JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF LOCAL AUTHORITIES
KISUMU MUNICIPAL COUNCIL
THE REPUBLIC OF KENYA

THE STUDY ON KISUMU WATER SUPPLY AND SEWERAGE SYSTEM IN THE REPUBLIC OF KENYA

FINAL REPORT

Volume 4

Appendices (1)

September 1998

NIHON SUIDO CONSULTANTS CO., LTD.
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LIST OF ABBREVIATIONS AND ACRONYMS USED

ORGANISATIONS

ALGE	-	Association of Local Government Employers
DDC	-	District Development Committee
DFID	-	Department for International Development of United Kingdom (formerly ODA-Overseas Development Administration)
DPM	-	Directorate of Personnel Management
ESAMI	-	East and South Africa Management Institute
FIDIC	-	International Federation of Consulting Engineers
GOJ	-	Government of Japan
GOK	-	Government of the Republic of Kenya
GTZ	-	Deutsche Gesellschaft fur Zumasammenarbeit (German Agency for Technical Cooperation)
HDD	-	Housing Development Department of Kisumu Municipal Council
HLR	-	Housing Loan Department of Kisumu Municipal Council
IDA	-	International Development Agency
IUCN	-	International Union for Conservation of Nature
JICA	-	Japan International Cooperation Agency
JKUAT	-	Jomo Kenyatta University of Agriculture and Technology
KARI	-	Kenya Agricultural Research Institute
KCCT	-	Kenya College of Communication Technology
Ken U.	-	Kenyatta University
KEWI	-	Kenya Water Institute
KfW	-	German International Development Bank
KIA	-	Kenya Institute of Administration
KIM	-	Kenya Institute of Management
KLGWU	-	Kenya Local Government Workers Union
KMC	-	Kisumu Municipal Council
KMFRI	-	Kenya Marine and Fisheries Research Institute
KPLC	-	Kenya Power and Lighting Company
LBDA	-	Lake Basin Development Authority
LGLA	-	Local Government Loan Agency
LVWT	-	Lake Victoria Wetlands Team
MMI	-	Modern Management Institute
MoiU	-	Moi University

MOLA	-	Ministry of Local Authorities (former Ministry of Local Government)
MOWR	-	Ministry of Water Resources
NEMA	-	National Environmental Management Authority
NES	-	National Environmental Secretariat
NWCPC	-	National Water Conservation and Pipeline Corporation
OECF	-	Overseas Economic Cooperation Fund of Japan
ONRI	-	Netherlands Association of Consulting Engineers
OSIENALA	-	Friends of Lake Victoria
PSC	-	Public Service Commission
SIDA	-	Swedish International Development Agency
UDD	-	Urban Development Department of Ministry of Local Government
UNai	-	University of Nairobi
UNICEF	-	United Nations Children's Fund
UNDP	-	United Nations Development Programme
WAB	-	Water Apportionment Board
W&S Dept.	-	Water and Sewerage Department of Kisumu Municipal Council
WRB	-	Water Resources Board
WSOU	-	Water and Sanitation operations Unit of Ministry of Local Government

PROGRAMMES AND PROJECTS

CSRP	-	Civil Service Reform Programme
GEF	-	Global Environmental Facility
KLGRP	-	Kenya Local Government Reform Programme
KMRP	-	Kenya Municipal Reform Programme
LVEMP	-	Lake Victoria Environmental Management Programme
NEAP	-	National Environmental Action Plan
NWMP	-	National Water Master Plan
PAMNUP	-	Partnership Approaches to Meeting the Needs of the Urban Poor
PHRD	-	Policy and Human Resources Development Project
RDWSSP	-	Rural Domestic Water Supply and Sanitation Programme
UWASAM	-	Urban Water and Sanitation Management Project

