the Study. The Study Team was composed of a numbers of experts

in the various fields. Members of JICA Advisory Committee and Study Team were as presented in Table S.1.1.

1.3 Objective and Scope of the Study

The objective of the Study is to carry out a feasibility study of the Project. The Scope of the Study was as summarized below.

(1) Phase 1 Study

- Collection of data and review of existing data and information
- Identification of alternative dam sites
- Preparation of topographic map of reservoir areas and dam sites
- Preliminary geological investigation
- Preliminary construction material survey
- Hydrological investigation
- Water demand forecast
- Selection of a promising dam site

(2) Phase 2 Study

- Socio-economic survey
- Additional geological investigation
- Additional construction material survey
- Additional hydrological investigation
- Preliminary environmental investigation
- Formulation of development plan
- Preliminary design of the major project components
- Construction planning and cost estimate
- Economic and financial evaluation

(3) Phase 3 Study

- Collection of data and information, including preparation of topographic map of Lake Nakuru
- Agricultural survey/inventory survey of irrigation facilities in Lake Naivasha area
- Reconnaissance groundwater survey in Lake Naivasha area
- Analysis of water balance in Lakes Naivasha and Nakuru
- Water quality investigation
- Forecast of impacts of the Project

II. BACKGROUND

2.1 General Socio-Economy

The population in Kenya was estimated to be approximately 23 million in 1988 and was subject to the relatively high growth rate of 3.8 per cent per annum during the period from 1984 to 1988. It has been forecast by the Government that the population would continue to increase at an average growth rate of 3.7 per cent per annum during the period from 1988 to 2000, reaching 34.8 million in 2000.

GDP was estimated at around Kshs.76,770 million in 1988, showing an average rate of growth of 5.1 per cent per annum during the period from 1984 to 1988. The agriculture sector is predominant, providing 28.9 per cent of GDP. The Government has set the GDP growth rate at 5.9 per cent per annum for the period from 1988 to 2000, 2.2 per cent higher than the population growth rate.

2.2 Major National Policies related to the Project

The Sixth Five Year Development Plan, 1989 - 1993 proposes that 61 per cent of the Kenyan population will be provided with clean piped water by 1993. This will benefit 95 per cent of the urban population of 5.6 million and 50 per cent of the rural population of 21.6 million. In conjunction with this target the Government has set out to invest Kshs. 905 million on the water sector including the electricity supply sector during the period of the Sixth Five Year Plan. This amount will account for about 5.2 per cent of the total fixed investment.

2.3 Water Supply Sector

2.3.1 Public Water Supply Organization

The public water supply in Kenya is mainly administered by MOWD, NWCPC and the local government authorities concerned. MOWD concentrates mainly on the Rural Water Supply Development Programme. NWCPC is an autonomous body, established in 1988, and its main functions are the development, operation and maintenance of specified water supply projects, the supply of water in bulk or otherwise to such consumers as designated by MOWD, and assistance in formulation and execution of national water development policy. The local

authorities also engage themselves in development, operation and management of water supply schemes in their administrative areas.

2.3.2 Present Supply Level

At present about 75 per cent of the urban population is provided with piped water, of which over 90 per cent is supplied through communal points or kiosks. As far as the rural population is concerned, only 26 per cent is accessible to piped water and the remaining population is forced to fetch water from natural sources at remote locations. Water consumption in the urban area is in the range of 70 to 160 lpcd, while that in the rural area is 50 lpcd on an average.

2.3.3 Development Constraints

The public water supply sector has been facing such constraints as insufficient provision of water supply and limited budget allocation. Recurrent expenditure on water development had decreased to Kshs. 282 million in 1989 from Kshs. 320 million in 1985. The Government expects MOWD to reinforce cost recovery at least for operation and maintenance costs.

The financial situation of MOWD is, however, considered to be unfavorable. The total O& M cost was actually Kshs. 2.90 per cu.m in 1984, whereas the average water tariff was only Kshs. 1.04 cu.m.

III. THE STUDY AREA

3.1 General Description

3.1.1 Location and Topography

The proposed water service area covers the Nakuru municipality with an area of 91.7 sq.km, Gilgil town with an area of 3.9 sq.km, Naivasha town with an area of 78.0 sq.km, Gilgil rural area with an area of 550 sq.km and Eburru rural area of 721 sq.km.

The Nakuru municipality, which is situated on the southern slopes of the Menengai Crater at an altitude of El.1,780 to 2,000 m, is about 160 km distant from Nairobi, the capital of Kenya, and is bounded by the Lake Nakuru National Park to the south. Lake Nakuru which is saline acts as the receptacle of the rain runoff and sewage from the municipal area, and is famous over the world for millions of flamingoes.

The Gilgil and Naivasha towns are located between Nakuru municipality and Nairobi and lie on undulating land at an altitude of around El. 2,000 m. In view of the drainage area, both the towns is within Lake Naivasha, which is characterized by a fresh water.

Both the Gilgil and Eburru rural areas encompass a vast area of undulating land with elevations ranging from El. 1,800 to 2,300 m, extending over both Lakes Naivasha and Lake Elementaita. The later lake is also saline and inhabited by flamingoes.

3.1.2 Water Resources and Quality

The Study Area covered an area of approximately 5,525 sq.km extending across the drainage basins of three lakes : Lake Naivasha (3,401 sq.km), Lake Elementaita (588 sq.km), and Lake Nakuru (1,536 sq.km). There are two distinct wet seasons, and one dry season in a year. The annual rainfall varies greatly not only throughout the year and from year to year but also with altitude. In fact the average annual rainfall is 1,453 mm at South Kinangop (El. 2,591 m) in the Aberdare Range and only 627 mm in Nakuru (El. 1,872 m) on the floor of the Rift Valley.

Although the project area spans three large lake drainage basins, it is hardly blessed with abundant water resources because of its geographical location. Groundwater is currently

widely used for water supply but is contaminated by a high concentration of fluoride, for instance 1.9 - 5.5 ppm in Nakuru municipality. Both Lakes Elementaita and Nakuru are located close to the main water consumption area, but their water quality is not suitable for water supply.

It has been ascertained that the surface runoff of the Malewa river basin is the precious and sole source for achieving of the purpose of the Project in view of its quantity and quality. The Malewa river with a drainage area of 1,653 sq.km is the largest water source of Lake Naivasha, and its runoff remains almost untapped. The average annual runoff has been estimated at 3.19 cu.m/sec or 90 million cu.m at the proposed dam site.

3.2 Socio-economic Condition

The population was estimated to be approximately 240,000 in Nakuru municipality in 1987, 15,100 in Gilgil town in 1987, 37,500 in Naivasha town in 1989, 13,600 in Gilgil rural area in 1985, and 25,000 in Eburru rural area in 1985. The urban areas have been subject to a very high population growth, exceeding 10 per cent per annum in recent years, while the rural areas have also recorded population growth rate slightly higher than the national average of 3.7 per cent per annum. The rapid population growth rate in the urban areas is attributed to rural - urban migration.

Although there are no statistic data available concerning the present socio - economic situation in the proposed area, it is evident that agriculture is the predominant economic activity and absorbing the majority of the economically active population. It is worth to noting that Lake Nakuru National Park recorded about 129,000 visitors in 1987, which had showed an increase of 7.1 per cent per annum since 1983. Around Lake Naivasha, horticultural crop cultivation has been expanded rapidly by using the lake water in recent years and the fishery in the lake is also thriving , although the catch of fish varies greatly from year to year. Both the tourism industry and horticultural crop development have been contributing greatly to the economy of Kenya as major source of foreign exchange earning.

3.3 Current Public Water Supply

The current public water supply is estimated at 22,060 cu.m/day from five sources in the Nakuru municipality, 2,680 cu.m/day from two sources in Gilgil town, 1,480 cu.m/day from two sources in Naivasha town, and 1,000 cu.m/day from one source in Gilgil rural area.

Especially in Nakuru municipality, out of the entire supply more 70 per cent is dependent on groundwater. There is no systematic public water supply system in Eburru rural area.

The water supply in Nakuru municipality is managed by NMC, excepting the Lanet area. NTC receives a bulk supply from NWCPC and undertakes the distribution within the town. The water supply in Gilgil town is directly managed by MOWD.

The Stage 1 Project will supply fully treated water to Nakuru municipality and Gilgil town at the rates of 13,300 and 4,700 cu.m/day respectively. The treatment works is sited on the outskirt of the town of Gilgil and is of the rapid sand filtration type. The supply to Gilgil town has four bulk consumers, NYSTC, ASTU, KMB and GMB in addition to the public supply.

3.4 Existing Sewerage System

The water-borne sewerage system covers only 10.7 sq.km of the 91.7 sq.km Nakuru municipal area. There are two sewage treatment works in Nakuru municipal area : one is the Town treatment works with a treatment capacity of 3,400 cu.m/day and the other is the Njoro treatment works with a treatment capacity of 3,600 cu.m/day. Sewage effluent has been recorded recently at 3,100 cu.m/day at the Town treatment works and 5,720 cu.m/day at the Njoro treatment works.

In other parts of the proposed water supply area, sewage disposal is mainly dependent on aqua pits, cess pits and/or septic tanks.

IV. FORMULATION OF DEVELOPMENT PLAN

4.1 Forecast Future Population

The population in the proposed water service area has been forecast to grow at a rate slightly higher than the national average of 3.7 per cent per annum during the planning horizon.

Water Service Area	Unit	1990	1995	2000	2005	2010	2015
Nakuru municipality	10^3	295.6	412.0	574.0	752.4	960.3	1,225.6
Gilgil town	10^3	18.0	24.1	30.7	39.2	50.0	63.9
Naivasha town	10^3	41.2	60.8	78.7	96.7	118.7	145.8
Gilgil rural area	10^3	20.5	24.7	28.5	32.9	38.0	43.8
Eburru rural area	10^3	30.9	37.5	45.7	55.6	66.0	78.4
Total	10^3	406.2	559.1	757.6	976.8	1,233.0	1,557.5

4.2 Water Demand and Deficit

The water demand is increasing rapidly and keeping pace with the growth in population and the continuous expansion of economic and industrial activities. The future water demand adopted in the Study has basically been derived from the previous studies, and it has been forecast at intervals of 5 years during the planning horizon as presented in Table S.4.1.

The required water supply by the Project has been worked out for the respective supply area, assuming that the existing source works, excepting groundwater sources, continue to serve even in future.

