REPUBLIC OF KENYA

LAKE BASIN DEVELOPMENT AUTHORITY

THE STUDY OF INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE LAKE BASIN DEVELOPMENT AREA

FINAL REPORT

Volume 5

SECTOR REPORT 3

WATER RESOURCES/TRANSPORTATION/ENERGY

October 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

REPUBLIC OF KENYA

LAKE BASIN DEVELOPMENT AUTHORITY

THE STUDY OF INTEGRATED REGIONAL DEVELOPMENT MASTER PLAN FOR THE LAKE BASIN DEVELOPMENT AREA

FINAL REPORT

Volume 5

SECTOR REPORT 3

WATER RESOURCES/TRANSPORTATION/ENERGY

October 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

LIST OF REPORTS

Volume 1.	EXECUTIVE SUMMARY REPORT
Volume 2.	MASTER PLAN REPORT
Volume 3.	SECTOR REPORT 1: Agriculture/Livestock/Fishery
Volume 4.	SECTOR REPORT 2: Manufacturing/Mineral Resources/Tourism
Volume 5.	SECTOR REPORT 3: Water Resources/Transportation/Energy
Volume 6.	SECTOR REPORT 4: Land Use/Human Resources
Volume 7.	REPORT ON PREPARATORY STUDY

Volume 5. SECTOR REPORT 3

Contents

Chapter 7 Water Resources

Chapter 8 Transportation

Chapter 9 Energy

Abbreviations

ACFC	Agro-Chemical and Food Company
ADT	Average Daily Traffic
AED	African Economic Digest
AESD	Agricultural Extension and Service Division
AFC	Agricultural Finance Corporation
AI	Artificial Insemination
AIRS	Ahero Irrigation Research Station
BAT	British American Tobacco Kenya Ltd.
BOD	Biochemical Oxygen Demand
CBK	Coffee Board of Kenya
CBS	Central Bureau of Statistics
CL SMB	Cotton Lint and Seed Marketing Board
CPCS	Cooperative Production Credit Scheme
DAO	District Agricultural Officer
DC	District Commissioner
DCDC	District Community Development Committee
DDC	District Development Committee
DEC	District Executive Committee
DEO	Division Extension Officer
DFCK	Development Financial Company of Kenya
DME	Distance - Measuring Equipment
DO	District Officer
EAI	East African Industries Limited
EATEC	East African Tanning Extract Company Limited
EEC	European Economic Community
EIU	Economic Intelligence Unit
ESMAP	Energy Sector Management Assistance Programme
FAO	Food and Agriculture Organization of the United Nations
FISS	Farm Input Supply Scheme
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product
GRDP	Gross Regional Domestic Product
GTZ	Germen Agency for Technical Cooperation
HCDA	Horticultural Crops Development Authority
HFA/2000	Health for All by the Year 2000 AD.
IADP	Integrated Agricultural Development Program
IBRD	International Bank for Reconstruction and Development
ICA	International Coffee Agreement
ICDC	Industrial and Commercial Development Corporation
ICIPE	International Center for Insect Physiology and Ecology
ICOR	Incremental Capital-Output Ratio
IDA	International Development Association
IDB	Industrial Development Bank
IDS	Institute of Development Studies
IE	Industrial Estate
IFAD	International Fund for Agricultural Development
ILO	International Labour Organization
ILUS	Integrated Land Use Survey
IPA	Industrial Promotion Area
IRD	Integrated Rural Development
IRRI	International Rice Research Institute
IRS	Integrated Rural Survey
JICA	Japan International Cooperation Agency
JSCE	Japan Society of Civil Engineers
KCC	Kenya Cooperative Creawerdes
KCPE	Kenya Certificate of Primary Education
KENAFYA	Kenya - Finland
KENGO	Kenya Energy Non-Governmental Organizations Association
KETA	Kenya External Trade Authority
KFA	Kenya Farmers Association
KGGCU	Kenya Grain Growers Union
KIE	Kenya Industrial Estates Limited
KITI	Kenya Industrial Training Institute
K£	Kenya Pounds (20 Kenya shillings)
KMC	Kenya Meat Commission
KNAIS	Kenya National Artificial Insemination Service
KPCU	Kenya Planters Cooperative Union
KPLC	Kenya Power and Lighting Company Limited
KQ	Kenya Airways
KRC	Kenya Railways Corporation
KREDP	Kenya Renewable Energy Development Programme
KSA	Kenya Sugar Authority
KSB	Kenya Sisal Board
KSC	Kenya Seed Company
Kshs	Kenya Shillings
KSS	Kenya Soil Survey
KTDA	Kenya Tourism Development Authority
KTDA	Kenya Tea Development Authority

KWDP	Kenya Woodfuel Development Project
LBDA	Lake Basin Development Authority
LPG	Liquefied Petroleum Gas
LSI	Lake Shore Irrigation
LU	Livestock Unit
MCH/FP	Matenal Child Health/Family Planning
MOLG	Ministry of Local Government
MOA	Ministry of Agriculture
MOALD	Ministry of Agriculture and Livestock Development
MOERD	Ministry of Energy and Regional Development
MOEST	Ministry of Education Science and Technology
MOH	Ministry of Health
MOLD	Ministry of Livestock Development
MOPND	Ministry of Planning and National Development
MOTC	Ministry of Transport and Communication
MOWD	Ministry of Water Development
MP	Member of Parliament
MSC	Mumias Sugar Company
MSS	Multispectral Scanner
MSY	Maximum Sustainable Yield
NCC	National Construction Corporation
NCPB	National Cereals and Produce Board
NCST	National Council for Science and Technology
NEP	National Energy Policy
NEP	National Extension Project
NGO	Non-Governmental Organization
NIB	National Irrigation Board
NMWP	National Master Water Plan
NSCC	New Seasonal Credit Scheme
OD	Origin-Destination
OECD	Organization for Economic Cooperation and Development
PBME	Project Benefit Monitoring and Evaluation
PC	Provincial Commissioner
PCU	Passenger Car Unit
PHC	Primary Health Care
PIU	Provincial Irrigation Unit
RAES	Rural Afforestation Extension Service
RIDC	Rural Industrial Development Center
ROK	Republic of Kenya
RTPC	Rural Trade and Production Center
RWSDP	Rural Water Supply Development Project
SCIP	Smallholder Coffee Improvement Project
SEFC	Small Enterprise Financial Corporation
SEP	Special Energy Programme
SP1	Sessional Paper No.1 of 1986 on Economic Management for Renewed Growth
SPSCP	Smallholder Production Services and Credit Scheme
SRRP	Smallholder Price Rehabilitation Project
SSIOP	Small Scale Irrigation Development Project
SWAP	Surface Water Extraction Permit
T&V	Training and Visit
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific, and Cultural Organization
UNCEF	United Nations International Children's Emergency Fund
UNIDO	United Nations Industrial Development Organization
USAID	United States Agency for International Development
VOR	Very High Frequency Ommidirectional Radio Range
WHO	World Health Organization

Abbreviations of Measures

Length

mm	=	millimeter
m	=	meter
km	=	kilometer

Area

ha	=	hectare
km^2	=	square kilometer

Volume

ℓ	=	lit = litre
m^3	=	cubic meter
MCM	=	million cubic meter

Weight

mg	=	milligram
g	=	gram
kg	=	kilogram
t	=	ton = MT = metric ton

Time

sec	=	second
hr	=	hour
d	=	day
yr	=	year

Money

Kshs.	=	Kenya shilling
K£	=	Kenya pound
US¢	=	U.S. cent
US$	=	U.S. dollar

Energy

kcal	=	kilocalorie
J	=	joule
MJ	=	megajoule
HP	=	horsepower
TOE	=	tons of oil equivalent
kW	=	kilowatt
MW	=	megawatt
kWh	=	kilowatt-hour
GWh	=	gigawatt-hour

Others

%	=	percent
°	=	degree
'	=	minute
°C	=	degree Celsius
cap.	=	capita
LU	=	livestock unit
md	=	man-day
mil.	=	million
no.	=	number
pers.	=	person
PCU	=	passenger car unit

CHAPTER 7 WATER RESOURCES

This chapter presents the results of the water resources study conducted as a part of the study of the Integrated Regional Development Master Plan for the LBDA region. The water resources study covers urban and rural water supply, irrigation, flood control, hydropower, and water quality.

Section 7.1 deals with water resources in the Lake basin, i.e., rainfall, runoff including flood and sedimentation, and water resources potential on the basis of subbasin. Section 7.2 analyses the present condition of water resources development and management. The results of analyses and findings of various fields of water resources were utilized in subsequent sections in water demand projection and formulating a plan of water resources development and management. Section 7.3 presents the results of a balance study of projected water demands in 2005 and water potential; the water balance was analyzed for each subbasin -- 63 subbasins in total. Section 7.4 and 7.5 are devoted to water resources development and management plan. Section 7.4 describes basic strategies and Section 7.5 presents the plan. The plan consists mainly of water supply, multipurpose water resources development, irrigation and water quality control. The plan includes projects and programmes to achieve the goals and objectives of the Integrated Regional Development Master Plan for the LBDA region.

CHAPTER 7 WATER RESOURCES

7.1 Water Resources in the Region ---------- 7-1
7.1.1 Lake basin area ---------- 7-1
7.1.2 Rainfall and evaporation in Lake basin area ---------- 7-1
(1) Rainfall ---------- 7-1
(2) Evaporation ---------- 7-2
7.1.3 River Flow ---------- 7-2
(1) Runoff data ---------- 7-2
(2) Flood flow ---------- 7-2
7.1.4 Sedimentation ---------- 7-4
7.1.5 Subbasin water resources ---------- 7-4
(1) Basins and subbasins ---------- 7-4
(2) Subbasin surface water potential ---------- 7-5
(3) Subbasin groundwater potential ---------- 7-6

7.2 Present Water Resources Development and Management ---------- 7-7
7.2.1 Policies and institutions ---------- 7-7
7.2.2 Water supply ---------- 7-8
(1) Traditional water acquisition ---------- 7-8
(2) Population with improved water supply ---------- 7-9
(3) Implementation and operation of water supply projects ---------- 7-10
(4) Piped water supplies under operation ---------- 7-10
(5) On-going major rural water supply projects ---------- 7-11
(6) Municipal water supply ---------- 7-13
7.2.3 Sanitation ---------- 7-15
7.2.4 Irrigation ---------- 7-16
(1) NIB schemes ---------- 7-17
(2) Small scale irrigation schemes ---------- 7-17
(3) LBDA schemes ---------- 7-17
7.2.5 Flood protection ---------- 7-18
(1) Kano Plain and floods ---------- 7-18
(2) Past flood protection work of Nyando ---------- 7-21
(3) On-going flood protection project in Kano Plain ---------- 7-21
(4) Flood protection in other rivers ---------- 7-22
7.2.6 Water quality control ---------- 7-23
(1) Water quality control of Kenyan Government ---------- 7-23
(2) Sources of water pollution ---------- 7-24
(3) Water quality of Lake basin waters ---------- 7-26
7.2.7 Water related problems and district needs ---------- 7-29
7.2.8 Water abstraction by subbasin ---------- 7-29

7.3 Water Demand and supply Balance in 2005 ---------- 7-31
7.3.1 Water demand projection ---------- 7-31
(1) Domestic water demand ---------- 7-31
(2) Livestock water demand ---------- 7-33
(3) Industrial water demand ---------- 7-33
(4) Irrigation water demand ---------- 7-34
7.3.2 Water demand and supply balance ---------- 7-34
(1) Surface water balance ---------- 7-34
(2) Groundwater balance ---------- 7-36
7.3.3 Water quality control ---------- 7-36
(1) Present nutrient transport ---------- 7-36
(2) Projection of nutrient load in 2005 ---------- 7-37

7.4 Strategy of Water Resource Planning ---------- 7-38
7.4.1 Overall planning strategies ---------- 7-38
7.4.2 Rural water supply ---------- 7-39
(1) Target of water supply ---------- 7-39
(2) Basic strategy of rural water supply ---------- 7-39
(3) Advantages in hand pump well ---------- 7-40
(4) Community involvement ---------- 7-41
7.4.3 Irrigation ---------- 7-41
7.4.4 Flood control ---------- 7-41
(1) Priority area ---------- 7-41
(2) Integrated approach to Kano Plain flood control ---------- 7-42
(3) Community involvement ---------- 7-43
(4) Roles of LBDA ---------- 7-43
7.4.5 Water quality control ---------- 7-44

7.5 Water Resources Development and Management Plan ---------- 7-45
7.5.1 Water supply and sanitation development ---------- 7-45
(1) Rural and urban water supply ---------- 7-45
(2) Rural sanitation ---------- 7-51
(3) Municipal water supply and sanitation ---------- 7-51
7.5.2 Multipurpose water resources development ---------- 7-53
(1) Preliminary assessment of water resources development project ---------- 7-53
(2) Integrated Kano Plain Development ---------- 7-58
7.5.3 Water Quality Control ---------- 7-64
(1) Water quality assessment and control study ---------- 7-64
(2) Water quality monitoring and control project ---------- 7-65
7.5.4 Catchment conservarion ---------- 7-65
(1) Objectives of catchment conservation ---------- 7-65
(2) Factors affecting floods and soil erosion ---------- 7-65
(3) Problem areas in the Region ---------- 7-66
(4) Measures ---------- 7-66