OTHER ABBREVIATIONS

AC	-	Asbestos Concrete
AP	-	Anaerobic Pond
ASS	-	Atomic Absorption Spectrophotometry
ATP	-	Affordability-to-Pay
B/C	-	Benefit Cost Ratio
BOD	-	Biochemical Oxygen Demand
BOT	-	Build-Operate-Transfer
CBM	-	Cubic Meter
CCTV	-	Closed Circuit Television
Central WTD	-	Central Wastewater Treatment District
COD	-	Chemical Oxygen Demand
Conventional STW	-	Conventional Sewage Treatment Works
DIP	-	Ductile Iron Pipe
DO	-	Dissolved Oxygen
DR	-	Distribution Reservoir
DSR	-	Debt Service Ratio
Eastern WTD	-	Eastern Wastewater Treatment District
EIA	-	Environmental Impact Assessment
EIRR	-	Economic Internal Rate of Return
EL	-	Elevation
F/C	-	Foreign Currency Portion
FIRR	-	Financial Internal Rate of Return
FP	-	Facultative Pond
F/S	-	Feasibility Study
FTT	-	Flavour Threshold Test
GDP	-	Gross Domestic Product
G. L.	-	Ground Level
GM	-	General Manager
GMS	-	Galvanised Mild Steel
GRP	-	Glass Reinforced Plastic
HP	-	Horse Power
HRD	-	Human Resources Development
HWL	-	High Water Level
IEA	-	Initial Environmental Assessment
IEE	-	Initial Environmental Examination
IER	-	Initial Environmental Report

IRR	-	Internal Rate of Return
Kajulu WTW	-	Kajulu Water Treatment Works
Kanyakwar DR	-	Kanyakwar Distribution Reservoir
Kibuye DR	-	Kibuye Distribution Reservoir
Kibuye WTW	-	Kibuye Water Treatment Works
Kogony DR	-	Kogony Distribution Reservoir
Lake WTW	-	Lake Water Treatment Works
LA	-	Local Authority
L/C	-	Local Currency Portion
MC	-	Municipal Council
MGD	-	Million Gallons (English) per Day
M/P	-	Master Plan
MP	-	Maturation Pond
MSL	-	Above Mean Sea Level
ND	-	Not Detectable
NGO	-	Non-Governmental Organisation
NPV	-	Net Present Value
NTU	-	Nephelometric Turbidity Units
NRW	-	Non-Revenue Water
Nyalenda STW	-	Nyalenda Sewage Treatment Works
O/M	-	Operation and Maintenance
Otongolo STW	-	Otongolo Sewage Treatment Works
PAO	-	Public Administration Officer
PDWF	-	Peak Dry Weather Flow
PS	-	Pumping Station
PSP	-	Private Sector Participation
PST	-	Primary Sedimentation Tank
PVC	-	Poly Vinyl Chloride
RCP	-	Reinforced Concrete Pipe
SCF	-	Standard Conversion Factor
SDB	-	Sludge Drying Bed
SDT	-	Sludge Digester Tank
SP	-	Steel Pipe
SS	-	Suspended Solids
STW	-	Sewage Treatment Works
TDS	-	Total Dissolved Solids
TF	-	Trickling Filter
T-N	-	Total Nitrogen

TOR	-	Terms of Reference
T-P	-	Total Phosphorous
TS	-	Total Solids
UFW	-	Unaccounted for Water
uPVC	-	Unplasticised Poly Vinyl Chloride
VAT	-	Value Added Tax
VIP Latrine	-	Ventilated Improved Pit Latrine
Western WTD	-	Western Wastewater Treatment District
WSP	-	Waste Stabilisation Ponds
WTP	-	Willingness-to-Pay
WTD	-	Wastewater Treatment District
WTW	-	Water Treatment Works

APPENDIX-A

WATER RESOURCES

APPENDIX A
WATER RESOURCES

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A1 INTRODUCTION

This Appendix A (Water Resources) compiles the study results on water sources mainly from the hydrological viewpoint. This Appendix aims to present the fundamentals of planning framework in terms of water sources for the establishment of the Master Plan and the Feasibility Study for the selected Priority Project.

The contents of the report are as follows:

- Chapter A2 describes the general natural condition in and around the Study Area;
- Chapter A3 describes the review on water sources mainly from the viewpoint of low flow condition based on the various previous studies;
- Chapter A4 describes the master plan level evaluation of water sources for the selection of optimum water sources; and
- Chapter A5 describes the evaluation of the selected optimum water sources for the priority project for the Feasibility Study.