(Unit cu.m/day)

Supply Area	2000		2005		2010		2015	
	Ave. daily	Max. daily	Ave. daily	Max. daily	Ave. daily	Max. daily	Ave. daily	Max. daily
Nakuru Municipality	41,040	53,180	59,550	75,390	84,020	104,750	116,150	143,310
Gilgil Town (incl.bulk supply)	2,620	4,420	5,330	7,670	8,860	11,910	13,490	17,460
Naivasha town	11,700	14,040	14,370	17,240	17,650	21,180	21,180	26,020
Gilgil rural area	900	1,270	1,210	1,640	1,560	2,060	2,000	2,590
Eburru rural area	2,700	3,240	3,300	3,960	4,030	4,840	4,930	5,920
Total	58,960	76,150	83,760	105,900	116,120	144,740	158,250	195,300

4.3 Water Resources Development Scheme

Various comparative technical and economic studies have been elaborated to formulate the optimum water resources development scheme. As the result the Malewa Dam Scheme has been selected among the possible alternatives. The basic concept of the scheme is to use jointly the surface runoffs of both the Malewa and Turasha rivers : the Malewa reservoir water would be released into the Turasha river through a trans-basin diversion tunnel, when the runoff of the Turasha river falls short of the required water.

The Malewa dam will be located approximately 10 km upstream from the confluence of the Turasha river and will create a reservoir with a gross storage capacity of 71.8 million cu.m. The full and minimum supply levels of the reservoir have been set at El. 2,149.00 m and El. 2,123.50 m respectively. This reservoir capacity has been proved to capable of yielding 176,300 cu.m/day at a dependability of 96 per cent and is judged to be the most technically and economically promising. As demonstrated in Fig.S 4.1, the proposed dam scheme is the cheapest in terms of unit construction cost, taking advantage of the topographic and hydrological potentials to the maximum extent. The trans-basin diversion tunnel will link on intake on the Turasha river with the Malewa reservoir in a length of 2,400 m.

4.4 Water Supply Scheme

The water supply scheme is an integral part of the Project and comprises a raw water transmission system, treatment works, both Nakuru and Naivasha treated water transmission systems, both Eburru and Gilgil rural water supply systems, and bulk supply systems for the ASTU, NYSTC, KMB and GMB. It is proposed that the raw water intake should be located adjacent to the that of the Stage 1 Project in the Turasha river. It would be most beneficial to expand the water supply capability at appropriate time intervals consistent with growing water demand. Through an economic comparative study, it is recommended that the water treatment works be implemented in three phases and the Nakuru and Naivasha treated water transmission systems in two phases as shown in Figs. S.4.2 through S.4.5.

4.5 Micro Hydro-electric Power Generation

There is a possibility of generating hydro electric power by harnessing the hydraulic head of about 12 m between the Malewa reservoir and the Turasha river using the water to be diverted into the Turasha river . The maximum discharge available is 2.30 cu.m/sec.

The possible installed capacity is 200 kw and the annual energy production is estimated at 427,000 kwh only. According to the water balance study of the Malewa reservoir, the water diversion is required only for 65 per cent of the time so the operation of the power station would be limited to the same period.

It is concluded that such a micro power generation would not be technically or economically attractive, since the power supply would be unstable and the power generation cost would be far higher than the alternative of diesel power.

4.6 Overall Development Sequence

The overall implementation schedule of the Project has been developed as summarized below.

(1) Stage 2-1 (Expected year of commissioning : 1997)
- Malewa dam scheme, including the trans-basin diversion tunnel
- Raw water transmission system, Phase 1
- Water treatment works, Phase 1
- Nakuru treated water transmission system, Phase 1
- Naivasha treated water transmission system, Phase 1
- Gilgil and Eburru rural supply systems, Phase 1
- GMB-NYSTC and KMB bulk supply systems

(2) Stage 2-2 (Expected year of commissioning : 2004)
- Raw water transmission system, Phase 2
- Water treatment works, Phase 2
- Nakuru treated water transmission system, Phase 2
- Naivasha treated water transmission system, Phase 2
- Gilgil and Eburru rural supply systems, Phase 2
- ASTU bulk supply system

(3) Stage 2-3 (Expected year of commissioning : 2011)
- Water treatment works, Phase 3
- Nakuru treated water transmission system, Phase 3 (only construction of Central Reservoir and 7 service reservoirs in Nakuru)
- Naivasha treated water transmission system, Phase 3 (only construction of two reservoirs in Naivasha)

V. PRELIMINARY DESIGN

5.1 Malewa Dam Scheme

5.1.1 Site Conditions

The bed of the Malewa river is at El. 2,082 m at the dam site and in a narrow and steep gorge. Both banks of the river are at around El. 2,145 m at their top and the width of the gorge is about 190 m. The reservoir area lies in a flat hill zone with gentle slopes and composed of sub-horizontally bedded lava and phyroclastic flows. The gently undulating terrain is dissected by the Malewa river to a depth of 50 to 60 m from the surface of the flat hills.

The bedrock of the dam site is composed of phyroclastic rocks of the Pliocene Kinangop Tuffs, including welded tuffs and non-welded layers, massive tuffs with intercalations of the lake sediments and Quaternary overburden of colluvial deposits and river deposits. The Pliocene lake sediments are the weakest among the young volcanic and phyroclastic bed rocks at the site, but are judged stable enough for foundation of the proposed dam.

Residual and lateritic soils, usable as an impervious material, have been found in the East Road borrow area, located at about 3.5 km east from the center of Gilgil town. Two quarry sites have been selected : one is the Kipipiri Road quarry site formed of welded tuff and highly welded tuff and is 5 km distant from the dam site, and the other is the South Gilgil quarry site formed by the trachytes and is about 23 km west of the dam site. There is no appropriate natural deposit of concrete aggregates and filter material of the dam in the vicinity of the proposed dam site. Trachyte are usable for production of the aggregates and filter material.

5.1.2 Diversion Tunnel

The river diversion plan has been worked out based on a 20-year probable flood with a peak discharge of 240 cu.m/sec. The crest of the upstream coffer dam has been set at El. 2,115.0 m and two diversion tunnels, each with a diameter of 3.65 m and a length of 342 m have been located on the left bank.

5.1.3 Main Dam

The Malewa dam with the maximum height of 80 m has its crest at El. 2,154.00 m and 360 m in crest length. It is designed of zoned rockfill type, with of a center core, filter, inner shell, and outer shells 1 and 2, in due consideration of the characteristics and availability of the embankment materials. As the result of the stability analysis, the upstream and downstream slopes have been set at 1 to 2.70 and 1 to 2.20 respectively. The impervious core material will be borrowed from the East Road borrow area. The inner shell will be constructed from rock materials selected from the dam foundation and tunnel excavations, the outer shell 1 by both the welded and high degree welded tuffs to be quarried from the Kipipiri Road quarry site and the outer shell 2 by trachyte to be exploited from the South Gilgil quarry site. A gallery will be provided beneath the impervious core to facilitate the curtain grout works and to monitor leakage through the foundation and dam embankment.

The welded tuff is not excellent rock embankment material and it is recommended that a test embankment and large-scale shearing test be carried out to further verify the physical and mechanical characteristics in the stage of detailed engineering design.

5.1.4 Spillway

The spillway has been designed on the basis of a 1,000-year probable flood with a peak discharge of 960 cu.m/sec and is located at the left abutment of the dam taking advantage of the topographic conditions. Through an economic comparative study, it is ascertained that a fan-shaped spillway with ungated weir length of 101.0 m is the least cost option among other alternatives. The chuteway is 20.0 m in width and sloped at 1 : 20 in the upper part and 1 : 2.0 in the lower part. The energy dissipator will be of the stilling basin type, having a length of 80 m, and capable of settling a 100 - year probable flood with a peak discharge of 460 cu.m/sec.

5.1.5 Trans-basin Diversion Tunnel

The trans-basin diversion tunnel will have its intake in the Malewa reservoir, a tunnel, and an outlet in the Turasha river, and has a conveyance capacity of 2.30 cu.m/sec in free flow. The intake, sited on the left bank of the reservoir, is of a vertical shaft type equipped with a hollow jet valve to regulate the quantity of water diversion. The tunnel is 1.8 m in diameter, minimal diameter for tunnel construction, and 2,400 m in total length. A step-wise energy

dissipator is furnished at an outlet of the tunnel to dissipate a hydraulic head of about 20 m between the minimum supply level in the reservoir and the normal water level in the Turasha river.

5.2 Water Supply Scheme

5.2.1 Design Conditions

Based on the proposed phased development and the required water supply by the Project, design discharges of the water treatment works and transmission systems have been set forth as tabulated below.

(cu.m/day)

	Transmission Systems	Stage 2-1	Stage 2-2	Stage 2-3
(1)	Raw water transmission system	102,500	102,500	-
(2)	Water treatment works	100,000	50,000	50,000
(3)	Treated water transmission systems			
(3.a)	Nakuru treated water transmission	82,520 - 70,960	89,550 - 75,900	-
(3.b)	Naivasha treated water transmission	16,700	9,900	-
(3.c)	Gilgil West rural supply	780 - 150	550 - 150	-
(3.d)	Gilgil East rural supply	780 - 295	550 - 205	-
(3.e)	Eburru rural	3,700 - 950	2,220 - 555	-
(3.f)	ASTU bulk supply	-	1,140	-
(3.g)	GMB - NYSTC bulk supply	7,060	-	-
(3.h)	KMB bulk supply	2,030	-	-

The designs of all the water supply components have been referred to the "Design Manual for Water Supply in Kenya" issued by the MOWD. The principal features of the respective facilities are summarized at the front of this report. All the water supply components have been designed to cater for the maximum daily water demand.

5.2.2 Water Treatment Works

The water treatment works have been sited adjacent to those of the Stage 1 Project in the outskirts of the town of Gilgil. In view of the quality of the river water, a rapid sand filtration type has been selected. It is proposed to introduce a treatment work unit of 50,000 cu.m/day throughout the stages : two units would accordingly be constructed in the Stage 2-1.

5.2.3 Raw and Treated Water Transmission Systems

In anticipation that the purchase cost of the pipe material would be the initial investment of the water transmission systems, technical and economic comparative study was deployed, and as a result a steel pipe is is concluded to be best suited for all the pipelines to be constructed under the Project.

The raw and Nakuru treated water transmission systems have been aligned along with those of the Stage 1 Project, while the other pipelines have been followed to those proposed by the previous studies. There are two transmission systems, East and West, in the Gilgil rural area, owing to dispersion of the service centers in the wide area. Both the GMB and NYSTC have been planned to be served by one transmission system. The hydraulic conditions of all the transmission systems are as summarized below.

Gravity flow system	:	- Raw water transmission system
		- Nakuru treated water transmission system
		- Naivasha transmission system
		- KMB bulk supply system
		- GMB bulk supply system
Pump flow system	:	- Gilgil East and West rural supply systems
		- Eburru rural supply system
		- ASTU bulk supply system

The treated water transmission system associates with construction of the service reservoirs. The expansion plan has been worked out in conjunction with the plan proposed by the Stage 1 Project and the proposed phased development. The Central Reservoir, which will be constructed by the Stage 1 Project in the out skirts of the town of Gilgil, will be expanded to evenly distribute the treated water into the Gilgil and Naivasha towns, Nakuru municipality and other bulk consumers.