References ---------- 7-68

Tables

Table 7.1 Major Rivers in the Lake Basin
Table 7.2 Daily Evaporation Rate
Table 7.3 Major Stream Gauges and Average Annual Rainfall and Runoff
Table 7.4 Monthly Flow Record at Major Gauge Stations (1/13-13/13)
Table 7.5 Record of Annual Maximum Discharge
Table 7.6 Probable Flood at Stream Gauges
Table 7.7 Specific Discharge of 100-year Flood
Table 7.8 Suspended Loads of the Rivers
Table 7.9 Subbasins in the Lake Basin
Table 7.10 Comparison of Estimated and Measured Annual Average Flow
Table 7.11 Annual Mean and Low Flow Volumes
Table 7.12 Past Performance and Problems of Water Development (1/3-3/3)
Table 7.13 Piped Water Supply under Operation
Table 7.14 Piped Water Supply Projects under Construction or Planning
Table 7.15 Present Water Abstraction by Subbasin and Purpose
Table 7.16 Human and Livestock Population by Subbasin in 2005
Table 7.17 Water Demand by Subbasin and by Purpose in 2005
Table 7.18 Water Utilization Ratio by Subbasin
Table 7.19 Rural and Urban Water Supply Programmes
Table 7.20 Kisumu Municipal Water Supply Expansion Plan
Table 7.21 Kisumu Municipal Sewerage Expansion Plan
Table 7.22 Principal Features of Proposed Large Scale Water Resources Deveopment Project (1/3-3/3)
Table 7.23 Alternative Development Schemes
Table 7.24 Cost of Flood Protection Measures in Kano Plain

Figures

Figure 7.1 Rivers and Major Gauge Stations
Figure 7.2 Lake Basin Area and Isohyet
Figure 7.3 Mean Monthly Rainfall (1931-60)
Figure 7.4 Longitudinal Profile of Major Rivers
Figure 7.5 Non-dimensional Accumulated Flood Hydrographs
Figure 7.6 Configuration of River Basin and Subbasin
Figure 7.7 Surface Water Potential by Subbasin
Figure 7.8 Groundwater Potential by Subbasin
Figure 7.9 Area Susceptible to Flood in Kano Plain
Figure 7.10 Population Density by Subbasin
Figure 7.11 Water Demand and Supply Balance in 2005
Figure 7.12 Possible Water Resources and Irrigation Development Projects
Figure 7.13 Area-Storage Curves for Reservoir Projects (1/2-2/2)
Figure 7.14 Plan and Profile of Water Resources Project (Webuye)
Figure 7.15 Plan and Profile of Water Resources Project (Nandi Forest)
Figure 7.16 Plan and Profile of Water Resources Project (Namba Kodero)
Figure 7.17 Project Components of Integrated Kano Plain Development
Figure 7.18 Flood Protection Measures in Kano Plain - Alternative 1
Figure 7.19 Flood Protection Measures in Kano Plain - Alternative 2

7.1 Water Resources in the Region

7.1.1 Lake basin area

The land of Kenya is broadly classified into five drainage areas: Lake Victoria, Rift Valley, Athi River, Tana River and Ewaso Ng'iro River (north) drainage areas. The area under the jurisdiction of LBDA comprises the entire catchment area of rivers draining into Lake Victoria (1,134 m above mean sea level), 47,709 km^2 in total. The water surface area of 3,830 km^2 of Lake Victoria is also under the LBDA jurisdiction. The Lake Victoria catchment area lies between 34° and 36° east in longitude and between 1°15' north and 1°5: south in latitude, the equator passing through the centre of the Region.

The climate of Lake Victoria catchment area is mild with small variation in monthly average air temperature between 19°C and 25°C throughout the year, as it extends over the elevatioı of 1,350 m to 2,700m (except Mt. Elgon area). Daily temperature fluctuates more widely, ranging from 15°C to 30°C. Rainfall in this catchment area has an annual average of about 1,300 mm, varying from 2,000 mm in highlands to 1,000 mm in the north, south-west and lowlands along the Lake shore. Rainfalls exhibit a bimodal pattern with long and short rainy seasons in the period of March to June and in October to December, respectively. There exists no remarkable dry month.

There are seven major rivers in Lake Victoria catchment area: the Sio, Nzoia, Yala, Nyando, Sondu, Kuja/Migori and Mara Rivers as shown in Figure 7.1. These rivers originate in vast highlands with gentle undulation and drain into Lake Victoria, meandering generally south-westward. Seasonal variation of flow is similar to that of rainfall. Main features of the seven major rivers are summarized in Table 7.1.

The total area drained by these seven major rivers is 39,599 km^2, accounting for about 83% of Lake Victoria catchment area of 47,709 km^2. Remaining 17% is drained by the Malaba River (flowing into Uganda) and small rivers along the Lake shore such as the Kibos and Oroba in Kano Plain, the Awasi Kibuon (flowing into Kendu Bay), Awasi Tende (flowing into Homa Bay) and others.

7.1.2 Rainfall and evaporation

(1) Rainfall

Rain gauges of more than 500 in number have been established and operated in the LBDA region, although some were abandoned after a short time of observation. The areas with a high density of rain gauges extend in the highlands of Kisii, Kericho and Trans Nzoia, where tea is produced by plantation. The rain gauges are sparsely distributed in the southern part of the Region, the Migori and Mara river basins.

Monthly rainfall data were collected for 65 stations of the Region from the Hydrology Section of the Ministry of Water Development (MOWD) with the assistance of staff of the Hydrology Section of the MOWD. These 65 stations have been selected based on the criteria that the stations should be distributed evenly in the Lake basin and record periods should be long enough to represent the rainfall at each station.

An isohyet map of average annual rainfall has been prepared for the LBDA region based on the 65 stations selected and shown in Figure 7.2. The Mean Annual Rainfall Map of East Africa prepared by the Meteorological Department was referred to for supplementing the rainfall data for the southern part of the Region, i.e. the Migori and Mara river basins. Average annual rainfall of the entire LBDA region, was calculated as 1,330 mm based on this isohyet map. The mean rainfall varies from 1,680 mm/year in the Sio river basin to 980 mm/year in the Mara river basin as shown in Table 7.1. Figure 7.3 depicts the seasonal rainfall patterns of 13 rain gauges selected in the Region. A predominant peak appears in the period of March to May.

(2) Evaporation

Daily pan evaporation data are presented in Table 7.2 for four meteorological stations of Ahero Experimental Station (Alt. 1,219 m), Kisumu Airport (Alt. 1,157 m), Sotik Water Supply (Alt. 1,950 m) and Kericho T.R.I (Alt. 2,134 m). The annual potential evaporation in these stations is calculated to be from 1,400 to 2,200 mm/year. The monthly variation of the data shows that high evaporation is expected in a dry season from January to March, and low evaporation in a wet season, May to August.

Actual annual evaporation in a basin can be calculated as the difference between annual rainfall and annual runoff. Annual evaporation calculated from the data presented in Table 7.3 falls in the range from 900 to 1500 mm/year but mostly varies between 1000 and 1200 mm/year.

7.1.3 River flow

(1) Runoff data

Stream flow records were collected for 13 gauging stations of the seven major rivers in the LBDA region from the Hydrology Section of MOWD and reports such as Lake Basin River Catchment Development - River Profile Studies (ref.7). The features and locations of those stream gauge stations are shown in Table 7.3 and Figure 7.1, respectively.

These 13 stream gauges are expected to play a key role for evaluating water resources potential in the Lake Victoria catchment area, as these stations (except 1LA3) are located in the middle or downstream reaches of the seven major rivers and runoffs are observed for a long period. Projects are identified mostly in the middle and downstream reaches as shown in Section 7.5. The record of monthly mean discharge is given in Table 7.4 for 13 stream gauge stations.

(2) Flood flow

Preliminary estimates of flood flow were made for the purpose of planning such hydraulic structures as spillways and diversion works of water resources development projects and also for assessing flood discharges of flood prone areas. Annual peak discharges recorded at seven stream gauges out of 13 stations were collected from the MOWD and the report of Sondu River Multipurpose Project (ref. 11). The seven stream gauges were selected at downstream of the rivers since flood prone areas are located mainly along lower reaches. The data are given in Table 7.5. The annual peak discharge at 1KB5 is affected by the operation of existing Gogo Falls reservoir constructed in 1957.

Stage height of these seven gauges is currently being recorded automatically. A measurement of stage height before the installation of such recorders was made by staff readings twice a day at most. Thus, actual annual peak discharges before the installation of recorders would have been greater than those recorded by staff readings. In the Nyando River, the highest value in a year recorded at any one of 1GD1, IGD3 and 1GD4 is taken as an annual maximum of all these stations.

A frequency analysis was made to estimate floods at the seven gauge sites applying the density function of Extremal Type 1 as summarized in Table 7.6. The majority of flood series at the seven stations fit best to the function.

Specific discharges of a 100-year flood, Q^{100}, were computed to see the characteristics of floods in the Region as shown in Table 7.7. As observed in the table the gauge stations may be classified into two groups by the specific discharge: the first group of 1AH1, 1DA2, 1EE1 and 1FG1 with the relatively small values and the second group of 1GD1/3/4, 1JG1 and 1KB5 with higher values. An observation of the longitudinal profiles presented in Figure 7.4 for the seven rivers reveals that the Sondu and Nyando Rivers have steeper river gradient as compared with others.

The ratios of selected probable floods to a 2-year flood were computed using the data in Table 7.6. The average ratio over all the stations except for 1AH1 (showing a rather different tendency from others) is summarized as below:

Q^5/Q^2	:	1.5
Q^{10}/Q^2	:	1.8
Q^{20}/Q^2	:	2.1
Q^{25}/Q^2	:	2.2
Q^{50}/Q^2	:	2.5
Q^{100}/Q^2	:	2.8

where, Q^2, Q^5, Q^{10} and so forth correspond to the probable flood of the year given to the superscript.

Duration of large floods was estimated by expressing observed floods in a non-dimensional and accumulated form after the subtraction of base flow. The results are shown in Figure 7.5. A single flood was selected out of these large floods for each river instead of a composite flood. Flood hydrographs are different depending on the types of rainfall; a tendency of a dull peak and long duration is observed (except for the Nyando River) probably due to the retention effects of swamps in the upper and middle reaches of the rivers. The steep slope in the middle reaches as shown in Figure 7.4 and fewer swamps in the upper and middle reaches of the Nyando River may be the cause of such a sharper peak and short duration of floods.

7.1.4 Sedimentation

An estimate of sediment load is important in determining a dead storage of reservoirs and in evaluating channel deposits along the lower reaches of rivers, which raise a river bed and cause flooding and pollution in the Lake as well. It is a normal practice to estimate sediment loads by establishing a rating curve between discharge and suspended load, but insufficient sampling of suspended loads hampers the establishment of the rating curves in rivers of the LBDA area. However, an attempt to develop such a rating curve of suspended load was made in the study of Sondu River Multipurpose Project. In the study, annual sediment load of the basin was estimated as 150 tons/km^2 based on the data sampled in early 1940's and 1950's. Care has to be taken in utilizing this estimate, however, as the land use has changed considerably since the years of data sampling and the sediment load might have increased.

The estimate of sediment loads for other rivers in the LBDA area was attempted by several studies with insufficient data. The results summarized in the River Profile Study are presented in Table 7.8. Estimated suspended load of the Sondu River differs between 150 tons/km^2 cited above and 38 tons/km^2 estimated by TAMS for the National Master Water Plan (ref.31). Suspended loads of 38 tons/km^2 in the Nzoia River was also referred to from the National Master Water Plan. Higher suspended loads of 423 tons/km^2 were estimated for the Nyando River in the study of Lotti (ref.7). This may be due to the large tractive force of a flood descending steep slope of the Nyando as shown in Figure 7.4.

More accurate estimate of suspended loads will have to base on future accumulation of data. It is therefore recommended to intensify the measurement of sediment yield especially during floods. This is particularly important for the Nyando River since suspended load seems to be relatively high compared with other rivers. Such a measurement will help to identify need for catchment conservation by subcatchment. In fact, the Ministry of Water Development and LBDA have been requested to undertake a study to update the data for sediment load.

7.1.5 Subbasin water resources

Water resource potential has been analyzed by subbasin and the results are presented in this subsection. The subbasin water resource potential will be utilized as a basis for looking at a balance between water resource potential and projected water demand of 2005 in each subbasin in a subsequent section.

(1) Basins and subbasins

The National Master Water Plan (ref.31) divided the Lake basin into 11 basins and named as basin 1A, 1B... and 1L. The basins are further divided into 63 subbasins and named as 1AA, 1AB, ..., 1AH, 1BA, 1BB,... , 1BH, ...,1LA and 1LB. Basin codes, names of basin, areas of subbasins are shown in Table 7.9. Relations and configuration of basins and subbasins are schematically depicted in Figure. 7.6.