A2 GENERAL CONDITIONS

A2.1 Meteorology

General meteorological condition such as monthly rainfall, evaporation and temperature at Kisumu Airport Meteorological station in the Study Area are shown in Table A2-1 and Figure A2-1. The monthly rainfall records at the station are also shown in Table A2-2. The Study Area experiences warm to hot and generally humid climate with monthly maximum and minimum temperatures varying 28°C to 31°C and 16°C to 18°C, respectively. Higher and lower temperatures are experienced during October to March and April to August, respectively. The isohyetal map of Lake basin is shown in Figure A2-2. Annual rainfall at the Station is about 1,320 mm in average. Annual rainfall is influenced by the topography varying from over 1,800 mm in the northern plateau and around 1,200 mm on the Winam Gulf. About 40 % of annual rainfall is measured during the first rainy season from March to May; the second rainy season from November to December is not clear in the Study Area. The Study Area has monthly 10 rainy days in average.

A2.2 Topography

General geographical classification of Kenya is shown in Figure A2-3. Highland extends from north to south and Rift Valley runs parallel with the highland; the areas along the Indian Ocean and Lake Victoria form low lying area. Kisumu Municipality, the Study Area, is located in the Lake Victoria basin facing the Winam Gulf in the east part of Lake Victoria.

Kisumu District is located between the scarps, namely the Kendu-Nyabondo Escarpment in the south and Nyando Escarpment in the north, respectively. In the east of district, the highland of elevation between 1,200 m and 1,400 m and the Winam Gulf of Lake Victoria is faced to in the west. In the middle, the area forms very flat low-lying alluvial plain known as Kano Plain with the elevation between EL 1,135 m and 1,300m, which has been formed by the Nyando River. Scarps are formed by the main rift fault having the direction of E-W to ENE-WSW, which shape the Kavirondo Rift branching from the main north-south oriented Kenya Rift Valley system.

General topography and slopes of Kisumu Municipality, the Study Area, are shown in Figures A2-4. In the north, it is bordered by the Nyando escarpment (fault), which forms steep fault in the east and rounded Kisyan hills in the west. Elevation above the escarpment exceeds EL 1,500 m. The southwestern part consists of piedmont narrow plain bordering on the Winam Gulf. The eastern part of the Study Area falls onto the very flat low-lying Kano Plain. The

Kisumu old town is located on the hill lying to the east of Kisumu Bay with the elevation from around EL 1,160 m to 1,200 m. The hill has two peaks at Kibuye and Watsons Bank.

A2.3 Geology

The general geology in and around the Study Area is shown in Figure A2-5. From the geological viewpoint, in and around the Study Area can be divided into three zones as follows:

- High elevation plateau areas above the scarp features;
- Kisyan-Nyando escarpment; and
- Lake Victoria and Kano Plain.

The high plateau is largely composed of a pre-Cambrian suite comprising Kavirondian and Nyanzian sediments that have been intruded by post-Kavirondian granites and minor intrusion. To the northeast of the Study Area are truncated by the NNW-SSE trending Nandi fault, a major peneplain of granitoid gneiss persists up to the Gregory rift valley east of Eldoret. It is over this peneplain that the Yala tributaries originate and flow west to Lake Victoria. In the vicinity of Kisumu and the Kisyan-Nyando scarps, a Tertiary lave flow was extruded over the granite terrain contemporaneously with the down faulting of the Kavirondo rift. This Kavirondo rift is geologically closely associated with the basin-swell development of Lake Victoria in the west. The high plateau area has been extensively faulted and invaded by later intrusions, and this tectonic cycle is directly related to the cycles of Kavirondo rifting.

The escarpment comprises dissected granites and represents the walls of the Kavirondo rift system. Down faulting of the rift along well-defined east trending fault lines have produced the spectacular scarp features which are characteristic of the high country bounding the Lake and Kano plains. Sympathetic faulting is evident in and beyond the scarps but these have been truncated in the northeast by the major Nandi fault. Drainage within this rugged and dissected terrain is largely controlled by ancient tectonics with numerous faults and shear zones evident that relate to the tectonic disruption of this area in Tertiary times.