There will be 7 service reservoirs in Nakuru municipality, two in Naivasha town, 3 in Gilgil East area, 2 in Gilgil west area, and 9 in Eburru rural area.

VI. CONSTRUCTION PLAN AND COST ESTIMATE

6.1 Mode of Construction

The construction of the Project is assumed to be executed on a contract basis, and thus qualified contractors are assumed to be procured through local and international competitive bids. In due consideration of the phased development and the nature of the construction works, it is proposed to divide the entire construction works into 18 contract works and the mode of procurement is also proposed as presented below.

Stages	Package Number	Contract works	Mode of Procurement
2-1	D-1	Access Road	LCB
	D-2	Malewa dam	ICB
	D-3	Trans-basin diversion tunnel	ICB
	W-1	Raw water transmission system, Phase 1	ICB
	W-2	Water treatment works, Phase 1	ICB
	W-3	Nakuru transmission system, Phase 1	ICB
	W-4	Naivasha transmission system, Phase 1	ICB
	W-5	Gilgil East and West and Eburru rural supplies, Phase 1	LCB
	W-6	KMB and GMB - NYSTC bulk supply systems	LCB
2-2	W-7	Raw water transmission system, Phase 2	ICB
	W-8	Water treatment works, Phase 2	ICB
	W-9	Nakuru transmission system, Phase 2	ICB
	W-10	Naivasha transmission system, Phase 2	ICB
	W-11	ASTU bulk supply	LCB
	W-12	Gilgil East and West and Eburru rural supplies, Phase 2	LCB
2-3	W-13	Water treatment works, Phase 3	ICB
	W-14	Nakuru transmission system, Phase 3	LCB
	W-15	Naivasha transmission system, Phase 3	LCB

6.2 Construction Time Schedule

A construction time schedule was prepared for the respective component of the Project by stages as shown in Fig. S.6.1. The construction period is assessed to extend from 1994 to 1997 for the Stage 2-1, from 2002 to 2004 for the Stage 2-2 and from 2009 to 2011 for the Stages 2-3.

6.3 Construction Cost Estimate

The construction cost has been estimated for the respective components of the Project on the basis of price level in 1990 as presented in Table S.6.1 and as summarized below.

	Stage of the Project	Foreign Currency Portion (US$10^6)	Local Currency Portion (Kshs.10^6)	Total (Kshs.10^6)
(1)	Malewa Dam Scheme	41.5	349.1	1,282.6
(2)	Water Supply Scheme			
	Stage 2-1	59.7	511.5	1,854.6
	Stage 2-2	58.3	544.6	1,856.8
	Stage 2-3	13.1	201.6	497.4
	Sub-total	131.1	1,257.7	4,208.8
	Total	172.6	1,606.8	5,491.4

The annual disbursement schedule of the construction cost is estimated on a basis of the proposed construction time schedule as given in Table S.6.2.

VII. PRELIMINARY ENVIRONMENTAL STUDY

7.1 General Description

The Study was actually composed of two different levels of studies : one was the preliminary environmental study (the PES) covering the proposed Malewa reservoir area and Lake Naivasha, and the other was the fundamental environmental survey (the FES) for Lake Nakuru.

The PES includes data collection, agriculture/irrigation survey, groundwater survey, lake water balance and quality analyses, and forecast of the Project impacts, and the FES consisted of collection of fundamentals including preparation of a topographic map of the lake area, and the lake water balance and quality analyses. The field survey was conducted in a very limited period : the first during a two- month period from October to November, 1989 and the second during a three-month period from May to July,1990.

7.2 Present Environmental Conditions

7.2.1 Fluctuation of Lake Level

The general characteristics of both Lakes Naivasha and Nakuru are as summarized below.

	Description	Unit	Lake Naivasha	Lake Nakuru
(a)	Water level fluctuation			
	Maximum	El. m	1,886.9	1,760.6
	Minimum	El. m	1,883.2	1,756.3
	Average	El. m	1,885.2	1,758.6
(b)	Max. water depth at average level	m	13	2.2
(c)	Lake area at average level	km^2	185	43.7
(d)	Water volume at average level	10^6m^3	863	76.3

Both lakes suffer from long spells of drought from time to time. The drought in 1988 was the most severe in the last 25 years. Lake Nakuru almost dried up and Lake Naivasha level had declined to El. 1,882 m at the lowest .

Within the proposed Malewa reservoir area, there reside five families and there are the cultivation lands of 13.1 ha.

7.2.2 Water Quality

Systematic water quality analysis was conducted on the Malewa river and Lakes Naivasha and Nakuru during a three-month period from June to August, 1990 under the Study. The most representative parameters of the water quality are summarized here based on the observations results.

Items	Unit	Malewa river	Lake Naivasha		Lake Nakuru	
			Photic Layer	Aphotic Layer	Photic Layer	Aphotic Layer
pH		8.2	8.7	8.7	10.4	10.5
Conductivity	µs/cm	130	275	278	17,560	17,520
DO	mg/l	7.4	8.3	7.8	9.7	5.5
COD	mg/l	8	39	39	191	192
T-N	mg/l	2.7	3.3	3.3	33.8	28.6
T-P	mg/l	0.89	0.34	0.32	3.01	3.10

As noted in Section 3.5 of this report there is a large amount of sewage inflow into Lake Nakuru, which drained out from two sewage treatment works. The quality of the sewage before and after treatment has been revealed as follows.

Items	Unit	Njoro treatment Works		Town Treatment Works	
		Raw water	Treated water	Raw water	Treated water
pH		7.4	8.7	7.5	7.6
Conductivity	µs/cm	1,060	1,250	990	960
Turbidity	mg/l	230	19	165	51
SS	mg/l	483	36	580	136
DO	mg/l	1.2	6.9	0.8	0.8
COD	mg/l	128	196	364	201
T-N	mg/l	117	24	107	79

As is clear from the above, since the treatment works have been over-loaded, a lot of pollutants have been flowing into the lake. In fact the values of the COD have been largely exceeding the effluent standards concluded between the Nakuru Municipal Council and the Ministry of Water Development. The effluent standards are presented in Table S.7.1.

7.2.3 Ecology

Fauna and flora in the study area have been inventoried based on existing data and information. The most significant ecological aspects are as summarized below.

(a) Aquatic fauna

Lake Naivasha is the most peculiar in its aquatic fauna of the three contemplated study areas. Tilapia, black-bass, and crayfish are the main species of aquatic fauna in the lake, but it is reported that they were introduced from the outside in the last 25 years.

In Lake Nakuru, there are also Tilapia, which were also introduced in 1961 for the purpose of mosquito control . Tilapia is said to be tolerant of a relatively highly saline and alkaline water.

(b) Aquatic flora

In Lake Naivasha, Salvinia molesta is the predominant of nine aquatic species identified and is deemed to be closely connected with the ecology and human activity in the lake. It sometimes extends over as much as 15 sq.km of the lake surface as recorded in 1979.

In Lake Nakuru, a blue-green algae, Spirulina Plantensis is the most common and is the basis of all the food chains in the lake. It is grazed by Lesser Flamingoes in the lake, but its growth is said to be sensitively influenced by the salinity and alkalinity of water.

(c) Birds

Lake Nakuru is rich in bird in terms of variety and quantity. Among more than 30 species of birds, Lesser Flamingoes and white-pelicans are the most common and precious. Lake Nakuru also has an international reputation as "the lake of a million of flamingoes". It has been reported by many sources that there is a close linkage between the water quality, the growth of Spirulina and the habitual condition of Flamingoes, although this has not been clarified yet quantitatively . According to the previous studies, the number of Flamingoes varied widely in the past : 1.4 million in 1977 to only 3,300 in 1990. The Flamingoes, however, do not breed on Lake Nakuru.

7.2.4 Groundwater

The groundwater is also an important water source for irrigated farming in Lake Naivasha area, but is in many cases used as a supplementary source. The preliminary groundwater investigation was accordingly carried out to assess a relationship between the lake level and the groundwater aquifer.

No very thick and extensive aquifer has yet been identified in the area surrounding the lake, which is generally alluvium composed of sand and/or gravel. Alluvium, mainly composed of silt and clay with a thickness less than 10 m, is distributed in a narrow area in the northern part of the lake.

137 boreholes have so far been constructed, of which only 31 are currently under operation. In many case the boreholes have provided supplemental irrigation supply. It has been proven by evidence in the 1988 drought year that the groundwater resources are unlikely to be influenced by the Project, if the lake level is maintained at El. 1,882 m at the lowest.

7.2.5 Existing Water Uses

The waters of the Malewa river and Lake Naivasha are being used for the various purposes and a number of the water rights has been registered at the Water Apportionment Board as shown in Table S.7.2.

7.2.6 Horticultural and Agricultural Activities

It has been reported that there are the irrigated lands of approximately 7,895 acres around Lake Naivasha, of which of 2,426 acres is solely dependant on the lake water for irrigation water supply and 815 ha on both lake water and groundwater. A door-to-door survey was conducted during the period from May to June, 1990 to determine the prevailing land use and the problems encountered during the 1988 drought year. The survey covered irrigated land of 6,908 acres, corresponding to 87 per cent of the entire irrigated land.

The surveyed irrigated lands can broadly be classified into a fodder crop cultivation area of 3,543 acres and a horticulture crop cultivation area of 3,365 acres. Among the fodder crops, pasture is the predominant and followed by maize and lucerne. The main horticultural

crops are flowers (1,631 acres), french beans (533 acres) and asparagus and carrot (611 acres).

According to the results of the door - to -door survey, the majority of the farms have already relocated/adjusted their intake facilities to be capable of taking water from the lake, even if the lake level dropped to the level (El. 1,882 m) as in the 1988 drought period. Further it has been clarified that, although the salinity concentration and pH increased slightly in 1988, there was no damages or adverse effects on the growth of crops.

7.2.7 Fishery

The fishery of Lake Naivasha is one of the most important economic activities in Naivasha. According to the Fishery Department, the catch of fish was 289,000 tons on average during the period from 1984 to 1988, varying from 513,000 tons at the maximum in 1986 to 52,200 tons at the minimum in 1988. It is, however, found out that the catch of fish has tended to decrease in recent years.

7.3 Forecast Environmental Impacts

7.3.1 Change in Lake Water Balance

It is explicit that implementation of the Project will reduce the inflow into Lake Naivasha, causing a decline in the level of Lake Naivasha and, while sewage effluent from Nakuru municipality will induce a rise of the level of Lake Nakuru. The changes of the lake levels have been analyzed by means of a simulation based on the available climatological and hydrological records. The water balance of the lakes is, therefore, presented in relation to the quantity of the water supply/sewage inflow as summarized below.