(2) Subbasin surface water potential

Since flow gaging stations are not located in all subbasins, it is difficult to estimate water potential for every subbasin. The National Master Water Plan presents estimates of mean annual runoffs of each subbasin. The mean annual runoffs expressed as water depth in mm are shown in Figure 7.7. The basins 1E (lower Nzoia) and 1J (upper Sondu) appear to have good water potential and the basins 1L (Mara), 1H (Lake shore), and 1C (upper Nzoia) appear to be poor in water potential.

The estimated runoffs were cross checked with the available monthly flow records of 30 to 40 years. The comparison between estimated average flows and measured average flows at stream gauge stations is given in Table 7.10. The differences are within a reasonable range (i.e., less than 10%) for most rivers. Nyando River shows a large difference. Since the gauge record at Nyando is said to be unreliable, the estimated flow at Nyando was not adjusted to the gauge record. All the estimated flows were used without adjustment because they were considered accurate enough for the purpose of water balance study. The mean annual runoffs were converted into annual mean flow volumes in million m^3.

Low flows were also estimated. The lowest monthly flow recorded in the 30 to 40 years can be considered as the flow which may occur in one month during 30 to 40 years. The length of 30 to 40 years is simply the length of available flow records at most of the gauge stations and the exact length depends on the gauge stations as given in Table 7.4. Low flows of basins with shorter length of flow record were estimated using the data for neighboring basins with 30 to 40 years flow record. A percentage of such a low monthly flow to annual mean discharge was computed, and the percentage was multiplied by the annual mean flow volume mentioned above. This gives the amount of water volume available for use in a year of low flow occurring once in 30 to 40 years.

Low monthly flows occurring once in 3 to 4 years were also found out from the monthly flow records of stream gauge stations. For instance, if there is a flow record of 30 years (360 months), the average monthly flow that is 8th to 10th smallest among the monthly flow record is defined as the low monthly flow occurring once in 3 to 4 years. The percentage of such a low flow to annual mean discharge was computed and the percentage was multiplied by the annual mean flow volume. This gives the amount of water volume available in a year of low flow occurring once in 3 to 4 years.

For water users, such a frequency of water shortage occurring in one month in 3 to 4 years is considered as rather frequent while one month in 30 to 40 years is considered as rare. A frequency of once in 5 years or 10 years is moderate (neither frequent nor rare). The criterion of selecting 3 to 4 years and 30 to 40 years is, therefore, explained as the time length which is perceived frequent or rare, respectively, for various water users.

These annual mean flow volume and low flow volume were estimated for each subbasin and accumulated from upstream to downstream according to the subbasin configuration mentioned previously. Table 7.11 presents annual mean flow volumes and low flow volumes produced in each subbasin by itself, accumulated flow volumes supposed to be available in each subbasin, and the percentages to the mean flow volumes used to estimate the low flow volumes. These data are used later in the water balance study.

Since surface water potential is based on subbasin runoffs, water in the Lake was not accounted for. It would not be a feasible idea to lift Lake water all the way up to the highlands. However, Lake water may be utilized along the Lake shore at most 20 km to the inland if stream water is not found and use of Lake water is economically and operationally feasible.

(3) Subbasin groundwater potential

The MOWD made a study (ref.35) of groundwater potential of the Lake basin. The study does not deal with groundwater potential in detail but the potential is based on a subbasin or a basin as a whole. In the MOWD study, basins were classified according to groundwater recharge potential measured as a percentage of rainfall, where more than 15% is assessed very good, 10 to 15% good, 5 to 10% moderate, and less than 5% either low or poor.

Groundwater development has been undertaken recently in Nyanza Province by LBDA. Such groundwater development activities have revealed that the southern part of the Lake basin has more groundwater potential than the MOWD study indicated. Although groundwater recharge in the southern part is not as high as in the northern part, groundwater development potential was found to be good to moderate in most of the southern part of the Region. The groundwater potential map made by the MOWD study has been updated for the southern part of the Region and presented in Figure 7.8. The highest potential of groundwater is found in Sio and Malaba basin, Lower Nzoia basin, Yala basin and Kuja basin. Low and poor potential zones are found in a part of the Lake shore and the Mara river basin. This classification of groundwater potential should be looked at as tentative and be revised when detail studies cover the whole Lake basin.

7.2. Present Water Resources Development and Management

7.2.1 Policies and institutions

Policies

The National Development Plan (ref.43) states the policies and goals for government water programmes. They include rural water supplies, water supplies in urban areas, urban/service centre water supplies, sewage disposal programme, land reclamation, minor irrigation, flood protection, integrated development programme, water quality and pollution control, water surveys and planning, and water conservation.

The goals of water development and management addressed in the National Master Water Plan (NMWP) include i) providing potable water and controlling sewage and pollution to reduce disease and to increase available labour and energy for productive work, ii) developing the hydroelectric power potential to increase the productivity and the personal comforts of the citizens, and iii) managing and conserving the land and water resources of Kenya, thereby increasing the national agricultural production. The NMWP is used in all water related projects in recent years and, therefore, it should be regarded as a guideline for formulating any development plan involving water resources.

Institutional set-up

There are many institutions involved in various fields of water resources development and management. The Ministry of Water Development (MOWD) has the primary responsibility for planning, development, operation and maintenance of public water supply, sewage disposal and pollution control. However, most sewerage projects are implemented by the local governments such as municipal councils through the Ministry of Local Government. Irrigation projects are mainly implemented by the agencies such as Provincial Irrigation Unit and National Irrigation Board of the Ministry of Agriculture, and MOWD has also taken a responsibility of minor irrigation schemes. Flood control projects have been undertaken by MOWD in some disaster-stricken areas. MOWD provides technical services to other ministries, agencies, and local governments in water supply and sewerage. Such ministries and agencies include the Ministry of Health, the Ministry of Environment and Natural Resources, the Ministry of Lands and Settlement, the Ministry of Energy, and the Kenya Power and Lighting Company.

At a local level, provincial and district headquarters of MOWD take responsibilities for water development; and provincial water officer and district water engineer represent the Ministry in each province and district. The Lake Basin Development Authority, which encompasses fifteen districts in three provinces, was established as a development coordinating agency as well as an implementing agency to undertake some large scale projects such as hydropower development and basin drainage. According to the Lake Basin Development Authority Act, the Authority has thirteen functions altogether, of which many functions are related to water resources management and development.

As a result of the recently emphasized district focus, each district is taking greater responsibilities in proposing district-specific projects and executing them. MOWD selects water supply projects from a list of projects prepared by DDC considering the population not served with water. However, a capacity of district headquarters of MOWD is so limited with respect to staff, facilities and fund that the performance of project proposals and implementation has not been adequately considered, although the capability of district water office is slowly improving.

Functions and roles of various agencies are partly overlapping, particularly for water supply and irrigation. It seems desirable to establish functional demarcation among different agencies; however, if such a change is deemed unlikely, coordination among them have to be sought.

Legislation

Water in Kenya belongs to the nation; thus with a few exceptions, water use requires a permission of the Kenyan Government. The legislation regarding such a matter can be found in the Water Act which deals with conservation, control, apportionment, and use of water resources in Kenya. It also describes the functions of MOWD. A permission for water abstraction from any source of water is issued by the Water Apportionment Board of the Water Law Section of MOWD. The Water Act defines an order of priority for water abstraction, which is supposed to reflect the government policy. It is in the order of domestic water, agriculture, industrial, and power generation. Other water related legislative provisions are also found in Agriculture Act, Health Act, Chief's Authority Act and others.

In the field of water supply, the Water Act, the Local Government Act, and the Public Health Act provide the legal framework. Based on the Water Act, MOWD holds a primal responsibility of supplying water to rural and urban areas, except those under the jurisdiction of local governments. The Local Government Act authorizes a municipal council, which is under the Ministry of Local Government (MOLG), to undertake the supply of water; such municipalities include Kisumu, Kitale and Eldoret in the Region. Water supply in early days as guided mainly by the Ministry of Health and WHO. Ministries of Agriculture and Livestock Development, county councils and public and private institutions (such as health centres, schools, missionaries, and estates) have also developed water supply schemes. MOWD has been gradually taking over water supply schemes run by the other ministries and agencies (particularly those of county councils).

7.2.2 Water supply

(1) Traditional water acquisition

A traditional way of acquiring domestic water is still dominant in rural areas. Usually women or children fetch water from a natural stream or springs. The Integrated Rural Survey (ref.2) shows the following results as percentage distribution of households by distance to water source in dry season.

(Unit: %)

	Rift Valley	Nyanza	Western	National total
On holding	62.1	41.3	65.5	50.7
0 - 1 km	15.1	26.8	22.9	23.8
1 - 2 km	9.6	19.9	9.1	14.2
2 - 4 km	7.9	10.3	1.7	7.5
4 - 8 km	4.3	1.7	0.8	3.1
8+ km	1.0	0.0	0.0	0.7
Average distance to water source from holding (km)	2.1	1.4	1.0	1.7

The average distance to water source from holding seems to reflect the humidity of different areas : Western Province being most humid, having the shortest distance. Most of water sources, at least 80%, are traditional sources : stream, springs, well, pool, small dam and rain water; while improved water sources include piped water supply, bore-hole, protected well, protected springs and roof catchment. The dominant type of traditional water source depends mainly on area: e.g.people in wetter areas use springs while those in drier areas use streams, rivers, and wells.

(2) Population with improved water supply

The NMWP (ref.31) estimated the rural population being served by safe or improved water supply as 13% of the Kenyan rural population in 1977. Similar estimates are 15% in 1980 ("World Water '83", 1984), and 16% in 1985 (ref.17).

In the Lake basin in particular, it is estimated that 5% of Western Province rural population is served with piped water supply (ref.33). In the Nyanza Province, an estimate of both rural and urban population having access to improved water supply is 18%, of which 50% depends on piped water and is considered to be mostly urban population (ref.5). Therefore, rural population served by piped water supply would be similar to that of Western Province.

The Integrated Rural Survey shows the following percentage distribution of households by source of water and season for the three Provinces in the Region.

(Unit: %)

	Rift Valley		Nyanza		Western		National total (rural)	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Stream	43.0	48.6	48.7	52.8	25.7	26.3	42.4	47.8
Spring	17.3	16.4	20.2	18.5	33.1	33.1	15.9	14.9
Well	10.1	9.2	2.0	1.4	27.0	26.2	12.3	13.2
Piped	15.1	15.0	8.3	8.1	1.8	1.8	8.8	14.9
Other	14.5	10.8	20.8	19.2	12.4	12.6	20.6	9.2

These statistics differ from the estimates mentioned previously, but seem to agree with them on the order of magnitude. It may be concluded that the rural population actually served by piped water is more or less 5 to 10% in the Lake basin as a whole.

(3) Implementation and operation of water supply projects

District Development Plan 1984/88 of each district explains past activities or performance of water supply projects and existing water supply facilities. Table 7.12 includes information obtained from the Plans, such as implementation rate of water supply projects in the previous development plan period (1979/83), number of water supply facilities and boreholes as well as major problems with regard to water supply. The type of information may be different among districts.

Table 7.12 shows that the implementation rates of overall water sector projects range from 25-75% and 50 % on the average, and the rate of utilization of the operational water supply facilities are high due mainly to population increase. The problems associated with implementing water projects and operating water supply appear to be common among most districts. These problems include limited capacity of MOWD to carry out surveys and designs of approved water supply projects, limited budget for recurrent and development expenditure, frequent mechanical breakdown due to lack of proper maintenance and lack of supplies, over utilization of facilities due to population increase, slow implementation of self-help projects, and many water supply facilities not operational.

According to the final report of the Lake Basin Shallow Wells Pilot Project (ref.9),a field study carried out in Nyanza Province in 1982 revealed that about 80% of the existing rural piped water supply systems were out of order and some of them had been out of order for some months or even some years.

(4) Piped water supplies under operation

The inventory of existing piped water supplies has been made by the study team. Information with regard to all the water supply systems in districts was requested to district water engineers of 15 districts in the Region. There were some districts where requested information was not available. Most of the information obtained from district water engineers are those of water supplies run by MOWD. The information was organized and presented in Table 7.13. The table includes the name of each water supply system, category, operating agency, name of service area, kind of water source such as a river or borehole, kind of treatment, system capacity, actual production, service population, served area, number of connections, total yearly water production, yearly water production accounted for, percentage of domestic use, per-capita consumption, water tariff, yearly revenue, yearly operation and maintenance cost, total population of a served area including unserved people and information with regard to a system expansion (if it is planned) such as expansion cost, expanded total capacity, planned service population after expansion, and sufficiency of present source of water.