Beneath the alluvial blanket that stretches from the Nyando to the Sondu scarp in the south, and to the foot of the Tindaret volcanic in the east, are the down-faulted granites and Kavirondian/Nyanzian sediments at indeterminate depth. The lake has progressively retreated to the west with the deposition of material carried by the numerous rivers that disgorge onto the plains from the high country.

A2.4 Hydrology

A2.4.1 Lake Victoria

Lake Victoria, which lies within the countries of Kenya, Tanzania and Uganda, has a surface area of 68,800 km2 (3,950 km2 in the territory of Kenya), and is the second largest freshwater lake in the world. Basic hydrological features on the lake are as follows:

- Surface Area : 68,800 km2
- Catchment area : 184,000 km2
- Water depth : Maximum=84 m, Average=40 m
- Storage Capacity : 2,750k m3
- Lake shore length : 3,500 km
- Elevation : 1,134 m
- Hydraulic retention time : 23 years
- Water Balance:

  Inflow : 85 % (rainfall to the surface), 15 % (inflow from rivers)

  Outflow : 85 % (evaporation from the surface),
  15 % (discharge to Victoria Nile river)

The fluctuation of lake water level is shown in Figure A2-6 for the period from 1899 to 1985. The level rose after extremely heavy rainfalls during the early 1960's. The lake water level started rising on November 1961 and reached its peak on May 1964. The lake water level has not yet fallen to previous level. The maximum monthly increase of 56 cm occurred in November 1961; the maximum monthly decrease of 22.5 cm occurred in July 1924.

A2.4.2 Rivers

The monthly mean flows and runoff coefficients of the objective rivers at the representative gauging stations selected in Chapter A3 are shown in Table A2-3 and Figure A2-7. The maximum peak of monthly mean flows appears on May in each river excluding the Yala River. The second peak appears on September in the Sondu River, the second peak of other rivers is not clear though. The Kibos and the Awach/Nyangori (a tributary of the Kibos) Rivers show similar runoff pattern reflecting small adjoining catchment. The runoff patterns of the Sondu and Nyando Rivers show remarkable difference. The runoff of the Sondu River is abundant (runoff coefficient: 0.27) and the fluctuation of flow is relatively big between rainy and dry seasons. On the other hand, the runoff of the Nyando River is scarce compared with that of the Sondu River (runoff coefficient: 0.10) and the monthly mean flows do not show significant difference throughout the year. The monthly, annual and/or 10-day flow records of each river are shown in Table A2-4.

A2.5 Hydrogeology

According to "Rural Domestic Water Supply and Sanitation Programme" (LBDA, 1987 - 1988) conducted by Netherlands, the hydrogeology in the Study area is summarized as follows:

On the western area, underlaid by Pleistocene deposits, shallow ground water can be exploited by dug wells up to a depth of 25 m. The weathered zone of granite and andesite as well as the transported erosion products of these rocks may have a relatively good hydraulic permeability; the factors cause the occurrence of good permeable aquifers. It was found that the weathered hard rock zone extends to a depth of 30 - 50 m. Accordingly, besides the exploitation of shallow ground water by dug wells, it is also possible to develop the deeper, preferable faulted or fractured, aquifers by means of 40 - 60 m deep boreholes. Where the upper part of the Pleistocene deposits are to clayey or silty to contain sufficient ground water, boreholes with a depth of 40 to 80 m will be the solution, since more sandy and gravelly deposits are expected to occur at these depths. In the Pleistocene deposits, neither wells nor boreholes will have to be sited, since the aquifers are sub-horizontal sediment layers.

On the eastern area, there are shallow aquifers in the fine-grained alluvial deposits from which water of poor quality is withdrawn by existing wells. It is recommended to withdraw from deeper Pleistocene aquifers: these aquifers are recharged at the foot of the escarpments.