(1) Lake Naivasha

Water Supply (m3/day)	Rate to 2015 Supply (%)	Lake Level (El. m)			Lake Area (sq.km)			Water Volume (mil.cu.m)		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Present, 0	0	1,886.9	1,883.2	1,885.2	297	138	185	1,273.0	536.0	863.0
56,000	34	1,886.4	1,883.0	1,884.8	257	138	170	1,128.6	536.0	794.2
105,000	63	1,886.2	1,882.5	1,884.3	235	133	156	1,075.0	471.0	715.4
121,000	73	1,886.0	1,882.0	1,883.9	226	129	150	1,029.4	407.8	657.4
138,000	83	1,885.8	1,881.5	1,883.6	213	123	145	983.8	345.2	615.6
151,000	91	1,885.7	1,881.0	1,883.4	207	117	143	961.0	284.4	588.8
166,000	100	1,885.5	1,880.0	1,883.1	198	101	139	921.8	171.2	549.0

(2) Lake Nakuru

Sewage Outflow (m3/day)	Rate to 2015 Outflow (%)	Lake Level (El. m)			Lake Area (sq.km)			Water Volume (mil.cu.m)		
		Max.	Min.	Ave.	Max.	Min.	Ave.	Max.	Min.	Ave.
Present, 8,840	9	1,760.6	1,756.3	1,758.6	52.0	26.0	43.7	171.8	22.9	76.3
17,400	18	1,761.2	1,757.5	1,759.3	53.9	36.9	46.7	203.6	31.9	107.7
34,700	36	1,762.9	1,759.5	1,761.0	58.7	47.0	53.2	299.4	117.0	192.8
52,000	55	1,765.1	1,762.0	1,763.3	65.4	56.1	59.9	436.0	247.6	323.2
69,200	73	1,767.3	1,764.3	1,765.6	72.4	63.0	67.2	587.8	384.6	469.2
95,000	100	1,771.7	1,768.9	1,770.1	90.0	76.9	81.2	935.3	707.2	802.2

Thus, at the stage of full water supply, the level of Lake Naivasha falls two meters below the lowest level recorded in the 1988 drought year and the lake area diminishes to a great extent as above noted. The level of Lake Nakuru level increases tremendously, approximately 11 m higher than the recorded maximum level in the last 25 years, if the whole of the potential sewage effluent of 95,000 m3/day, corresponding to 70 % of the water demand in the municipal area in 2015, discharges into the lake.

7.3.2 Change in Lake Water Quality

The water quality of the Malewa reservoir has been projected and the changes in water qualities in both Lakes Nakuru and Naivasha have been predicted in relation to change in the water balance as presented below.

Lake	Lake Level (El.m)	DO (mg/l)		COD (mg/l)		T-N (mg/l)	T-P (mg/l)
		Photic Layer	Aphotic Layer	Photic Layer	Aphotic Layer		
Malewa reservoir		10.2	1.4	15.9	11.4	3.06	0.13
Lake Naivasha	1,883.1	9.6	8.3	38.9	38.3	3.33	0.30
	1,883.4	9.6	8.1	38.8	38.1	3.34	0.30
	1,883.6	9.6	8.0	38.6	37.9	3.34	0.30
	1,883.9	9.6	7.8	38.1	37.4	3.35	0.30
	1,884.3	9.6	7.7	37.8	37.0	3.35	0.30
	1,884.8	9.6	7.2	39.3	38.3	3.36	0.30
Lake Nakuru	1,758.6	9.9	7.6	191.5	192.4	31.85	5.28
	1,761.0	9.7	0.1	183.5	177.1	63.98	18.57
	1,765.6	9.7	0.0	180.9	187.5	64.37	20.86
	1,770.1	9.4	0.0	188.8	193.3	73.58	23.82

Although the Malewa reservoir water is expected to eutrophicate, it is judged suitable as a source of water supply.

The water quality of Lake Naivasha in general shows little change, probably due to the fact that the decreased in water quantity is quite small compared to the lake water volume.

In Lake Nakuru, it is deduced that T-N and T-P will continue to increase over a considerable period of time. COD value is too high in present situation, so it is predicted that COD value may not change much. It is presumed that, with increasing sewage inflow, the lake area and volume expand proportionally, resulting in increasing the sedimentation and decomposition of organic matter (COD). The increased decomposition of organic matter will probably augment the consumption of oxygen, and the rise of water level will impede the supply of oxygen from the surface to the bottom, resulting in a great reduction of DO value to the level of almost nil in the aphotic zone.

7.3.3 Major Impacts on Natural and Social Environment

It is foreseeable that the Project will eventually have various effects on the natural and social environment in the Malewa river basin and Lakes Naivasha and Nakuru, including their surrounding areas, unless adequate counter measures are taken up. Most of the impacts will arise subsequent to the changes in the lake water balance and quality. Among others, the following is especially to be noted.

(1) Lake Naivasha

(a) When the lake level falls to El. 1,880 m, most of the existing pumping facilities will eventually become inoperable properly for a long period , probably resulting in severe damage to the cultivation of horticultural crops.

(b) Another small lake will appear in a dry period to the east of Crescent Island, since the lake bed between the island and the western shore of the lake will be exposed at lake levels below El. 1,881.0 m as shown in Fig. S.7.1. Dredging will be required to secure water for traffic for fishery and tourism.

(c) Reduction in the water volume and recession of the lake area may naturally lead to changes in the ecology of the aquatic ecosystem and also decrease the attractiveness of the lake as a tourism resource, although it is impossible to assess this quantitatively at this stage.

(2) Lake Nakuru

(a) The rise in the lake level will cause submergence of the southern part of the municipal area, the whole of the road encircling the lake and the greater portion of the grass land on the southern rim of the lake as shown in Fig. S.7.2. The grass land is the main feeding ground of the wildlife.

(b) The salinity of the lake water will be reduced to a great extent, probably causing substantial changes in the aquatic ecosystem, which will directly affect the habits and condition of the flamingoes.

(c) The DO value is predicted to decrease to a very low level in the lower layer. The situation will be so critical that the aquatic fauna would be brought to the verge of extinction.

7.4 Conservation of Environment

It is essential to create an appropriate atmosphere for coexistence of the contemplated water supply and the natural and social environment. A conceptual countermeasure is introduced here, which will , however, require further verification and study at a later stage.

(1) Lake Naivasha

It has been enggested to reduce the quantity of the water supply and to set for the lowest lake level to be maintained for conservation of the natural and social environment. The lowest level is proposed tentatively at El. 1,882 m, the same level as the recorded in the 1988 drought period, mainly based on the following facts :

(a) There will be no notable obstruction in operation of the existing intake facilities at the lake level El. 1,882 m.

(b) The segregation of the Crescent Island will evidently not take place.

(c) Such drought as experienced in 1988 occurs very rarely in the long run and will last no more than a year, if it should occur. The 1988 drought year corresponded to a drought frequency of once in 25 years.

(d) Since the water quality changes little, no special qualitative problem is foreseeable as the source of irrigation supply.

At the proposed lowest lake level El. 1,882 m, the Project secure 73 per cent of the water supply required for 2015.

(2) Lake Nakuru

It is essential to introduce dynamic physical countermeasures to reduce the augmented sewage inflow into the lake, such as by trans-basin diversion of sewage into other basins, re-use of sewage for irrigation, or a combination of these measures.

VIII. ORGANIZATION AND MANAGEMENT

8.1 Organization for the Project Implementation

NWCPC will be responsible for construction, operation and maintenance of the Project. It is, however, recommended that an inter - ministerial committee be organized to effectuate overall management and to coordinate all the issues relative to the implementation of the Project. The committee is assumed to be formed by the Ministries of Water Development, Environment and Natural Resources, Tourism and Wildlife, Regional Development, Local Government, Agriculture, and Finance. The proposed organization chart is presented in Fig. S.8.1.

8.2 Operation and Maintenance of the Project

The NWCPC will also assume direct and overall responsibility for operation and maintenance of the project facilities. The NWCPC's regional offices in Nakuru municipality and Gilgil town need to be strengthened in terms of manpower and facilities and they will actually be engaged in the operation and maintenance works as well as collection of the water tariff.

8.3 Organization for Environmental Monitoring

For environmental monitoring, it is recommended that an organization, be set up to include an inter-ministerial committee, a data bank unit, an environmental management unit and a coordinating unit. The proposed organization is shown in Fig. S.8.2.

IX. ECONOMIC AND FINANCIAL EVALUATION

9.1 Economic Evaluation

The main economic benefits of the Project will accrue from the incremental consumers' surplus and water revenue, improved sanitation, and contribution on the regional development, although there may be negative benefit as well. Only incremental consumption is adopted in calculation of an Economic Rate of Return (EIRR) as it is measurable quantitatively.

The economic benefit is assessed in terms of a willingness-to-pay, which is the result of a questionnaire survey in Nakuru municipality. The unit economic benefit has been evaluated as follows :

Residential category, urban area	:	Kshs. 5.70/cu.m
Residential category, rural area	:	Kshs. 4.55/cu.m
Institutional category	:	Kshs. 6.91/cu.m
Commercial/industrial category	:	Kshs. 22.82/cu.m

The annual economic benefits are derived from the annual volume of the water supply and the unit economic benefit. The annual water supply volume is, however, limited to 35.0 million cu.m at the maximum as shown in Fig. S.9.1, when the ruling level of Lake Naivasha is set at El. 1,882.0 m at the lowest.

The EIRR has been calculated at 4.52 %, which is lower than the opportunity cost of capital in Kenya. It is not to be hastily concluded that the Project is economically infeasible, since intangible benefits are not taken into account in the calculation of the EIRR. Such intangible benefits are explained as impacts on the socio-economy in sub-section 9.3.3 below.

9.2 Financial Evaluation

The financial benefit is the revenue of the Project, which has been calculated based on the quantity of the water supplied and the water tariff. The average water tariff has been derived from the prevailing tariff as follows :

Bulk supply	:	Kshs. 1.54 /cu.m
Gilgil town	:	Kshs. 2.04/cu.m (excluding bulk supply)
Gilgil and Eburru rural	:	Kshs. 1.25/cu.m

The Financial Internal Rate of Return (FIRR) is calculated at 2.60 %, assuming that the average water tariff is increased to keep pace with the assumed inflation rate of 8 per cent per annum. The resultant FIRR means that all the costs would be recovered by its revenue.

9.3 Socio-economic Impacts

The Project will bring about various positive impacts on regional socio-economic development in the service area. Among others the following are particularly to be noted.