Major piped water supplies under operation in South Nyanza District are Homa Bay, Isebania, Kendu Bay, Kiabuya, Kochia, Macalder, Magunda, Mawego, Migori, Ndhiwa, Obware, Oyugis, Rongo, and West Karachuonyo (ref. 12). Several institutional small scale water supplies are not included in this list. Population coverage and other details of these water supplies should have been revealed by the Lake Basin Rural Domestic Water supply and Sanitation Programme.

The number of water supplies amounts to 106 systems for 11 districts. Some water supplies produce less water than their capacity indicating incapability of a system to produce water at its full design capacity due probably to mechanical and budget problem. Other water supplies produce more water than their capacities. In this case, a water demand is likely to be higher than a production capacity. Most of present water sources have sufficient amounts of water, as indicated in the table, even when a capacity expansion is planned.

More than 95% of water produced is used for a domestic purpose. This is true not only for rural water supplies but even for urban water supplies. The per capita consumption is approximately 60*l* /day. Some water supplies indicate a per capita consumption of less than 10*l* /day. Such a consumption level seems quite low, and thus it implies that the population actually served is much more than design population of the water supply and people depend on the water supply only for a drinking purpose and other sources for other water uses.

A water tariff is in the range of approximately Kshs. 1 to 3 and Kshs. 2 on the average. A management aspect of water supply is shown by the amount of revenue and operation and maintenance cost. The table indicates most of water supplies require more money for operation and maintenance than the amount of revenue. For some water supplies, this is the case even when water charge is collected for all the water produced. Such a fact dictates necessity for in tariff increase or some kind of rationalization in operation and maintenance of water supply. Some measures of rationalization are listed in subsection 7.5.1.

(5) On-going major rural water supply projects

<u>Rural Water Supply Development Project in Western Province</u>

This project was initiated in 1981 under a cooperation agreement between Kenya and Finland governments. Data collection on available water resources and a water supply development plan were completed in 1983. Area covered by the project is 3,650 km^2 of rural area in Western Province (total area: 8,360 km^2) and estimated population in the area was 0.81 million in 1982 and will be 1.68 million in 2005. It is expected that the project will continue for the period of 20 years with the target of providing handpump wells for more than 90% of rural population in the project area.

The project components include seismic sounding, water production by means of hand-dug wells, borehole wells, spring protection, design and construction of piped schemes, rehabilitation of existing piped schemes, training in many fields, and the study of operation, maintenance and revenue collection. The achievement of the project from November, 1983 to September, 1985 is represented by 293 hand-dug wells, 190 drilled wells, and 183 cases of spring protection (ref.34). Most of the wells were fitted with handpumps, either Nira or India Mark II type.

Most parts of the project area have abundant groundwater resources. Groundwater resources are quite evenly distributed throughout the area. Shallow groundwater resources are especially good in the Kakamega district. Groundwater quality is generally good. Groundwater seems to be a promising source of water practically all over the project area (ref.33).

Lake Basin Rural Domestic Water Supply and Sanitation Programme

This is a five-year programme in the Nyanza Province started in 1984 following the Lake Basin Shallow Wells Pilot Project implemented from 1982, supported by the Netherlands government. Nyanza Province has a land area of 12,525 km^2 consisting of four districts with a total population of 2.64 million (1979), out of which 2.4 million people live in the rural areas.

During the pilot phase, it was found that there were 450 dug wells under the Ministry of Health crash programme in the past, and 200 to 250 wells constructed privately mostly equipped with locally made handpumps, of which less than 10 percent were operational. In the same phase, 41 handpumps were installed at drilled or dug wells. The water quality of shallow wells was found to be generally good except in a part of the Kano Plain and around the Lake, where high salinity levels were encountered.

Implementation target of the current programme is 750 water points, which are intended to serve as a first order network of reliable sources in the most needy areas of Nyanza Province. With this network, the water supply for approximately 300,000 people (or additional 10% of the present population of Nyanza Province) will be improved.

Under the current programme, about 100 hand-dug wells and 81 machine drilled boreholes have been constructed by February 1987, and a large number of hand-dug wells are still under construction. Approximately 80% of wells constructed to date produce permanent or non-intermittent groundwater (ref.55).

Piped water supplies under implementation and planning

The data of water supplies under implementation and planning were requested by the study team to district water engineers of 15 districts in the Region. For some districts, such data were not available. Table 7.14 presents the data obtained from 11 districts. The table includes the name of water supply, category, funding agency, name of service area, source of water, kind of treatment, total cost, supply capacity, service population and area, present status and expected completion year. Piped water supplies under construction and design in South Nyanza district include those of Kochia/Migori-Kihancha, Kanyaluo, Ndhiwa/Ropedhi, Luanda, Got Kojowi, Karungu, Kehancha, Obera, Mbita/Gembe Hills, Oyani, Mulo, Nyandiwa, Wang' Ochieng, and Sena (ref. 12).

The water supply projects which are already under construction will have to be completed; however, those which are still under planning should satisfy the strategy of water supply programmes and screened by the criteria indicated in subsection 7.5.1.

People's participation and education

People's participation has been recognized to be of primal importance for both a piped water supply and particularly a handpump water supply.

The Rural Water Supply Development Project (RWSDP) in Western Province cited previously has been showing achievement in community involvement in its project implementation. The RWSDP established a systematic approach to involving various levels of people starting from PC, DC, DO, MP's, ministries concerned, NGO's, chiefs, assistant chiefs, councillors, ministry's extension staff, women's groups, and local leaders down to the level of local people. The systematic community involvement for well development consists of initial contact with various levels of people, siting of a well, an establishment of a well committee where a well attendant is selected and money collected, construction of a well and spring protection, community training by a training unit and mobile cinema unit, and education at a school. Established well committees were 203 from April to June 1984, and 346 from April to September 1985.

The training and education programme in the RWSDP project covers such fields as water related diseases, home hygiene and sanitation, by-laws and behavior at a well site, community participation with an emphasis on self-reliance, parts of handpumps and mode of function and faults, reporting on pump performance, and maximum utilization of water (ref.34).

The pilot phase of LBDA Shallow Well Project did not employ a community involvement approach; however, the report of the Socio-Cultural Investigation of the Project (ref.5) does recommend "a deliberate effort to involve the community" and that "LBDA should organize water education programmes that impress on the villagers the value of safe and clean water."

Under the current LBDA programme in Nyanza Province, the Community Development Department staffed by 20 people is involved in a socio-economic survey, community development, sanitation and health education, and monitoring and reporting.

(6) Municipal water supply

Kisumu water supply

The present Kisumu municipality consists of the old town area with population of 43,000 and peri-urban area with population of 81,000, which together amount to population of 124,000 as urban dwellers, a rural area with population of 12,000 commuting to urban area and a rural area with population of 53,000 being engaged in agriculture, which combined amount to 65,000 as rural dwellers. The total population of urban and rural areas is 189,000 in 1985 (ref. 23). The old town is nearly saturated with the present population, and future population growth is expected to take place mainly in the peri-urban areas.

The Kajulu waterworks, the first conventional treated water supply in the Region, was constructed in 1920's. It comprises run-of-river intake at the Kibos River, and a treatment plant with the capacity of 1,800 m^3/day. In 1956, a new intake was established at Hippo Point of the Lake Victoria as well as a new treatment plant; the Lake intake and treatment system have been expanded in 1964, 1968 and 1982 to keep up with increasing demand; the Lake system capacity is 15,100 m^3/day at present. Ground storage has been developed with the total capacity of 6,821 m^3 at Kibuye and the capacity of 2,273 m^3 at Watsons Bank. Some 87 km of distribution main have been laid out and are in service in Kisumu. The reticulation system is inadequate in some areas of the high ground adjacent to Watsons Bank, in large areas around Ondiek housing estate and Ondiek road, and at the extremes of distribution system especially at and beyond the Airport industrial estate(ref. 23).

Present water consumption by sector is as follows.

(Unit: m^3/day)

Domestic		Institutional	Commercial	Industrial	Total
House connection	Yard tap or Kiosk				
5,687	2,833	2,572	1,114	4,600	16,806

Service population is 31,000 people for house connections and 88,000 people for yard taps and kiosks.

Eldoret water supply

Eldoret is the second largest town in the Region. The town started to grow as an industrial center in the last decade and it is still growing. The population of the municipality was 68,000 in 1985.

Piped water supply has been provided for the town since 1923. The Eldoret Municipal Council embarked upon improvements to the water supply systems with the construction of a dam at the confluence of the Ellegirini and Sosiani Rivers in 1961/62, subsequently known as Two Rivers Dam, and also with the completion of the Sosiani water treatment works in the same year. The installation of the sewerage system and sewage treatment works in Eldoret West was also completed.

In the past, various studies were conducted such as Eldoret Water Resources Investigation (Preliminary Report of September 1980, and Final Report of April 1980), Engineering Study of Eldoret Two Rivers Dam (August 1981), and Eldoret Water Supply - Phase II (ref.21). The Eldoret Water Supply Project was divided into two phases: phase I is for the demand up to 1981/82 and phase II is for the demand of 2010, the latter corresponding to the ultimate development of Eldoret town.

Phase I was completed and the existing capacities of various works are 2,300 m^3 /day at Ellegirini intake and 7,200 m^3/day at Two Rivers Dam for water sources, 18,400 m^3/day for water treatment works, and 18,800 m^3 for storage reservoirs. In a wet season, water can be supplied with the maximum capacity of water treatment, but in a dry season, only 9,500 m^3/day can be provided at present. Estimated water demand (domestic and industrial water demand) of 1980 was 19,530 m^3/day (ref 21). The municipality experienced severe water shortage in 1984 with water rationing of a few hours a day.

In order to cope with water shortage of Eldoret town, a dam is under construction at the upstream of Ellegirini intake. The dam has a safe yield of 9,900 m^3/day and will be completed in 1987. After the completion of Ellegirini dam, the total safe yield will increase to 19,400 m^3/day. The completion will alleviate water shortage but the total supply capacity will still be less than the water demand of 26,240 m^3/day of 1985 estimated by the study (ref.21). It may be necessary to revise such a demand estimate since it appears rather high.

Other towns

Water supply for other towns such as Kitale, Bungoma, Kericho, Migori, and Siaya has been studied and planned recently. The present conditions of water supply in these towns can be found in existing study reports (refs.22,25,27,30 and 36). Table 7.13 presents the current conditions of water supply in urban centers.

7.2.3 Sanitation

As indicated in the District Development Plans (ref.24) and the National Development Plan, some municipalities plan to construct sewerage systems or to extend service areas. However, the priority of sewerage construction appears to be lower than water supply and the performance of existing sewage works has been generally very poor. Existing sewage treatment works include those in Kisumu, Eldoret, Kericho, Kisii, Bungoma, Webuye, Kakamega, and Homa Bay.

Except Nairobi and rural service centres, the sewerage projects in Kenya are implemented by municipalities through the Ministry of Local Government, where MOWD provides technical advises. The Pollution Control Unit of MOWD inspects the performance of treatment works and monitors the domestic effluents. Such an inspection indicates that the Bungoma sewage work is overloaded, the Kakamega sewage work is poorly maintained, and the Kisumu sewage work is sometimes not operational (ref. 49). The inspections by MOWD have not been sufficient or frequent enough to control the performance of such sewage treatment works.

Kisumu sewerage

According to the Kisumu Water Supply and Sanitation Study (ref.23), 87% of the population in the old town is served with water borne sewerage, while low density areas are served by septic tanks. A small percentage within high density areas use low cost sanitation method such as bucket latrines or pit latrines.

The existing sewerage is divided into two sewerage systems by the ridge through the town: one flows to the Nyalenda waste water stabilization ponds from the southeast section of the town, and the other to the conventional treatment works from the northwest section of the town, where sewage from four low lying areas in this section is pumped into the system.

The conventional treatment works provide preliminary, primary and secondary treatment to domestic, commercial, and industrial waste water. After the currently undergoing rehabilitation, the mean effluent quality from the system is expected to be less than 75 mg/l for BOD and 90 mg/l for SS. However, the effluent quality is still below the standard. The Nyalenda waste water stabilization ponds provide preliminary, secondary, and tertiary treatment to inflow predominantly domestic in origin. The ponds will require desludging by 1995. The estimated present sewage flows are 4,200 m^3/day from residential, 1,200 m^3/day from institutional, 900m^3/day from commercial, and 3,600 m^3/day from industrial sectors, the total sewage amounting to 9,900 m^3/day.

The traditional mode of on-plot sanitation in urban area is either septic tanks or bucket latrines, the former associated with high installation cost in low density housing area, and the latter with low installation cost in high density housing area. Milimani residential areas in the old town are served by septic tanks. In the peri-urban area of Pandipieri, Nyalenda, Manyatta, Migosi and Kanyakwar, pit latrines are the only on-plot sanitation mode in use (ref. 23).

Other towns

The operation and maintenance of urban sewage treatment facilities in other towns have been found to be inadequate by several studies (ref. 6,41 and 44). None of sewage treatment produces effluent which meets a government water quality standard. Most of such facilities, except Homa Bay's facility, require rehabilitation and expansion. More details of the present conditions of urban sewerage facilities are discussed in the section of water quality (subsection 7.2.6).

Information with regard to urban sanitation was requested by the study team to district public health officers. Such data were not available for most of the districts in the Lake basin. Sporadic data were obtained for some towns. Kakamega town, Busia township, Bungoma town and Webuye township have oxidation ponds serving populations of 44,000, 25,000, 25,000 and 18,000 people respectively. The first three towns have a problem of blockages in reticulations at times and the Webuye system experiences an over load frequently resulting in low water quality of effluent. In Kitale municipality, approximately 40,000 people are served by sanitation facilities, of which 60% are served by water born sanitation and 40% by pit latrines.

Rural sanitation

Information was requested to district public health officers for rural sanitation. Such information was not available for most of the districts in the Region. In the Human Resources Sector report, rural sanitation is touched on and the percentages of households without sewage facilities are presented in a table summarized from the data of CBS survey of 1982. Only a few percent of rural population utilize ventilated improved pit latrines septic tanks.

7.2.4 Irrigation

Most of the irrigation schemes in Kenya are controlled and managed by Irrigation and Drainage Branch of Ministry of Agriculture (MOA) or National Irrigation Board (NIB) of MOA. Irrigation and Drainage Branch performs their services through subordinate offices in each province and district, mainly managing small scale irrigation schemes. Large scale irrigation schemes are under the control of NIB. In the LBDA region, there are three NIB's national irrigation schemes of 2,010 ha in total area and a number of small scale irrigation schemes of about 1,400 ha.

(1) NIB schemes

The three schemes of NIB's are Ahero, Bunyala and West Kano. Ahero scheme has 840 ha mainly for paddy in the area on the right bank of the Nyando River near Ahero market. Four pumps lift about 19 million m^3/year from the Nyando River and about 30 % of irrigation water is drained back to the Nyando River by gravity.

Bunyala scheme has 200 ha of paddy field located along the left bank of the Nzoia River. Irrigation water of about 5 million m^3/year is pumped by four pumps from the Nzoia River. Drained water flows back into the Nzoia River by gravity.

West Kano scheme of 970 ha is located along the Winam Gulf of the Lake. About 60 % is paddy and 40 % is sugarcane. Irrigation water is pumped from the Lake by four pumps. Volume of water pumped into the scheme is about 15 million m^3/year.

(2) Small scale irrigation schemes

A number of small scale irrigation schemes are now operating mainly in the Nyanza Province, developed and supervised by the Provincial Irrigation Unit (PIU) of Irrigation and Drainage Branch of MOA.

As shown in Figure 7.13, present PIU's schemes of about 1,400 ha are scattered in the LBDA region. Two schemes with total area of 9 ha are irrigated by pumped water from the Lake and other schemes with total area of 1,390 ha use river water for irrigation. The sizes of these small scale schemes range from less than 1 ha to some hundred ha. Water consumption of these schemes are estimated at 1.0 million m^3/100ha/year for vegetable schemes and 1.6 million m^3/100ha/year for rice schemes. About 21 million m^3/year of water is withdrawn from the river for rice or vegetables and about 0.1 million m^3/year of Lake water is pumped for vegetables or other horticultural crops.

(3) LBDA schemes

There is a LBDA irrigation scheme other than NIB and PIU schemes. Yala Swamp Agriculture Development Project is located in the Yala swamp area with 17,500 ha potential land. Currently, 2,300 ha (Area I) is in operation but less than 100 ha is irrigated. About 39 MCM/year of water will be diverted from the Yala River to the field by gravity when the whole Area I is irrigated.

Area II (9,200 ha) and Area III (6,000 ha) are expected to be developed within the next decade. Area II can be developed and reclaimed by gravity irrigation and drainage. Area III will require protection dikes and pump drainage, and therefore high costs, as the ground level of Area III is lower than the Lake water level. The possible negative environmental effects would also have to be carefully examined before a decision is made to reclaim Area III.

7.2.5 Flood protection

The plains at the downstream reaches of the Nzoia, Nyando, Sondu and Kuja Rivers are susceptible to floods due to the limited flow capacity of river channels caused by the small gradient of each river near the mouth and backwater from Lake Victoria. The development of Kano Plain is especially restricted by periodic floodings of the Nyando and other rivers such as the Kibos and Oroba as well as by the insufficient water in dry months.

(1) Kano Plain and flood

The following information has been adopted mainly from two reports: Lake Basin River Catchment Development-River Profile Studies (Lotti & Associates, 1985; ref.7) and Pre-investment Study for Water Management and Development of the Nyando and Nzoia River Basins, Nyando River Basin Pre-development Report (Italconsult, 1983; ref.32).

Kano Plain

The Kano Plain of 70,000 ha can be classified into the following areas according to morphological characteristics : high-lying areas of 22,000 ha accounting for 31%, low-lying areas of 16,000 ha accounting for 23%, which requires main and secondary drainage system, low-lying areas of 25,000 ha accounting for 36%, consisting of 14,000 ha where flooding lasts shorter than 2-3 days and 11,000 ha where flooding lasts longer than 3-5 days, permanent swamp area of 7,000 ha, which corresponds to 10% of the Kano Plain. This classification is depicted in Figure 7.10. The figure shows the formation of large swamps in the central part of the Kano Plain (Central Kano Swamp), along the coast of Lake Victoria (Coastal Swamps), and at the mouth of the Nyando River (Nyando Swamp). It also shows that areas along the Kisumu - Ahero - Sondu road is liable to flooding; the flooding starts several kilometers upstream of the main road and extends downstream of the road as far as to the Lake shore.

Most of the Kano Plain, about 60,000 ha, is utilized for agricultural production as farm lands or pasture lands but not intensively. Besides swamps, flooded areas (with more than 3-5 days) of 11,000 ha is used for pasture lands, which correspond to 46 percent of the total pasture area or 24,000 ha in the Kano Plain.

Major rivers and other natural factors

Major rivers flowing through the Kano Plain are as follows:

River	Nyando	Kibos	Lielango	Nyangeta	Oroba	Nyaidho	Awach	Asawa
Catchment(km^2)	3,450	241	82	32	111	231	344	71

The Nyando River is the major river flowing through the centre of the Kano Plain. Two main branches of Nyando River are Nyando itself originating from Kericho area, and Ainomotua draining the northeastern side of the Nandi Escarpment, which makes substantial contribution to Nyando flood flows. Kibos river basin is located almost entirely at the upstream of the Nandi Escarpment. Water courses entering into the Central Kano swamp are Lielango, Nyangeta, and Oroba, which flow down the Nandi Escarpment between the Kibos and Ainomotua. Rivers between the Nyando River and Nyakach Escarpment are the Asawa, Nyaidho and Awach-Kano. These rivers in the Kano Plain are characterized by very small longitudinal gradients of the river beds near the mouth and small cross section areas, both of which lead to very low flow capacity, resulting in the stagnation of the surface water flow.

High intensity rainfall, low water permeability of cotton soil predominant in the plain, soil erosion causing siltation in a river channel near Lake Victoria, and an incidental rise in the water level of Lake Victoria are the other major factors causing frequent flooding.

Over the period of 1899 to 1960, mean water level of the Lake was 1,133.65 m above the mean sea level and over the period of 1961 to 1978 the Lake water level was 1,134.95m, where the difference was 1.30 m. In the latter period, the water level exceeded in 1966 the maximum daily water level of 1,136 m (ref. 32). The abnormal rise in the Lake water level since 1961, which is most likely attributable to abnormal rainfall on the Lake surface still persists (ref.52). The elevation of 1,136 m is therefore considered to be the highest Lake water level for the flood protection work and land development as well; the contour line of 1,136 m lies as far as about 7 km from the present Lake shore line. The distance from the Lake shore to the contour line varies depending on locations and it is maximum at Nyando Swamp.

<u>Population</u>

The total population in the Kano Plain was 126,000 in 1979 and it will be 180,000 in 1990 according to the CBS projection (ref.1). Population density varies from 135 persons/km^2 in S.E. Kano location and 259 persons/km^2 in a part of Kisumu municipality, and 179 persons /km^2 on the average. Four locations of N.E. Kano, W. Kano, S.E. Kano, and N. Nyakach and a part of Kisumu municipality exist in the Kano Plain; W. Kano and S.E. Kano locations are more seriously affected by flooding. Nearly half the population in the Kano Plain is more or less affected by flooding (ref. 51). This Plain, however, has been an immigration area due to its high productive potential.

<u>Flood damage</u>

In March 1925, the Region had exceptionally heavy rain, and many houses were abandoned and people settled in the upper lands. After a few years, people came back to the Lake shore and the life returned to normal. The biggest trouble was in early 1961 when the famous "Uhuru Rains" drove people from the Lake shore to Miwani and other areas; the majority reached Lambwe Valley in South Nyanza, where many people met even a worse luck, i.e., sleeping sickness, and died. Since 1961 the Lake level has remained high as described previously.

Damages caused by floods are damages to crops, buildings, and houses, interruption of main roads (Kisumu - Ahero, Ahero - Kericho, Ahero - Sondu) and minor rural roads, and sometimes loss of human and livestock lives. Agricultural damages caused by impeded drainage are reduction in agricultural production, loss of harvest, temporary inaccessibility to cultivated lands, and permanent inaccessibility to some cultivable lands. Sanitary conditions after flooding cause health problems such as rampant diseases.

An attempt was made to estimate a damage-frequency relation based on flood discharge record in Table 7.5 and the crop production value estimated in the Pre-Investment Study (ref. 32). The relation of damage - frequency has been estimated as US$ 1.1 million for 4-year recurrence flood and US$ 6.7 million for 40-year recurrence flood. This estimates should be looked only as indicative since the estimate was made based on the following assumptions:

i) Total cropped area of some 30,000 ha is inundated in every 40 years;
ii) An annual production value estimated to be KShs 51,837 x 10^3 (ref.32) from the cropped area (at the price level of 1979) was adjusted to US$ 5,540 x 10^3 (assuming the price escalation of 8 percent per annum from 1979 to date and an exchange rate of US$ 1= Kshs. 16);
iii) Some 20 percent of the annual production value is assumed equivalent to the losses accrued from others such as traffic interruption; and
iv) A flood of 4 year recurrence period inundates 10,000 ha (based on an interview by the study team), and a half of it is cropped areas damaged.

Flood discharge of Nyando

Flood discharge estimate is of particular importance for planning Nyando flood protection measures. Due to relatively short record at the Nyando River gauging station and also due to different rating curves used by different people and agencies, there exist great confusions and argument with regard to discharge estimates and resulting flood flow estimates of different recurrence intervals.

Flood flows were discussed in Section 7.1 and the historical maximum for Nyando River is estimated by the present study as 377 m3/sec (Table 7.5) occurred in 1961; however, the MOWD estimate is 707 m3/sec. Flood flow estimates are also different as shown below:

(Unit : m^3/sec)

Recurrence interval	Present study	MOWD	Italconsult	Lotti	Hydromet
Order*	5	3	2	4	1
25 years	362	605	650		450
50 years	411		750	514	524
100 years	459		850	580	598

* The number accords with the chronological order of each estimate.

The estimate by the present study is the lowest and that of Italconsult the highest. Although the present study utilized the most updated data, it may not offer sufficient information to convince everyone to agree on the value estimated. In order to reach an agreement on the estimates for different agencies concerned, it is proposed to conduct an extensive hydrological study for the Nyando including flow measurement and a cross-section survey, then to come up with one rating curve instead of many rating curves.

(2) Past flood protection work of Nyando

Government efforts on Nyando River flood protection started in 1961/62 by the Ministry of Agriculture and Livestock Development (MOALD), and a dike was built on harambee basis, but washed away later. In 1973, MOALD constructed a dike immediately downstream of Ahero bridge to Apondo; however, many parts were destroyed by pedestrians and animals and cut off later by floods.

For other rivers in Kano Plain, various government agencies undertook flood protection in 1970's (ref.10) ; National Irrigation Board constructed dikes around the West Kano Irrigation Scheme of 900 ha from 1975 to 1977 ; the District Development Committee of Kisumu district implemented several flood protection projects between 1975 and 1979 including Mayenya, Kabonyo, and Bwanda flood protection projects.

Currently, the Ministry of Agriculture, through Smallholder Rice Rehabilitation Programme, is constructing a 5-kilometre dike on the southern boundary of Kano swamp to control the flooding of 10-year recurrence interval to protect Kore rice schemes and also control the water entering the Miriu River form the swamp. The small-scale irrigation project of Provincial Irrigation Unit is engaged in river training works of Awach Kano on both the eastern and western side of the Kisumu - Kisii road.

These past flood protection efforts appear to be incomprehensive, uncoordinated and ad hoc, as they were made merely to protect particular government sponsored development projects; therefore more comprehensive and coordinated efforts will be required based on a long-term plan of Kano Plain development.

(3) On-going flood protection project in Kano Plain

A study by Italconsult recommended a flood protection plan of Nyando River in 1983 with design discharge of 750 m^3/sec of 50-year return period. The MOWD adopted the plan and designed flood protection dikes (with some changes from the Italconsult preliminary design) for design discharge of 650 m^3/sec of 25-year return period.