(a) Health benefits

About 38 % of the households in Nakuru municipality currently suffer negative influences of water supply problems on health and hygienic. With implementation of the Project, a safe and stable water supply will be realized, eliminating the possibility of fluoride related diseases.

(b) Impact on the regional socio-economy

The safe and adequate water supply will ensure sustained productive activities, and expansion of water supply facilities will alleviate the inhabitant from the laborious and time consuming job of fetching water. Approximately 10 % of the commercial and industrial entities in Nakuru municipality complain that the present water supply negatively affects their production. This problem will also be rectified.

9.4 Overall Conclusion

Notwithstanding the relatively low economic and financial returns, it could be recognized that the Project is one of the basic important needs to insure the subsistence of more than 1.5 million people in the central part of the Rift Valley Province. It has been confirmed that a safe and stable water supply greatly contribute for the preservation of the public health and hygiene and promotion of a sustained economic growth. It is evident that there is no adequate and ample water resources other than the Malewa river system in and around the proposed water service area.

The Project should, however, be designed and implemented with the utmost care to the prevailing natural and social environment, in particular in the areas of Lakes Naivasha and Nakuru. A further study and elaboration as noted in the "Recommendation" are absolutely prerequisite prior to the commencement of the Project.

X. RECOMMENDATIONS

(1) Further Studies

In order to make sound the implementation of the Project, further elaboration should be continued by the NWCPC. Among others the following is deemed to be key issues.

(a) Environmental aspects

Without exaggeration, it may be said that the Project's success depends chiefly on the formulation of countermeasures best adaptable to the environment of Lake Nakuru. For this purpose, it is recommended that the Government of Kenya takes up a master plan study on drainage and sewage disposal in the drainage area of Lake Nakuru. The study will focuse on, but not necessarily limited to ,(i) assessment of the ecology of the lake, (ii) study of draining storm water, (iii) study of sewage treatment and disposal including re-use of treated sewage, (iv) formulation of a long term drainage and sewage disposal plan, and (v) establishment of an action programme to realize the proposed plan.

As an integral part of the master plan study, the environmental monitoring should be initiated as early as possible. It is also important to clarify more qualitatively and quantitatively the natural and social environment under "with - "and "without - Project "conditions. Especially due attention should be paid for the water quality, aquatic fauna and flora, existing water uses, and horticulture crop production.

(b) Construction material survey

A test embankment and a large-scale shearing test are essentially required to further ascertain the physical and mechanical characteristics of the welded tuff, which will be used for the major part of the dam embankment.

(2) Conservation Flow

In order to sustain the existing water uses and preserve aqua-ecology in the river, it has been suggested to maintain a certain amount of flow throughout the year in the downstream from the Malewa dam site and the Turasha intake. In the current study, the conservation flow has actually been taken into account as set forth below.

River	Low Flow Season (cu.m/sec)	Flood Season (cu.m/sec)
Malewa river, downstream from dam	0.22	0.22
Malewa river, downstream from 2GB1	0.35	0.83
Turasha river, downstream from intake	0.24	0.24

(3) Operation of the Malewa Reservoir

The operation of the Malewa reservoir is of crucial importance to mitigate the adversed effect on Lake Naivasha and its surrounding area. It is strongly recommended that the reservoir shall strictly be regulated so as not to lower the proposed lowest level of Lake Naivasha. For this purpose, a reservoir operation rule should be established during the stage of detailed design.

(4) Resettlement and Afforestation Plans

There are five families in the proposed Malewa reservoir area. An adequate resettlement plan is prerequisite to ensure livelihood of the inhabitants. The afforestation and/or sodding are recommended to be carried out in the borrow area and quarry sites to protect the exposed land surface from erosion.

(5) Organization

In order to attain the environmental monitoring, it is recommended to constitute an organization, composing of an inter-ministerial committee, a data bank unit, an environmental management unit and coordinating unit.

(6) Regional development issue

The feasibility study was completed under such population distribution condition that, indeed, nearly 80 per cent of the whole population continues to concentrate in Nakuru municipality, which occupies only 92 sq.km in the western bound of the entire proposed water service area of 1,445 sq.km. Besides, the water source has been identified far way, about 50 km from the municipality in the Malewa river basin, which is separated from the Lake Nakuru drainage basin. As a consequence it is anticipated that the Project enhances various natural and social environmental impacts especially on Lake Nakuru, and incurs a greater amount of investment for construction of water transmission facilities.

In this context it is suggested that the Government of Kenya promptly takes the initiative to formulate a comprehensive regional development plan to set forth clearly a long term perspective of well balanced development in the area, covering the adequate population distribution, urban and rural development, land use, water and energy supplies, solid waste and sewage disposals, agricultural and industrial developments.

TABLES

Table S.1.1 Members of JICA Advisory Committee and Study Team

(1) Advisory Committee

Mr. K. Ichikawa	Chairman, Public Works Research Institute, Ministry of Construction
Mr. J. Kashiwagi	Member, Water Resources Development Public Corporation
Mr. H. Miyamoto	Member, Ministry of Construction
Mr. M. Takashima	Member, Ministry of Foreign Affairs
Mr. M. Suemori	Coordinator, JICA
Mr. T. Ezuka	Coordinator, JICA

(2) Study Team

Mr. M. Yamaguchi	Team Leader, Nippon Koei Co., Ltd.
Mr. K. Endo	Dam Planner, Nippon Koei Co., Ltd.
Mr. M. Inoue	Hydrologist, Nippon Koei Co., Ltd.
Mr. T. Bitoh/Y. Minami	Dam Engineer, Nippon Koei Co., Ltd.
Mr. S. Yamakawa	Pipe Engineer, INA Civil Engineering Consultants Co., Ltd.
Mr. J. Ebihara	Construction Planner, INA Civil Engineering Consultants Co., Ltd.
Mr. Y. Kokufu	Topo-survey Expert, INA Civil Engineering Consultants Co., Ltd.
Mr. J. Inoue/M. Yasuda	Geologist, Nippon Koei Co., Ltd.
Mr. K. Sakai	Environmental Expert, INA Civil Engineering Consultants Co., Ltd.
Mr. M. Fujii	Water Quality Analyst, Nippon Koei Co., Ltd.
Mr. K. Yamada	Agronomist, Nippon Koei Co., Ltd.
Mr. R. Nagase	Project Economist, Nippon Koei Co., Ltd.
Mr. T. Kasahara	Biologist, Nippon Koei Co., Ltd.

Table S.4.1 Forecast Average Daily Water Demand

	Demand Categories	1990	1995	2000	2005	2010	2015
(1)	Nakuru Municipality						
	Residential	21,390	29,670	41,160	54,440	72,200	95.700
	Institutional	3,210	4,100	5,230	6,680	8,530	10,900
	Industrial	8,000	8,000	10,210	13,030	16,600	21,200
	Livestock	450	400	300	200	150	100
	Military	1,200	1,400	1,720	2,200	2,810	3,580
	Sub-total	35,520	45,190	60,690	79,200	103,670	135,800
(2)	Gilgil Town						
	Residential	1,050	1,650	2,320	3,200	4,400	6,060
	Institutional, general public	180	250	320	400	510	650
	NYTSTC	1,310	1,760	2,240	2,860	3,650	4,660
	ATSU	760	860	1,100	1,410	1,800	2,300
	Commercial	30	40	60	70	80	90
	Industrial	140	180	230	290	370	470
	Livestock	30	40	60	70	80	90
	Military, KMB	870	940	1,160	1,480	1,890	2,410
	GMB	1,200	1,300	1,510	1,930	2,460	3,140
	Sub-total	5,570	7,020	9,000	11,710	15,240	19,870
(3)	Naivasha Town						
	Residential	3,710	5,470	7,080	8,700	10,690	13,130
	Institutional, general public	1,040	1,540	2,000	2,450	3,010	3,690
	WLFTI	990	1,460	1,890	2,320	2,840	3,500
	Prison	160	240	310	380	470	580
	Commercial	110	160	210	260	320	390
	Industrial	110	160	210	260	320	390
	Sub-total	6,120	9,030	11,700	14,370	17,650	21,680
(4)	Gilgil Rural						
	Residential	650	870	1,070	1,290	1,550	1,870
	Institutional	120	210	240	280	320	380
	Commercial	10	10	10	10	10	10
	Industrial	130	150	170	190	210	230
	Livestock	280	320	360	390	420	460
	Sub-total	1,190	1,560	1,850	2,160	2,510	2,950
(5)	Eburru Rural	1,800	2,200	2,700	3,300	4,030	4,930
	Total	50,200	65,000	85,940	110,740	143,100	185,230

Data source :

(1) Greater Nakuru Water Supply Project, Eastern Division, Stage 1, Preliminary Design Report, July 1988

(2) Greater Nakuru Supply Project, Supplementary Report to Preliminary Design Report, May 1985

(3) Greater Nakuru Supply Project, Preliminary Design Report, May 1985

Table S.6.1 Construction Cost Estimate (1/4)

Malewa Dam Scheme

Description	Foreign Currency Portion (US$10^3)	Local Currency Portion (Kshs.10^3)	Total (Kshs. 10^3)
(1) Direct Construction Cost			
1.1 Preparatory works	2,564	30,098	87,792
1.2 Diversion tunnel	2,155	11,615	60,094
1.3 Coffer dam	1,688	5,389	43,362
1.4 Main dam	14,037	47,986	363,824
1.5 Spillway	7,233	60,575	223,325
1.6 Trans-basin diversion tunnel	2,270	12,489	63,557
Sub-total for (1)	29,947	168,152	841,954
(2) Indirect Construction Cost			
2.1 Land compensation & acquisition	0	8,155	8,155
2.2 Government administration	0	25,259	25,259
2.3 Engineering services	2,395	13,469	67,356
Sub-total for (2)	2,395	46,883	100,770
(3) Contingency			
3.1 Physical contingency	3,234	21,504	94,272
3.2 Price escalation	5,912	112,549	245,580
Sub-total for (3)	9,146	134,053	339,852
Total	41,488	349,088	1,282,568

Table S.6.1 Construction Cost Estimate (2/4)

Water Supply Scheme, Stage 2-1

Description	Foreign Currency Portion (US$10^3)	Local Currency Portion (Kshs.10^3)	Total (Kshs. 10^3)
(1) Direct Construction Cost			
1.1 Preparatory works	2,854	17,227	81,442
1.2 Raw water transmission system	4,520	19,242	120,942
1.3 Water treatment works	10,148	86,784	315,114
1.4 Nakuru treated water transmission system	17,985	83,836	488,499
1.5 Naivasha treated water transmission system	5,117	23,189	138,322
1.6 Gilgil East rural supply system	709	6,566	22,518
1.7 Gilgil West rural supply system	577	7,305	20,287
1.8 Eburru rural supply system	1,666	18,792	56,277
1.9 KMB bulk supply system	43	359	1,326
1.10 GMB-NYSTC bulk supply system	6	28	163
1.11 ASTU bulk supply system	0	0	0
Sub-total for (1)	43,625	263,328	1,244,890
(2) Indirect Construction Cost			
2.1 Land acquisition and compensation	0	1,190	1,190
2.2 Government administration	0	37,384	37,384
2.3 Engineering services	3,490	21,066	99,591
Sub-total for (2)	3,490	59,640	138,165
(3) Contingency			
3.1 Physical contingency	4,363	26,333	124,501
3.2 Price escalation	8,215	162,215	347,053
Sub-total for (3)	12,578	188,548	471,554
Total	59,693	511,516	1,854,609