The MOWD started a construction project in 1985. The project consists of three phases. The first phase is to construct a dike of 12 km from Ahero bridge downstream up to the 1,136 m contour line, the second phase is to construct a dike of 8 to 10 km to upstream of Ahero bridge and the third phase is to strengthen the dikes of the first and the second phase for a 750 m^3/sec flood flow. Such a phasing is in line with the idea of LBDA (ref.10). The dikes designed by the MOWD are 2.7 to 3.0 m high and 4 m wide at the top of dikes, and the distance between left and right side banks is approximately 200 m at Ahero and 500 m at swamp areas.

Utilizing equipment and machinery of Kshs. 20 millions, it is expected to take five years and cost Kshs. 18 millions for the first phase and four years and Kshs.14 millions for the second phase, amounting to over Kshs. 50 millions in 10 years. The construction in 1985 completed 150 m but none in 1986 due to failure in machinery.

The Ministry has a plan to extend the flood protection to Kibos and Lielango Rivers, and also to construct drainage canals in swampy areas, expected after the completion of the Nyando flood protection dikes for a period of another 10 years. The completion of the whole project is said to depend on the fund availability and smooth running of machinery.

(4) Flood protection in other rivers

Nzoia River

Before the embankments were constructed by the MOWD, it was reported that floods of the lower Nzoia occurred once in every two years and approximately 1,000 families in 60 km^2 were forced to leave their homes in a major flood. Floods of the lower Nzoia River used to occur along the 30 km reach between the river mouth and Luamba. In 1965, a short dike along the left bank of the river was constructed to protect Bunyala Pilot Irrigation Scheme against approximately 25-year return period flood. In 1970, another dike was constructed further downstreams of the Bunyala Irrigation Scheme, but no significant dike had been constructed on the right bank.

In 1976, the Water Department studied possible solutions to the Nzoia floods and selected a solution of constructing two different heights of embankments for the left and right banks against 25-year flood and 10-year flood, respectively. This is because there is more developed agricultural land and denser population on the left bank than the right bank.

The construction of embankment started in 1976 and completed in 1986, with major work in between 1978 and 1984; on the right bank, the dike extends from Lumbwa to Munzojo hills, and on the left bank to Lugari. The dike is 4.5 m wide and 2.5 m high on the average. The construction was completed for the distance of 16 km x 2 (right and left banks) and the embankment of 700,000 m^3.

The dikes of right bank were built by heavy machinery with proper compaction, and thus they are very strong; however, the dikes of left bank were built by simple machinery and manual labour resulting in limited compaction. Because of this, the left banks are now subject to erosion and require rehabilitation work. Another problem is a drainage requirement caused by the embankment especially of the right bank. Attention will have to be drawn to the possible increase in the scale of floods which may occur in the future if swamps in the valley bottom of upper Nzoia are developed and changes in land use take place.

Sondu River

Agricultural production activity in a portion of Nyakach Plain located near the river mouth of the Sondu is low due to periodic flooding. The construction of Magwagwa reservoir, which will have a surcharge volume of some 100 million m^3, makes Nyakach Plain free from flooding. Furthermore, irrigation water supply from the Sondu and Magwagwa reservoirs will changes the entire Nyakach Plain into a land with high agriculture production.

Kuja River

It is necessary to provide flood protection measures in order to develop the swamp area extended along the lower Kuja. Dike construction is conceived as an appropriate measure, since floods in the Kuja/Migori River show characteristics of a long duration and a large volume as seen in Figure 7.6, and consequently the construction of Namba Kodero, as discussed in the subsequent Section 7.5 besides the existing Gogo Falls reservoir, may not provide an enough control volume for floods.

7.2.6 Water quality control

(1) Water quality control of Kenyan Government

Institutions

The most comprehensive legislation of water quality control is the Water Act. The Water Act gives the Water Apportionment Board the power to lay down standards of effluent quality, to determine whether or not any sewage and effluent from any works is harming the beneficial use of water, and further may order the removal of harmful matters (ref.46). The Public Health Act is the legislation to enable local authorities to control the quality of effluent discharged to their sewer systems. MOWD , LBDA and Fisheries Department are also responsible for water quality monitoring and control.

MOWD sets effluent standards for various industries such as a sugar industry, and a paper industry. The Water Act requires all coffee industries install water recirculation systems and no effluent be returned to any water course. Some industrial effluent standards can be found in literature (refs.6 and 44). Public sewers accept effluents from various kinds of industries and institutions. Standards for effluent entering public sewers are set by MOWD (refs. 6 and 44). Ambient standards of the World Health Organization are the general guideline followed by MOWD (ref. 44).

Efforts of water quality monitoring and control

Efforts on water quality monitoring have been made in the past mainly by the Water Quality and Pollution Control Section of MOWD. For the rivers in the LBDA region, several reports have been published on water chemistry (refs.37 and 38). A Workshop on the Quality of Water Input to Lake Victoria was held in 1982 and some case studies were conducted on industrial effluent associated with the workshop (ref. 16). Winam Gulf Baseline Study was conducted in 1984 and 1985 as a joint operation among several interested organizations in Tanzania, Uganda, and Kenya including LBDA and Kenya Marine Fisheries (ref.15).

Besides these, other workshops and surveys have been held or conducted in the past, reflecting the Kenyan Government's concern for the quality of rivers and lakes, particularly the Lake Victoria. Such efforts are described in a literature (ref.13). It seems that water quality study and monitoring have been performed in an ad hoc and uncoordinated manner. Various agencies and institutions have made water quality studies, but the collected data and knowledge have not accumulatively utilized or evaluated.

In spite of these efforts in water quality monitoring, water quality control has not been effectively enforced by the Kenyan Government even when industrial effluent and treated sewage are found below standards. This is mainly because the Water Act does not provide a sufficient legal support to MOWD and does not effectively impose a penalty to those who violate the effluent standards. However, according to an MOWD official, the act has been revised and sent to Attorney General for presentation and discussion in the Parliament.

(2) Sources of water pollution

Municipal sewage

Sewage from municipalities and towns in the LBDA region is a major source of water pollution in rivers and the Lake. Towns of Kisumu, Eldoret, Kericho, Bungama, Kakamega, Kisii and Homa Bay have either sewage ponds, lagoons, or conventional treatment plants. Several surveys and reports are available on the conditions of these sewage works (refs. 6, 41 and 44).

The Effluent Monitoring and Pollution Control Team of the LBDA made visits to five sewage works and collected samples (ref. 6). The survey reports the following. The Bungoma sewage ponds are overloaded, show no evidence of algal growth, and BOD of discharged effluent is too high (305 mg/l). Eldoret sewage lagoons showed absence of algal growth in all the ponds and high BOD effluent of 170 mg/l. Kakamega sewage works showed a total lack of maintenance full of litters, stones, and grass in the ponds. Kericho sewage works were managed properly with BOD of 30 to 65 mg/l. Kisii sewage works had a lagoon full of sludge, litter and grass, and is overloaded. Homa Bay sewage ponds were newly constructed, but aerators have not yet been installed, and BOD was 65 mg/l. None of the treatment works produce effluent which satisfies a BOD standard of 30 - 40 mg/l. It should be emphasized that Nyalenda stabilization lagoons, one of Kisumu waste water treatment works, were found to discharge a heavy load of inorganic pollutants : 4.8 mg/l of lead and 2.9 mg/l of mercury (ref.44), both highly toxic.

It is, therefore, evident that most (if not all) of sewage works in the Region are not maintained properly resulting in effluent of low quality, and some works are overloaded.

Industry

An analysis made by subbasin on water abstraction permit data of the Water Apportionment Board indicates the following number of permits for industries (Section 7.2).

Basin	1A	1B	1C	1D	1E	1F	1G	1H	1J
No. of permits	7	70	15	16	2	18	37	11	16

The number of industries are distributed fairly evenly among basins except basins 1B and 1G which are the upper basins of Nzoia and Nyando Rivers, respectively. Subbasins of 1BE, 1BG and 1BH together have 58 permits and 1GC and 1GD together have 25 permits where tea and coffee are grown and their processing factories are located.

Many industries in the Region, such as coffee factories, sugar factories, dairy factories, agrochemical factories, textile factories, and a paper mill, are also major point sources of water pollution. Some studies report effluent water quality of existing industries in the Region (refs.6, 16, 41 and 44). An LBDA team visited various factories and found that major factories have some kind of treatment facilities except coffee factories, although most of the treatment facilities were not operated properly (ref. 6). Treated effluents were sampled and analyzed. The BOD of collected samples were 320 mg/l at Nzoia sugar factory, 40 mg/l at Mumias sugar factory, no treatment at all at Miwani Sugar Company, 195 mg/l at East African Sugar Industries, 115 mg/l at Sony sugar factory, 410 mg/l at K.C.C. Eldoret factory, 485 mg/l at Agrochemical industry (producing alcohol and cattle feeds from molasses), 290 mg/l at a textile industry of Rivatex, 135 mg/l at a paper mill of Panafrican Paper Mills in Webuye. None of them except at Mumias is within the standards set by MOWD.

BOD is not the only parameter to measure water pollution by industries. Other chemical materials including heavy metals are more toxic to environment. Two textile industries, Rivatex and Kicomi, discharge dyes which includes so many chemicals. The waste water of Panafrican Paper Mills contains heavy metals such as lead, copper, and mercury with concentration of 0.3 mg/l, 1.8 mg/l, and 0.05 mg/l, respectively (ref. 41) and the total heavy metal of 7.9 mg/l (ref.44). The waste water has to be well treated continuously ; however, cases were observed where all waste water was by-passing treatment works and flowing directly to a river (ref. 16).

Coffee factories are also widely dispersed sources of water pollution in the Region. A study gives data of effluent water quality from six coffee processing factories, indicating BOD of 2000 mg/l to 3000 mg/l, copper concentration of 0.7 mg/l to 3.4 mg/l and pH of 3.8 to 4.5 (ref. 44).

Agriculture and livestock

Major causes of non-point source pollution are human settlements, agriculture and livestock production. Human population has been increasing at a rate of 3 to 4 % annually; accordingly, livestock production has been increased, and agricultural production has also been increased by clearing forests and expanding cultivation up to river banks and mountains. Agricultural practice has been changed where more cash crops are introduced and therefore more fertilizers and pesticides are used.

These changes in agriculture cause water pollution in terms of soil erosion, nutrient, and toxic chemicals. A past survey on eutrophication and pollution load in the northern half of the Region provides useful information (ref. 41). The study indicates that tributaries draining agricultural areas have much higher nutrient levels than those draining forested subbasins -- concentration of total phosphorus and total nitrogen is nearly five times higher. Moreover, total nitrogen in tributaries draining wheat and maize belt subbasins, where fertilizers are used, is four times higher than sugarcane subbasins. The study took livestock population of each subbasins into consideration and found higher nitrogen concentration in the tributaries of subbasins with high livestock population density (although not proved quantitatively).

Effects of pesticides were also investigated by the study. A presence of methyl mercury was detected in eight subbasins of Nzoia River. Pollution loads largely of dangerous herbicide 2, 4 - D were also detected in Isiukhu and Lungusida Rivers. Levels of pesticide residue were analysed and presented in a water chemistry study for Nzoia River and its tributaries. The analysis indicates concentrations of 0.1 - 0.2 mg/l for BHC, Dielorin, and DDE and 2 mg/l for DDT. Many kinds of pesticides and their used amounts in the Nzoia river basin are presented in the study report (ref.41) including wood preservation, insecticides, herbicides, fungicides, slug and snail killers and fumigants.

It is reported that DDT is used in Ahero irrigation scheme by local farmers, which is cheaper than other recommended chemicals . Other chemicals used in the scheme are Cabaryl, Diazinon, Carbofuran, BHC and Mathion. Molluscides are used for the control of snails.

The amounts of fertilizers and pesticides used in the three provinces are shown below.

(Unit : tons)

	Fertilizers		Pesticides	
	1977	1978	1977	1978
Rift Valley	6,000	8,200	200	89
Nyanza	6,900	4,400	6	225
Western	3,400	3,200	0	33
National total	42,100	89,300	3,600	7,400

These amounts are based on a sampling survey (ref.2) and are much smaller than the amounts used in other developed countries; however, the amounts are expected to increase significantly in the future. It will be necessary to monitor the effects of agricultural chemical usage to rivers and Lake Victoria.

(3) Water quality of Lake basin waters

Rivers

Some past studies include chemical analyses of water quality sampled in the Lake basin river waters (refs. 37, 38, 41 and 44). Average BOD data sampled in July and September 1982 at a few sites away from factories for each major rivers of the Lake basin are shown below (ref. 44).

(Unit: mg/l)

	Nzoia	Yala	Nyando	Sondu	Gucha	Migori
Average BOD	118	31	125	43	108	76
Range	86-137	22-41	64-208	43	28-266	66-86

These BOD values are very high as water quality of natural rivers. BOD values should be less than 2 to 3 mg/l for rivers where water is utilized for a drinking purpose with water treatment. Considering locations of industries and cash crop agriculture in the Region, as discussed previously , the relative extent of water pollution shown in the BOD values appears to indicate the effects of industrial and agricultural activities.