Table S.6.1 Construction Cost Estimate (3/4)

Water Supply Scheme, Stage 2-2

Description	Foreign Currency Portion (US$10^3)	Local Currency Portion (Kshs. 10^3)	Total (Kshs. 10^3)
(1) Direct Construction Cost			
1.1 Preparatory works	2,312	13,065	65,085
1.2 Raw water transmission system	3,716	15,468	99,078
1.3 Water treatment works	5,229	44,795	162,448
1.4 Nakuru treated water transmission system	17,416	77,545	469,405
1.5 Naivasha treated water transmission system	3,613	15,697	96,989
1.6 Gilgil East rural supply system	709	6,566	22,518
1.7 Gilgil West rural supply system	577	7,305	20,287
1.8 Eburru rural supply system	1,666	18,792	56,277
1.9 KMB bulk supply system	0	0	0
1.10 GMB-NYSTC bulk supply system	0	0	0
1.11 ASTU bulk supply system	97	472	2,655
Sub-total for (1)	35,335	199,705	994,742
(2) Indirect Construction Cost			
2.1 Land acquisition and compensation	0	810	810
2.2 Government administration	0	29,867	29,867
2.3 Engineering services	2,827	15,976	79,584
Sub-total for (2)	2,827	46,653	110,261
(3) Contingency			
3.1 Physical contingency	3,534	19,970	99,485
3.2 Price escalation	16,622	278,271	652,266
Sub-total for (3)	20,156	298,241	751,751
Total	58,318	544,599	1,856,754

Table S.6.1 Construction Cost Estimate (4/4)

Water Supply Scheme, Stage 2-3

Description	Foreign Currency Portion (US$10^3)	Local Currency Portion (Kshs.10^3)	Total (Kshs. 10^3)
(1) Direct Construction Cost			
1.1 Preparatory works	456	3,936	14,196
1.2 Raw water transmission system	0	0	0
1.3 Water treatment works	4,912	42,709	153,229
1.4 Nakuru treated water transmission system	1,420	12,009	43,959
1.5 Naivasha treated water transmission system	179	1,513	5,541
1.6 Gilgil East rural supply system	0	0	0
1.7 Gilgil West rural supply system	0	0	0
1.8 Eburru rural supply system	0	0	0
1.9 KMB bulk supply system	0	0	0
1.10 GMB-NYSTC bulk supply system	0	0	0
1.11 ASTU bulk supply system	0	0	0
Sub-total for (1)	6,967	60,167	216,925
(2) Indirect Construction Cost			
2.1 Land acquisition and compensation	0	380	380
2.2 Government administration	0	6,519	6,519
2.3 Engineering services	557	4,813	17,346
Sub-total for (2)	557	11,712	24,245
(3) Contingency			
3.1 Physical contingency	697	6,017	21,700
3.2 Price escalation	4,925	123,688	234,500
Sub-total for (3)	5,622	129,705	256,200
Total	13,146	201,584	497,370

Table S.6.2 Disbursement Schedule of Initial Cost

(Unit:1000Kshs.)

Description	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
(A) Initial Cost																					
1) Foreign Currency																					
Malewa Dam and Diversion Tunnel	6404	14408	6404	180903	217725	338595	36021														
Raw Water Transmission System	1058	2273	1058	8483	29700	85208	698		855	1868	855	7178	29025	65768							
Water Treatment Works	2340	5063	2363	69300	104378	103388	1463		1193	2610	1193	42458	53798	47250		1148	2453	1148	39893	50535	44415
Nakuru Treated Water Transmission System	4140	9000	4140	167310	274005	49703	2610		4028	8730	4028	33705	222233	222075		338	720	315	2723	28665	7538
Naivasha Treated Water Transmission System	1170	2565	1170	9608	52628	77445	743		833	1823	833	6975	10328	81833		45	90	45	338	68	4500
KMB Bulk Water Supply System	0	23	0	90	23	1080	0														
NYSTC & GMB Bulk Water Supply System	2	3	1	12	2	159	1														
ASTU Bulk Water Supply System									23	45	23	203	1958	495							
Gilgil East Rural Water Supply System	158	360	158	1328	7290	10733	113		158	360	180	1373	7313	10800							
Gilgil West Rural Water Supply System	135	293	113	1080	5918	8753	90		135	293	135	1103	5940	8798							
Eburu Rural Water Supply System	383	833	383	3128	17145	25223	248		383	833	383	3218	17145	25380							
Price Contingency	474	2121	1464	55380	112896	135892	9652	0	2070	4950	2520	34650	135608	194220	0	720	1665	810	24503	47543	35573
Total	16264	36942	17254	496622	821710	836179	51639		9675	21510	10148	130860	483345	656618	0	2250	4928	2318	67455	126810	92025
2) Local Currency																					
Malewa Dam and Diversion Tonnel	3075	6387	3075	70962	57479	81369	14192														
Raw Water Transmission System	664	1205	664	2099	6218	16899	501		541	1000	573	2022	6179	12487							
Water Treatment Works	2106	3956	2106	27727	41228	41324	1447		1086	2041	1138	17296	21801	18516		1029	1935	1079	16482	20773	17648
Nakuru Treated Water Transmission System	2745	5005	2745	36917	59240	13438	2049		2606	4742	2758	9996	47826	45452		293	551	308	1508	11176	2985
Naivasha Treated Water Transmission System	771	1405	772	2591	11305	16491	578		536	973	567	2077	2800	16113		37	70	39	198	78	1707
KMB Bulk Water Supply System	9	16	9	50	16	408	7														
NYSTC & GMB Bulk Water Supply System	1	2	1	11	3	33	1														
ASTU Bulk Water Supply System									15	28	16	66	447	120							
Gilgil East Rural Water Supply System	155	290	154	661	3116	4563	105		154	291	162	733	3188	4516							
Gilgil West Rural Water Supply System	154	293	153	702	3439	5045	100		154	293	159	766	3504	5008							
Eburu Rural Water Supply System	410	780	410	1853	8876	13005	271		410	780	428	2025	9055	12897							
Price Contingency	807	3218	2620	51756	89604	113017	13742		3961	8102	5104	33589	98593	128922		1741	3475	2052	27646	51245	37530
Total	10897	22557	12709	195329	280524	305592	32993		9463	18250	10905	68570	193393	244031	0	3100	6031	3478	45834	83272	59870
3) Total Cost																					
Malewa Dam and Diversion Tonnel	9479	20795	9479	251865	275204	419964	50213	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Raw Water Transmission System	1722	3478	1722	10582	35918	102107	1199	0	1396	2868	1428	9200	35204	78255	0	0	0	0	0	0	0
Water Treatment Works	4446	9019	4469	97027	145606	144712	2910	0	2279	4651	2331	59754	75599	65766	0	2177	4388	2227	56375	71308	62063
Nakuru Treated Water Transmission System	6885	14005	6885	204227	333245	63141	4659	0	6634	13472	6786	43701	270059	267527	0	631	1271	623	4231	39841	10523
Naivasha Treated Water Transmission System	1941	3970	1942	12199	63933	93936	1321	0	1369	2796	1400	9052	13128	97946	0	82	160	84	536	146	6207
KMB Bulk Water Supply System	9	39	9	140	39	1488	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NYSTC & GMB Bulk Water Supply System	3	5	2	23	6	191	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ASTU Bulk Water Supply System	0	0	0	0	0	0	0	0	38	73	39	269	2405	615	0	0	0	0	0	0	0
Gilgil East Rural Water Supply System	313	650	312	1989	10406	15296	218	0	312	651	342	2106	10501	15316	0	0	0	0	0	0	0
Gilgil West Rural Water Supply System	289	586	266	1782	9357	13798	190	0	289	586	294	1869	9444	13806	0	0	0	0	0	0	0
Eburu Rural Water Supply System	793	1613	793	4981	26021	38228	519	0	793	1613	811	5243	26200	38277	0	0	0	0	0	0	0
Price Contingency	1281	5339	4084	107136	202500	248909	23394	0	6031	13052	7624	68239	234201	323142	0	2461	5140	2862	52149	98788	73103
Total	27161	59499	29963	691951	1102234	1141771	84632	0	19138	39760	21053	199430	676738	900649	0	5350	10959	5796	113289	210082	151895

Table S.7.1 Proposed Effluent Standards for Nakuru Municipal Sewage Works

A. Total Discharge into Lake Nakuru				
1)	Total BOD_5	not to exceed	800	kg/day
2)	Heavy metals (excl. Zn; Fe)	not to exceed	0.1	mg/l
B. Additional Standards for Discharge Directly into Lake Nakuru				
(Town Sewage Works)				
1)	BOD_5 at 20 °C (excl. algae)	not to exceed	50	mg/l
2)	COD	"	80	mg/l
3)	Suspended Solids	"	30	mg/l
4)	Free ammonia	"	10	mg/l
5)	Heavy metals total (excl. Zn; Fe)	"	0.1	mg/l
6)	Zinc	"	0.3	mg/l
7)	Cyanide	"	0.05	mg/l
8)	Total phenols	"	0.1	mg/l
9)	Organochlorines total	"	0.001	mg/l
10)	Oil			No trace
11)	Anionic detergents	not to exceed	0.5	mg/l
12)	Effluent at dilution 1:20 must not be toxic to Tilapia grahami in 48 hours.			
13)	Flow records must be maintained at the inlet and outlet of all sewage works.			
14)	The effluent must be aerated over a cascade before discharge into the lake.			
(Njoro River Sewage Works)				
1)	BOD5 at 20 °C (excl. algae)	not to exceed	30	mg/l
2)	COD	"	50	mg/l
3)	Suspended Solids	"	30	mg/l
4)	Free ammonia	"	5	mg/l
5)	Heavy metals total (excl. Zn; Fe)	"	0.1	mg/l
6)	Zinc	"	0.3	mg/l
7)	Cyanide	"	0.05	mg/l
8)	Total phenols	"	0.1	mg/l
9)	Organochlorines total	"	0.001	mg/l
10)	Oil			No trace
11)	Anionic detergents	not to exceed	0.5	mg/l
12)	Effluent at dilution 1:10 must not be toxic to Tilapia grahami in 48 hours. Toxicity = a water killing 50% or more of the test animals.			
13)	Flow records must be maintained at the inlet and outlet of all sewage works.			