Another water quality study in 1975 indicates BOD values of only 1 to 5 mg/l in the Nzoia River and its tributaries, except in the Sosiani River where 25 mg/l of BOD was measured at downstream of KCC dairy factory of Eldoret (ref. 37). A similar study indicates BOD values of 10 to 640 mg/l in the Nyando River and its tributaries (ref. 38).

Two-digit values of BOD are too high. It is said that there used to be more fish in rivers of the Lake basin coming up from the Lake Victoria. This implies the water quality in rivers of the Lake basin has been degraded. It is considered necessary to look at those past water quality studies more closely and find out the cause of high BOD and to adopt some measures. Otherwise environmental deterioration may be very severe particularly to Lake Victoria.

Winam Gulf

Winam Gulf Baseline Study conducted from July 1984 to August 1985 provides most recent and most comprehensive water quality data of Winam Gulf of Lake Victoria (ref. 15). The data presented in the summary report indicate some signs of Lake water pollution. Kenyan portion of the Lake Victoria basin is 48,000 km^2, predominantly agricultural land with population density of 170 persons/km^2 in 1985. Winam Gulf of the Lake Victoria is a rather closed water body and has water surface area of approximately 1,400 km^2 with its basin area of 12,000 km^2.

Secchi depths to measure the transparency of water were very low at all locations of Lake Victoria and Winam Gulf : 1.1 to 2.5 m in the main Lake, 0.6 to 1.6 m in the transition zone, 0.3 m in Nyakach Bay, and to 2.4 m at the center of the Gulf. This indicates considerably low transparency of the Gulf, which is mainly due to suspended sediment load from Nyando and Sondu Rivers entering the Gulf and blue-green algae blooms.

Dissolved oxygen in Lake Victoria is generally fairly high, and close to saturation near the surface but varies widely at bottoms between near saturation and 1 or 2 mg/l. Ammonia nitrogen in the Gulf is high ranging from 0.1 to 0.8 mg/l, the average being around 0.5 mg/l.

BOD was analysed by another water quality study (ref. 44). The measured BOD values in Winam Gulf at four points were 16 to 86 mg/l with an average of 48 mg/l indicating high organic pollution. In a country of tropical condition, Philippines, it has been proposed that BOD values should be 5 mg/l or lower as a source for domestic water supply, 10 mg/l or lower for bathing, and 15 mg/l or lower for fishing as the environmental standards of water body utilized for those purposes.

As a measure of eutrophication, total nitrogen and total phosphorus transported to various points of the Lake basin were analyzed in a survey (ref.41). The average values of those are 20 kg/km^2/year for total phosphorus and 400 kg/km^2/year for total nitrogen with the samples of August, November and January in 1982 to 1983. These nutrient concentrations are supposed to decrease as water flows along the river as a result of self-purification. Therefore, nutrient loads to the Lake should be less than these values.
Such nutrient loads of total nitrogen and phosphorus in the Lake basin are not high compared with those of industrialized countries, where nutrient loads in a drainage basin could be more than 10 times.

As a measure of primary production, chlorophyll-a content was analysed in a study (refs.13 and 28). The analyses show the contents of 10 to 20 mg/m^3 varying with depths in Winam Gulf. The aforementioned high BOD and nutrient values in Winam Gulf would be an indication of not only in-coming high organic pollution but also a high biological activity in a tropical climate.

The fact of lower pollution loads from the Lake basin and yet higher BOD for Winam Gulf indicates that Winam Gulf is naturally susceptible to pollution. The reasons are considered to be shorter residence time, shallow water depth and tropical climate. The residence time is estimated to be about 2 years for Winam Gulf. When in-coming polluted river water from the basin is retained for a short period of time, the polluted water has a shorter time of purification by biological and physical processes in the Lake. In an extreme case where there is no purification in the Lake, the Lake water quality would be as polluted as in-coming river water quality. Shallow lakes have small volumes of water and the effect of polluted bottom sediment is high due to wind mixing. In tropical climate, primary production in a lake is high due to high temperature and high photosynthetic oxygen production, which is reflected in relatively high dissolved oxygen values mentioned for Winam Gulf.

It has been found that water quality parameters of transparency, ammonia nitrogen, and BOD show a sign of water pollution in Winam Gulf. Also found was natural conditions of the Gulf which make the Gulf water susceptible to pollution. Since a carrying capacity or a limit of sustainability without environmental destruction is not known in such a tropical lake as Winam Gulf, it would be difficult to estimate an upper limit of human activities in its drainage basin. A capacity of water to sustain organic materials and BOD is probably high for the Gulf due to its climates. Nevertheless, the BOD values of Winam Gulf indicated above is too high for a source of drinking water. A filtration in water treatment plant can not work properly with such a high BOD value of more than 5 mg/l.

Concluding the water quality of Winam Gulf, it should be emphasized that Winam Gulf is obviously polluted by in-coming rivers and municipal human activities. The Gulf is susceptible to human activities due to natural conditions as discussed, and as a result, it is easily polluted. This has to be kept in mind in order to conserve water quality of the Gulf.

7.2.7 Water related problems and district needs

Water potential and water related problems and needs in each district of the Region are explained in the respective District Development Plan of 1984/88 (ref.24). Although the information in the Plans may lack consistency among many districts, it is worth describing them here to find out how each district looks at their own water related potential, problems and needs. Table 7.12 includes such information abstracted from the District Development Plans and information obtained from discussions with District Water Engineers.

It may be summarized from the table that water related district needs are water supply and sewage disposal, flood protection, watershed conservation, irrigation and drainage, groundwater development, small dam rehabilitation, and pollution control.

7.2.8 Water abstraction by subbasin

Surface water abstraction permit data

Surface water abstraction permit (SWAP) data was obtained from the Data Base Project of LBDA. The data are compiled and updated time to time by MOWD using the data of water permits or authorisations to abstract surface water issued by Water Apportionment Board. In order to estimate the present amounts of surface water abstraction, the SWAP data were analysed in this study. It is known that the data archives are still young and reliability of the data is said to be questionable (ref. 7). However, analyses of water abstraction with the data were conducted to give an estimate of present water abstraction since there are no better records kept.

There are some limitations in using the data for such an estimate. First, a water abstraction permit is not required for a traditional water use by people who go to fetch water at streams, and thus the data do not include those abstractions. Second, some permit holders may be abstracting more water than the amounts permitted and other permit holders may be abstracting less or no water at all. Therefore, the results of data analysis should be looked upon with reservations and certainly cannot be used as the basis of a domestic water demand projection.

The SWAP data have been updated recently in the late 1986 to include water permits issued from 1981 to 1985. However, the data newly included are found not inclusive and only some of water permits of this period appeared to be added to the SWAP data . For this reason, results of analyses presented in this section do not include the water permits issued after 1981. The data used for the analysis is a computer output of May 7, 1986 at MOWD.

The SWAP data include permit number, subbasin code, Water Abstraction Board file number, date of issue, date of expiration, name of permit holder, gross abstraction during normal flow and flood flow, percent of normal flow abstraction that is returned, land reference number, map number where the permit is located, percent of water use for various purposes such as domestic use, public use, minor irrigation, general irrigation, industrial use, power use, and others, administrative unit code, gauging station code, kind of abstraction works, and intake structure, lifting mechanism, and delivery scheme. Most of the water permit data do not include all of these.

Method of analysis

The SWAP data were organized by subbasin in this study. Water permits which were still effective in 1985 were included and expired permit were excluded. Abstractions during normal flow were used since abstractions during flood flow do not pose problems in water use but those during normal or low flow pose constraints in water use. Excluding return flows, net abstractions were totaled for each subbasin and for each water use purpose. Net abstractions were totaled by groups of issued date, i.e., before 1960, 1961-1965, 1966-1970, 1971-1975, and 1976 -1980. Five permits were dropped due to unreasonably high abstractions, viz. pemit number 12039 in 1CA, 18173 in 1CB, 893 and 3296 in 1GC, and 439 in 1GD. For example, the permit number 893 has a permit of 359,761 m^3/day for public water supply, which can not be true.

Results

The results are summarized and presented in Table 7.15. It is found that the amount of abstraction for domestic purpose is the largest followed by public, power (no consumptive use), minor irrigation, industrial and general irrigation in decreasing order in the Region as a whole. Relatively large amounts of industrial water abstraction in basins 1G and 1H indicates the existence of many big industries around Kisumu; however, industrial water abstractions are small as compared with domestic in most of the basins since industrialization in the Region is still in the early stage.

The incremental amount of domestic water abstraction permit for every five years since 1961 was found consistently increasing in the Lake basin as a whole, indicating an acceleration in domestic water development. Such increasing increments could not be found for industrial water abstraction, i.e., largest increment was found from 1966 to 1970, although accumulated industrial water abstraction has been constantly increasing. Since the amounts of industrial water abstraction in basins and subbasins appear to reflect the existence of small and large industries, the estimated present abstractions can be utilized as a basis of industrial water demand projections for each subbasin, which will be presented in Section 7.3. Irrigation water abstractions such as Ahero, West Kano, and Bunyala irrigation schemes do not appear in Table 7.15 since they are not included in the SWAP data. It should be noted that water abstracted by power use is not consumed but is returned to a river, although such abstractions are included in the table.

7. 3 Water Demand and Supply Balance in 2005

Water is one of important resources for regional development. Conflicts in water use among various water users and among different areas in the future can be avoided, if a projection is made to find areas which will be in short supply of water and those which will be in surplus with water and measures of water development and management are taken accordingly. Results of a study on water demand and supply balance are presented in this section.

7.3.1 Water demand projection

Water demands were projected for urban and rural population, livestock, industry, and irrigation for all the subbasins. Methods, assumptions, and projected water demands are described hereunder for each category of water use.

(1) Domestic water demand

Population of subbasin

Urban and rural populations for each district were projected for 2005 as a part of socio-economic framework (Master Plan Report). These district-wise population data were transformed to subbasin-wise rural and urban populations as shown in Table 7.16. For a rural population, the transformation was made according to area percent of subbasins in each district, or in other words district population was distributed among various subbasins shared in the district. This method involves an assumption that rural population is evenly distributed in a district. For an urban population, a subbasin was identified for each specific urban area.

A population density of each subbasin was computed for 1985 and 2005 as shown in Figure 7.10. It is found that rural population densities in basins 1B, 1C and 1G are generally lower; and those of 1E, 1FE, 1FF and 1KA which correspond to areas of Kakamega and Kisii are higher. Rural population densities of more than 500 and 600 persons/km^2 are considered very high and may not be achieved due to limitation of carrying capacity of lands. In those high density areas, existing urban and rural centres will grow and new service centers will probably emerge.

Populations in non-urbanized areas within administrative urban boundaries, assumed to be 10% in 2005, were included in rural population for the purpose of water demand projection.

Demand projection

Since water balance is computed separately for surface water and groundwater, percentages have to be estimated or assumed for the population dependent on either surface water or groundwater. According to a past survey, percentage of population dependent on water from springs or wells in dry season is 25.6% in Rift Valley Province, 19.9% in Nyanza Province and 59.3% in Western Province (ref.2). Another study by the LBDA Rural Domestic Water Supply and Sanitation Programme (personal communication) found the percentage as 46% in South Nyanza district. Due to the need of low cost water supply to provide a whole population with improved water by the year 2000, percentage of population dependent on groundwater has to increase up to even more than 90% at high groundwater potential areas (ref. 33). The present percentage of groundwater dependent population referred above and groundwater potential by subbasin presented in a previous section are taken into considerations for assuming future percentages of groundwater dependent population in each subbasin. Those percentages are shown in Table 7.16.

Water consumption rates per capita per day and service ratios for various service levels are other assumptions to be made. The National Master Water Plan and Design Manual for Water Supply in Kenya give the following rates.

	Rural			Urban		
	Tradi-tional	Communal	Individual connection	Communal	Rural center	Urban center
NWMP	15"	25"	100"	-	100"	140"
Design Manual	-	20"	60"	20"	150"	150"

The Design Manual shows the following service ratios for urban and rural areas as indicative (ref.26).

	Individual Connection			Communal		
	Initial	Future	Ultimate	Initial	Future	Ultimate
Urban Areas						
high and medium class housing	100%	100%	100%	0%	0%	0%
low class housing	10%	30%	50%	90%	70%	50%
Rural Areas	20%	40%	80%	80%	60%	20%

Considering these consumption rates and service ratios and other water supply study reports (refs.23 and 33), the following were assumed in this study for 2005.

	Surface Water					Ground water	
	Rural			Urban		Rural	
	Traditional	Communal	Individual connection	Communal	Individual connection	Traditional	Communal
Consumption rate	15"	20"	70"	30"	150"	15"	30"
Service ratio	10%	60%	30%	40%	60%	10%	90%

Institutional water demands such as schools and health facilities, and commercial water demands were not separately counted but assumed to be included in domestic water demand. The projected domestic water demands by subbasin are shown in Table 7.17.