Data source: MOWD

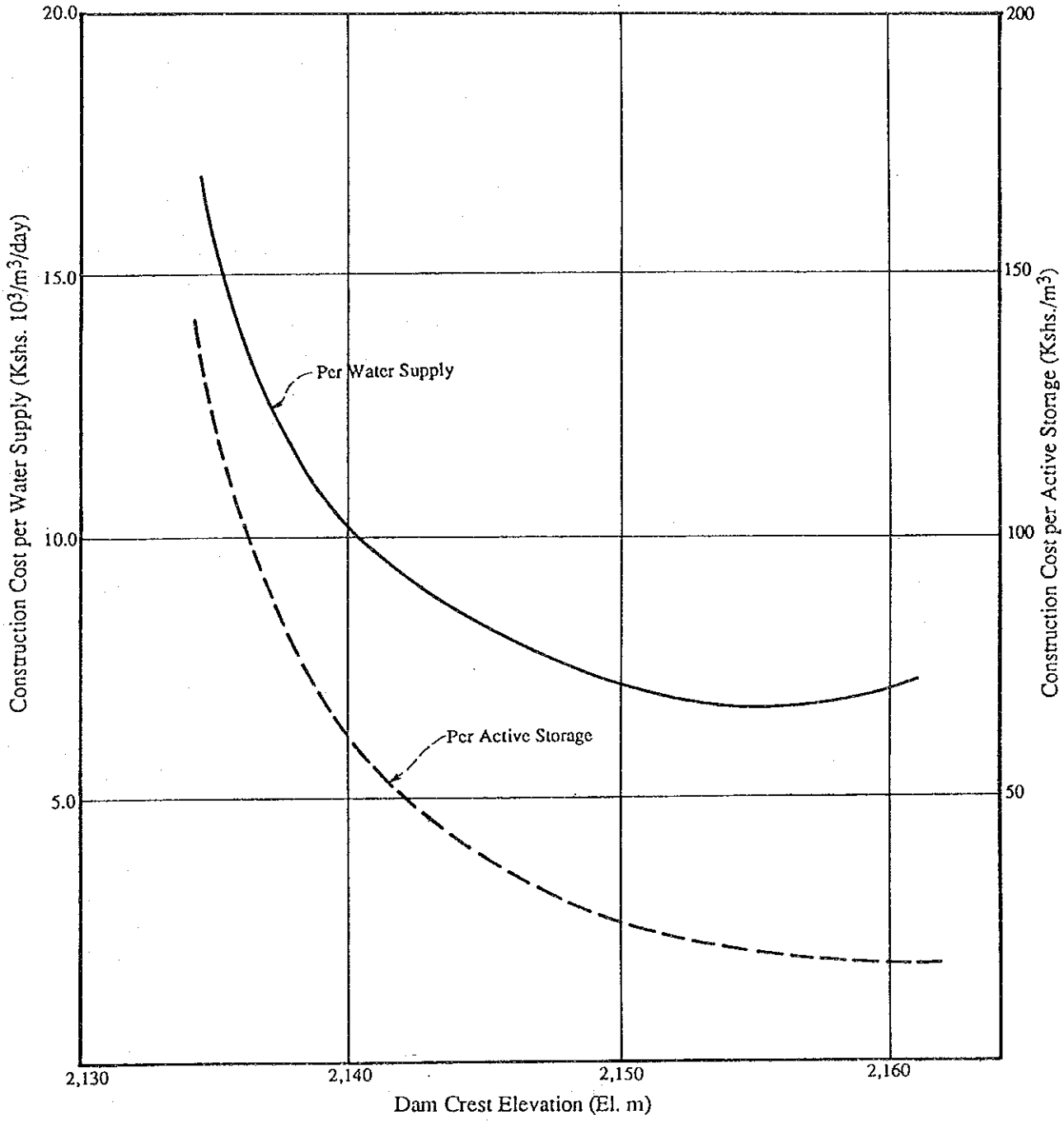
Table S.7.2 Existing water Rights

	Descriptions	Malewa River		Turasha River		Lake Naivasha	
		No.	Discharge (cu.m/sec)	No.	Discharge (cu.m/sec)	No.	Discharge (cu.m/sec)
(1)	Low Flow Season						
	Domestic	16	0.007	-	-	40	0.039
	Public	2	0.030	4	0.003	1	0.003
	Minor irrigation	-	-	-	-	-	-
	Industrial	-	-	-	-	1	0.001
	Power	-	-	-	-	-	-
	General irrigation	-	-	-	-	-	-
	Others	-	-	-	-	-	-
	Total	28	0.037	4	0.003	42	0.043
(2)	Flood Season						
	Domestic	-	-	-	-	-	-
	Public	-	-	-	-	-	-
	Minor irrigation	3	0.001	-	-	16	0.002
	Industrial	1	0.028	-	-	-	-
	Power	1	0.008	-	-	1	0.008
	General irrigation	8	0.068	2	0.010	62	0.819
	Others	1	0.007	-	-	1	0.03
	Total	14	0.112	2	0.010	80	0.858

Data Source : Water Apportionment Board

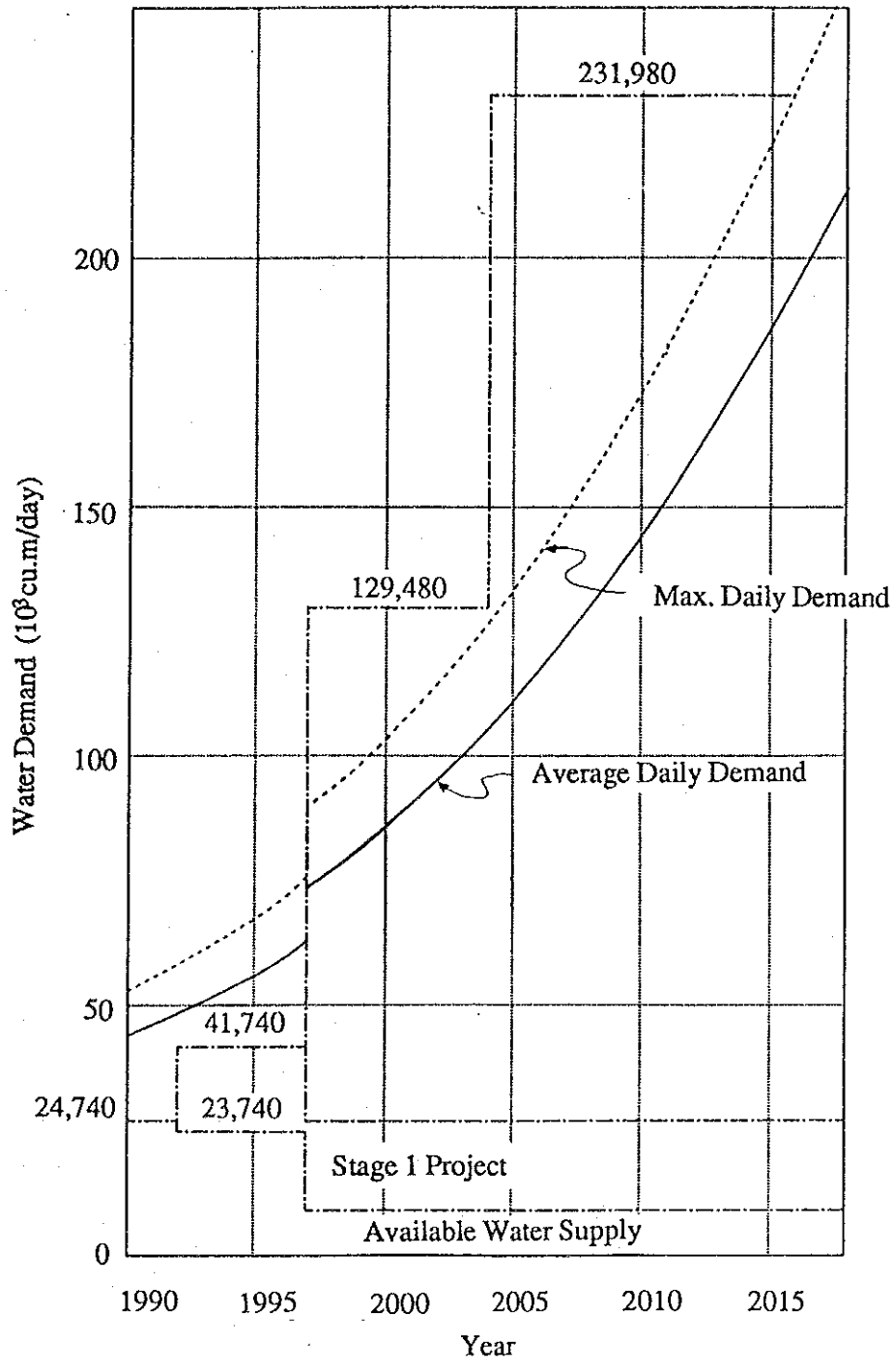
FIGURES

Fig. S.4.1



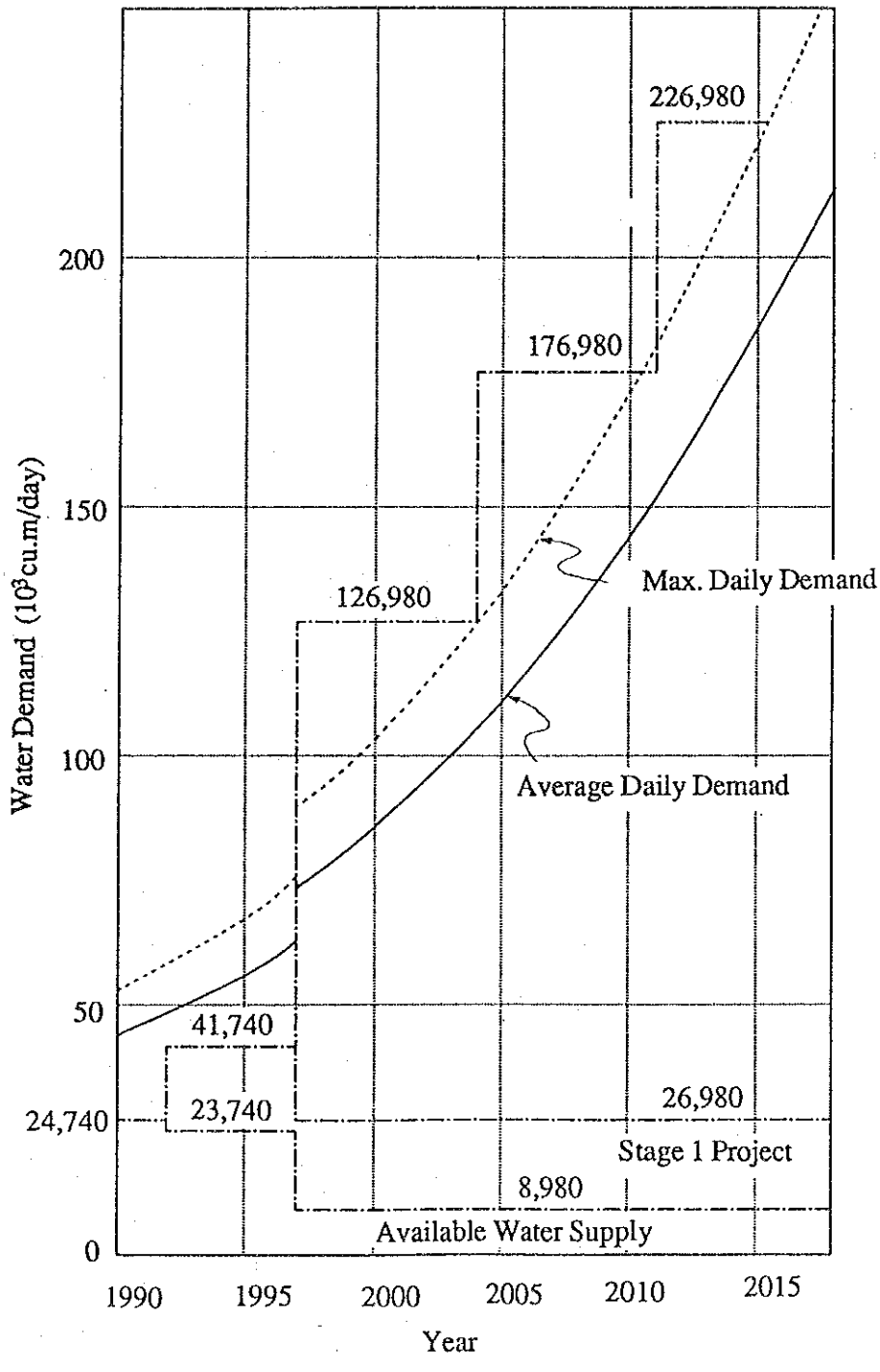
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Construction Cost per Water Supply and Construction Cost per Reservoir Active Storage

Fig. S. 4.2



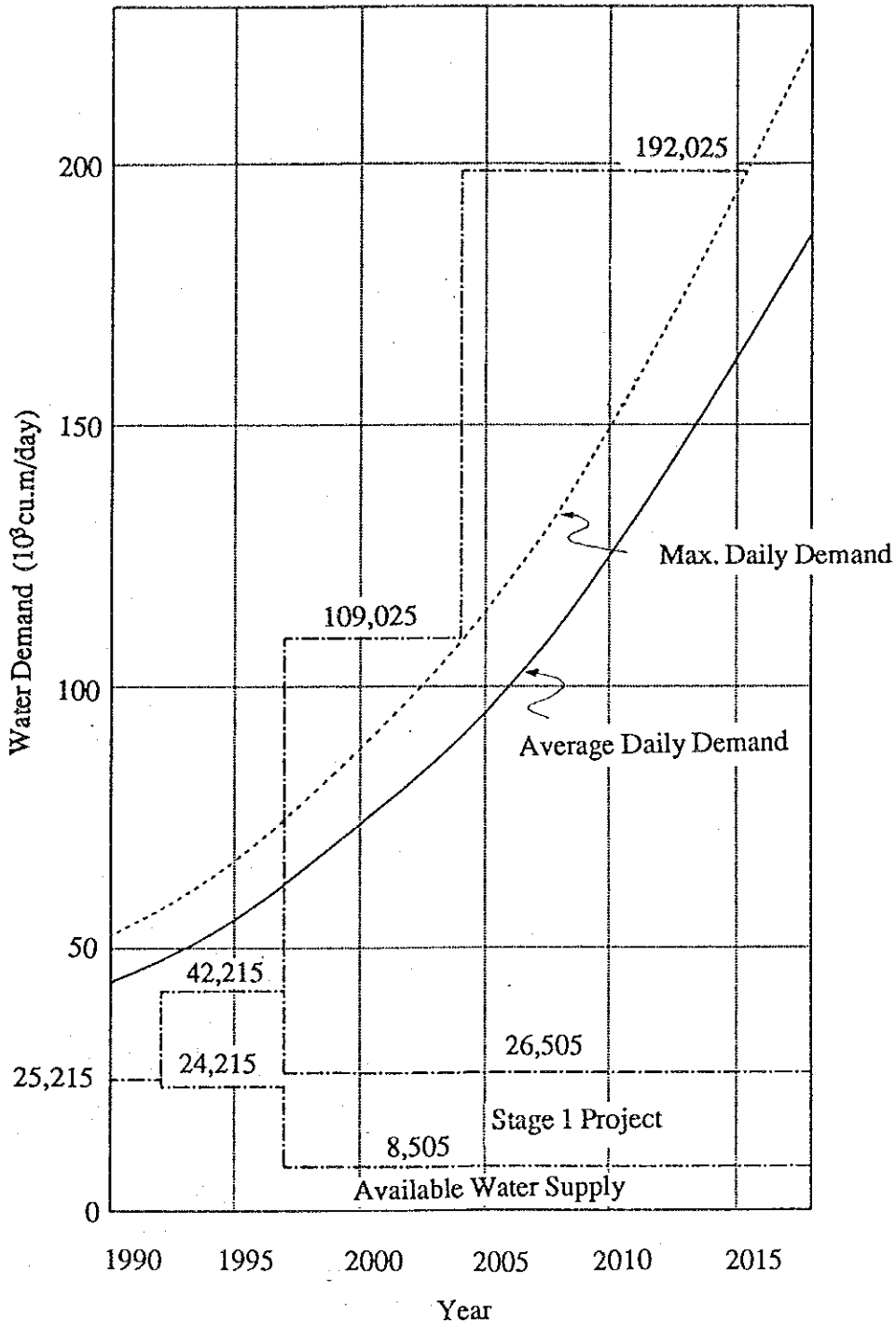
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Development Sequence of Raw Water Transmission System

Fig. S. 4.3



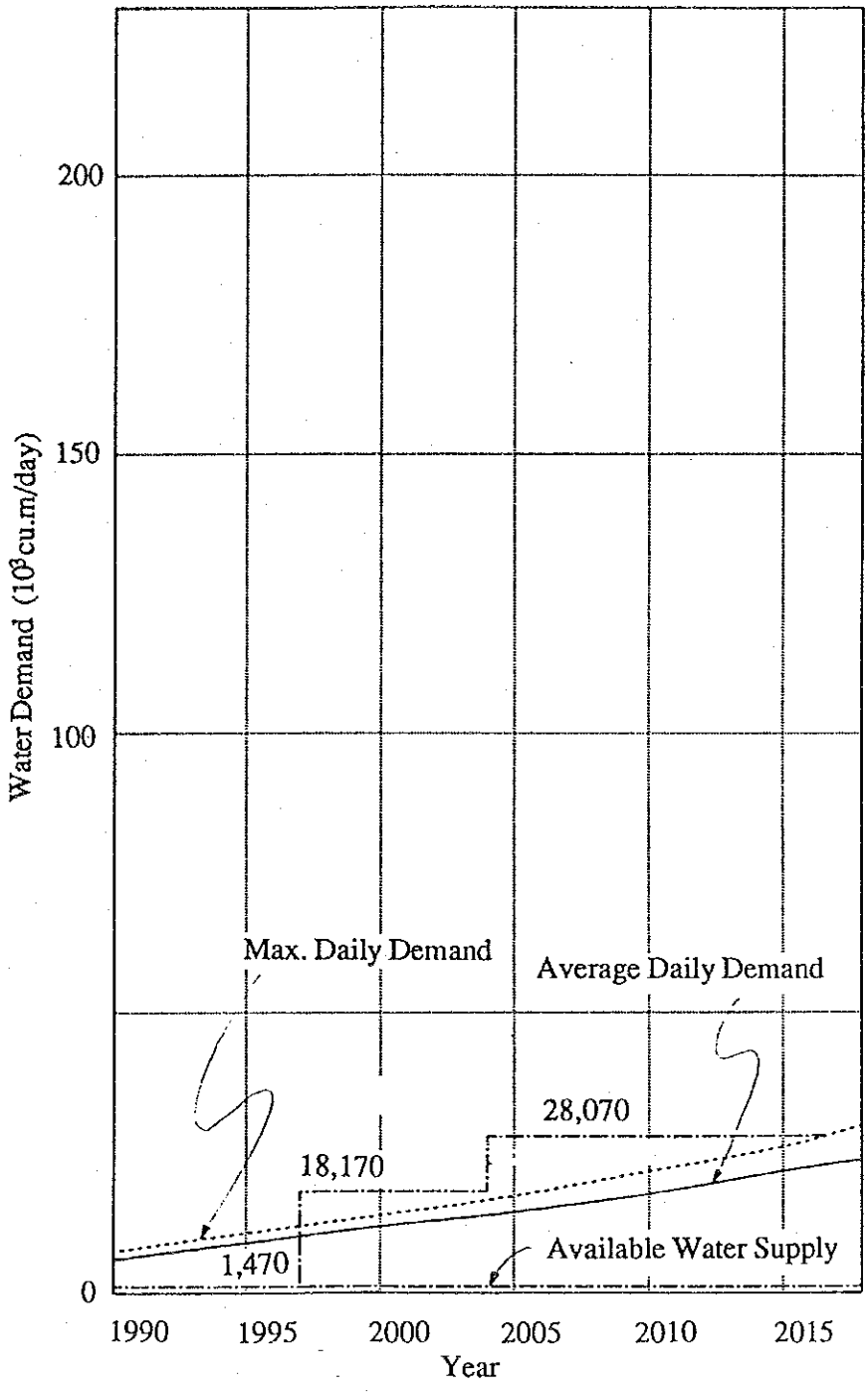
THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Development Sequence of Treatment Works

Fig. S. 4.4



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Development Sequence of Nakuru Treated Water Transmission System

Fig. S. 4.5



THE REPUBLIC OF KENYA MINISTRY OF WATER DEVELOPMENT NATIONAL WATER CONSERVATION AND PIPELINE CORPORATION	THE STUDY FOR CONSTRUCTION OF DAM IN MALEWA RIVER SYSTEM GREATER NAKURU WATER SUPPLY PROJECT EASTERN DIVISION JAPAN INTERNATIONAL COOPERATION AGENCY	TITLE Development Sequence of Naivasha Treated Water Transmission System