(2) Livestock water demand

A livestock population projection by district for the Lake basin was made in the agriculture sector (Chapter 1). The projected livestock population by district was transformed into those of subbasin with the similar method explained for domestic water demand. The livestock populations by subbasin are shown in Table 7.16. Since human water consumption has higher priority on the use of groundwater than livestock water consumption, percentages of groundwater dependent population of livestock by subbasin were assumed to be half of those of human populations. A water consumption rate of livestock unit per day and service ratio in 2005 were assumed, considering the NMWP's estimate, for both surface water and groundwater as shown below:

	Traditional	Communal
Consumption rate	75"	95"
Service ratio	60%	40%

The projected livestock water demand by subbasin is shown in Table 7.17.

(3) Industrial water demand

Industrial water demands were assumed to be met by surface water since industrial water allows lower quality of water than domestic water and groundwater potential in Lake basin area is not high enough for industrial purpose. As the base of industrial water demand projection, the results of industrial water abstraction estimates of 1980 were utilized. In order to obtain abstraction estimates of 1985, growth rates of industrial water abstraction from 1971 to 1980 for each subbasin were calculated and applied to 1981 to 1985. The average growth rate was 4% for the entire basin.

The average growth rate of industrial production was set at approximately 8% per year up to 2005 (Chapter 4). Industrial water demand was assumed to grow at 7.2% (8% x 0.9) from 1985 to 1995 and 5.6% (8% x 0.7) from 1996 to 2005. This assumption is based on the industrial growth rate mentioned above and implementation of water saving measures in the latter stage (1996 to 2005). The projected industrial water demand by subbasin is shown in

Table 7.17. This projection should be looked upon as provisional due to the limitation of water abstraction permit data as explained in the previous section.

(4) Irrigation water demand

Water demands for irrigation development in 2005 were estimated from previous study reports (refs.7,11,31 and 32). Areas for irrigation development have been identified as follows:

Area name	Area (ha)
Yala swamp	17,500
Kano plain	20,540
Upper Nzoia	6,420
Lower Nzoia	5,030
Lower Kuja	1,900
PIU Western	2,100
PIU Nyanza	6,000

Water requirements for estimating annual irrigation water demands was adopted from those studies as follow.

Area		Water Requirements
Yala swamp		1,124 mm
Kano Plain	- North area	1,612 mm
	- South area	1,494 mm
Upper Nzoia		1,073 mm
Lower Nzoia		1,124 mm
Lower Kuja		1,199 mm
PIU Western		1,124 mm
PIU Nyanza		1,612 mm

Water requirements of PIU Western area are applied to neighboring areas of Yala Swamp and Lower Nzoia areas; and requirements of Kano Plain north area were applied to PIU Nyanza area, since this area has no water requirement data. The implementation schedule for the irrigation development in the Region is shown in NMWP. Based on this schedule, irrigation development area will be about 32,000 ha in 1995 and 56,000 ha in 2005. Table 7.17 shows estimated irrigation water demand in each subbasin.

7.3.2 Water demand and supply balance

(1) Surface water balance

Water balances were computed from an upstream subbasin to a downstream subbasin by following a subbasin configuration presented in a previous section (Figure 7.7). The balance can be expressed as $I + R - D = O$; where I, R, D and O are inflow from an upstream subbasin, runoff within the subbasin under computation, surface water demand in the subbasin, and outflow to a downstream subbasin, respectively.

Three measures of water potential and two kinds of surface water demand for each subbasin were used to examine water balance conditions of subbasins. As water potentials, annual runoff volume, a low flow volume which may occur once in 3 to 4 years, and a low flow volume which may occur once in 30 to 40 years were used, as presented in Table 7.11. The method of obtaining the low flow volume is explained in subsection 7.1.5. The third measure of water potential may be considered close to the amount of natural flow which can be utilized without any storage facilities.

As water demands, total surface water demand of subbasin with irrigation and without irrigation was used. Major irrigation projects create large water demands so that the water balances with and without the major irrigation projects give very different pictures. Therefore, it would be better to study a water balance with the two kinds of water demand since it is uncertain whether or not all the major irrigation projects are implemented, while other demands such as domestic, livestock, and industrial are more likely to grow naturally.

Surface water utilization ratio

A numerical measure of water balance in each subbasin is defined as water utilization ratio. It may be noted that surface water will be utilized if water demand is actually achieved and water is withdrawn from a water source. The ratio is calculated as water demand divided by water potential in a subbasin: D/(I+R). Water utilization ratios of all the subbasins were computed for the three measures of water potential and the two kinds of water demand. A water utilization ratio of 0.8 or more is assumed to indicate a deficit. The utilization ratio of unity cannot be attained mainly due to the in-stream flow needs or unidentified perennial flow needs. The computed utilization ratios are presented in Table 7.18.

Water utilization ratios of subbasins were interpreted into a need of creating storage by employing three criteria. First, subbasins in which average annual runoff cannot meet all the water demand including irrigation; second, subbasins in which low flow occurring once in 3 to 4 years cannot meet water demand excluding irrigation; third, subbasins in which low flow occurring once in 30 to 40 years cannot meet water demand excluding irrigation and subbasins in which water demand including irrigation shows a high percentage of annual total water volume.

The implication of the first is that water demand cannot be met even by all the water potential of the subbasin, requiring water import from another basin. The second implies water demand cannot be met without a major storage reservoir to regulate flows in a subbasin. The third implies a major storage reservoir may be necessary to regulate flows, depending on future water demand growth, or seasonal pattern of irrigation water demand. Although a major storage reservoir is or may be necessary in a subbasin, many small ponds even now used for local needs of limited area will be necessary for the future as well. These implications for each subbasin are presented in a subbasin map as shown in Figure 7.11. The overall condition of future water balance can be seen in the figure.

Measures of surface water storage

Water demand in the Sio, Malaba, Lower Nzoia, most of Yala and Sondu river basins can be met with run-of-river flow, but water demand in the other areas will probably need augmentation of runoff by storage reservoir or other means. The condition will be severe near Eldoret, a part of the Lake shore, and Mara basin; and trans-basin transfer will be necessary for the irrigation water supply in the Kano Plain. The measures and sites of surface water storage are described except for the Lake shore in Section 7.5. Storages along the Lake shore can be developed for the Lake Shore Irrigation Project and may be used for other water usage as well, such as domestic, livestock and industrial water supply. Water from the Lake can be utilized if it is economically and operationally feasible. However, use of stream water by gravity is generally preferred since most of existing NIB schemes utilizing pumped water have not proved economically successful.

(2) Groundwater balance

The groundwater demands of domestic water in rural areas and of livestock are shown in Table 7.17. The rationale of estimating groundwater demand is explained in subsection 7.3.1. In the same table, required groundwater recharge in a year is calculated for each subbasin. The required recharges are only a few millimeters per year. These can be compared with subbasin groundwater potential presented in a previous section. A groundwater deficit may possibly occurs in Mara river basin and a part of the Lake shore. Otherwise groundwater potential is considered sufficient in all the subbasins. Groundwater potential will be sufficient in each subbasin as a whole; however, locating groundwater development sites is another matter and is not an easy task.

7.3.3 Water quality control

(1) Present nutrient transport

Nutrients are produced by various activities such as human population, agricultural activities, forests, livestocks, and industrial activities. In this subsection, a rate of nutrient transport reaching rivers from the Lake basin is estimated as a base of projecting water quality control demand. The estimation is based on various assumptions and should be looked only as indicative as there are so many unknown factors in nutrient transport.

Total nitrogen is used as a measure of nutrient production. As previously mentioned, the total nitrogen transported to Nzoia River and its tributaries from the basin was 400 kg/km^2/ year in 1983 (ref.41). Assuming the same amount is also transported from other basins, annual rate of total nitrogen from all the basins would be 19,000 tons/year (400 kg/km^2/ year x 48,000 km^2). Using a per capita load of total nitrogen, i.e, 10g/person /day, the present load by human population would be 29,000 tons/year (10g/person x 365 days x 8 million people). Assuming 50% of fertilizers used in three provinces in 1977 and 1978 were urea (Section 7.2), total nitrogen load would be 3,400 tons/year (16,000 tons/ year x 0.5 x 0.42). Using a per capita load of total nitrogen by livestock population in terms of livestock unit (LU), i.e., 300g/LU/day, the present nutrient load of livestock would be 310,000 tons/year (300g/LU/day x 365 days x 2.8 million LU's) (refs.3 and 47).

The total nitrogen load from the Lake basin thus amounts to 340,000 tons/year, where nutrient load by livestock accounts for 90%. The transported load to rivers of 19,000 tons/year corresponds to about 6% of the total load of 340,000 tons/year in the Lake basin.

(2) Projection of nutrient load in 2005

The nutrient load in the Lake basin in 2005 is estimated based on the projection of human population, fertilizer requirement, and livestock population. The estimate should be looked upon only as an indicative one.

Human population was projected as 17 million in 2005 for the Scenario 3 adopted as a macro- framework for the Master Plan. Using a per capita total nitrogen load of 10g/person /day, the future load of human population would be 62,000 tons/year (10g/person/day x 365 days x 17 million people). It should be noted, however, the share of urban population will increase from 7.8% at present to 13.2% in 2005; and transported nutrient from urban areas is far more than that from rural areas even if town or municipal sewage is treated.

A requirement of agricultural fertilizer of urea in the Lake basin was estimated at 350,000 tons per year in 2005 (Chapter 1, Sector Report). Since 42% of urea is total nitrogen, the total nitrogen load would be 150,000 tons/year. Livestock population in the Lake basin was projected to be 4.4 million (Chapter 2, Sector Report) in terms of livestock units. Using a per capita total nitrogen load of 300g/LU/day, the future load by livestock would be 480,000 tons/year (300g/LU/day x 365 days x 4.4 million LU's)

The total nitrogen load in the Lake basin will amount to 700,000 tons/year for human population, agricultural activities, and livestock combined; here, the total nitrogen load from industry and forest are excluded. The shares of nutrient among three categories of activities are 9% for human, 21% for agriculture, and 70% for livestock. The total nitrogen load in the basin will increase from 340,000 tons/year at present to 700,000 tons/year in 2005. If it is assumed that the estimated ratio of 6% for nutrient transport to rivers from the basin can be applied for 2005, transported total nitrogen will be 900 kg/km^2 /year.

Actual nutrient load in the basin of Winam Gulf may be more than estimated above. Considering the fact that water pollution of the rivers and Winam Gulf is already serious, the future increase of pollution load in the basin should indicates potential threats to the water environment.

For more precise estimate, effects of urban population increase have to be taken into consideration as well as effects of industrial activities. The output of manufacturing industry in the Lake basin was projected to increase from K£ 412 million in 1985 to K£1,386 million in 2005 (Chapter 4, Sector Report), representing over three times increase. Use of pesticides and industrial activities produce inorganic pollutants such as heavy metals, and these effects have to be assessed to find more precise and comprehensive needs of water quality control.

7.4 Strategy of Water Resources Planning

7.4.1 Overall planning strategy

The overall strategy of water resources development and management in this Master Plant study is described in this section in the following way.

Water resources development

As found in the previous section of water demand and supply balance in 2005, some subbasins will face shortage in water if the water demands increase as projected. Water shortages in such subbasins will be caused mainly by irrigation projects. In order to meet water demands in these subbasins, water storage would be required to regulate and augment river flow. Water storage schemes would be formulated as multipurpose river development projects, incorporating as relevant, hydropower development.

These river development projects will be discussed in subsection 7.5.2 under Multipurpose Water Resources Development. Viability and priority of these projects will also be discussed in the same section.

Water supply

Water supply may be categorized into urban, rural, irrigation, and industrial. An urban and rural water supply programme has been formulated and presented in subsection 7.5.1 under Water Supply and Sanitation Development. Underlying strategy for the urban and rural water supply is rehabilitation and expansion of piped water supplies for urban areas and development of groundwater with the use of handpumps for rural areas.

Industrial water supply in urban areas is included in urban water supply; and that in rural areas is considered to be developed by individuals and thus is not directly dealt with in this plan. However, industrial water demands are projected for 2005 and accounted for in water demand and supply balance. Livestock water supply in rural areas is included in rural water supply. Strategies of rural water supply and irrigation are further elaborated on in subsections 7.4.1 and 7.4.2.

Sanitation

Rural sanitation is considered to be undertaken by rural individuals and it is not subject to the direct government interventions related to water resources development and management. This plan just points out some important aspects of rural sanitation in subsection 7.5.1.

Kisumu municipal sewerage development is included as a project in one of eight area development schemes -- Kisumu- Eldoret dual core development (Master Plan Report). From an environmental point of view, Kisumu sewerage works are considered as the most important undertaking among many urban sewerage works. This is because Kisumu municipality has the largest urban population in the Region and the municipality is located on the Lake shore of Winam Gulf. Considering these aspects, Kisumu sewerage