A3 WATER SOURCES

Potential water sources to meet the future water demand of Kisumu Municipality are selected as below:

1) Lake Victoria (Winam Gulf)
2) Kibos River;
3) Awach/Nyangori River (hereinafter referred to as Awach River);
4) Sondu River;
5) Nyando River; and
6) Yala River.

The river systems in the Lake Basin are shown in Figure A3-1. The location of water sources and water level gauging stations are shown in Figure 3-2, and are described respectively in this chapter. The potential intake sites for each source are shown in Figure A3-3. The catchment area, basin mean rainfall and annual mean flow of the lake and rivers are shown in Table A3-1.

The rivers flowing on low-lying Kano plain such as the Luando, the Ombey, the Miriu and the Nyaidho are excluded from the objectives except the Nyando River. The reason is that the elevations of those rivers are lower than that of the Kisumu urban area and accordingly gravity water supply from those rivers is impossible. Besides, some of those rivers are the former river course of the Nyando River and have no own catchment area.

A3.1 General Description of Water Sources

A3.1.1 Lake Victoria (Winam Gulf)

The Winam Gulf with a surface area of 1,400 km2 is a part of Lake Victoria with 68,800 km2. It is relatively shallow with a mean depth of 6.8 m. The Gulf is fed by three (3) major rivers including the Nyando, Sondu and Kibos Rivers. These rivers and the direct rainfall provide water inputs to the Gulf. The Gulf is already important source of water supply and fish resource for a large population, and acts also as recipient of effluent from the catchment area. The Gulf is surrounded by densely populated area and agricultural lands. The urban activities and farming around the lake have tremendous impact on the water quality and the general integrity of the lake ecosystem. Kisumu Municipality is most populated area in the catchment, and one of most serious pollution source.

A3.1.2 Kibos River

The Kibos River catchment is amounts to 117 km2 at the intake site (gauging station 1HA04) where present Kajulu Intake Weir is located. The river falls from northeast to southwest from EL 1,940 m (Kobujoi market) to EL 1,273 m at the weir. The Kibos River passes down the Nyando Escarpment and runs southwards until the Awach River, the biggest tributary, is joined. After joining the Awach River, the Kibos runs into swampy alluvial plain near Lake Victoria, cutting a deep and altering channel. It is bounded in the north by the South Nandi Forest (Serem-Kobujoi-road) and in the south by the hill-range of the Nyando Escarpment. The westerly watershed to the Awach catchment is the Kepkerer-Banja-Serem-road and the easterly Kobujoi-Kibwareng Road is similarly aligned along the watershed. There is no major pollution in the catchment at present.

A3.1.3 Awach River

The Awach River is the biggest tributary of the Kibos River. The catchment area amounts to 108 km2 at the gauging station 1HA14, falling from EL 1,700 m (Kapsotik) in the north to EL 1,180 m at the confluence with the Kibos River. The northern watershed follows the alignment of the Majengo-Gavundunyi-Serem road, the western boundary, is the Kisumu-Mbale road. The catchment abuts on the Kibos catchment in the east and the Kisyan catchment in the west, respectively. There is no major pollution in the catchment at present.

A3.1.4 Sondu River

The Sondu River has three major tributaries, Yurith, Ainabkoi (Chemosit) and Kipsonoi. Total catchment of the Sondu River is about 3,287 km2. The highest elevation of the catchment area is over 2,750 m in the Mau Forest. After the confluence of the tributaries, Kipsonoi and Yurith Rivers, the river flows into the narrow gorge penetrating Nyakach Escarpment and falls in cascade with scenery waterfalls to the flood plain in Nyakwere and finally flows into Lake Victoria. The rivers drain extensive tea plantations in Kericho and Sotik. Major pollution source of this river is considered agricultural pollution load, and small scale industrial pollution from tea and coffee processing factories in the catchment area.

A3.1.5 Nyando River

The Nyando River runs through upland from southeast to northwest in the east of the Kisumu District and turns the direction to southwest in the central Kano plain after joining the Kendos River. It meanders with its way through Kano plain and pours into the central swamp adjoining to the Winam Gulf. The catchment of the Nyando River is about 2,520 km2. As the river flows downstream, it passes through an extensive sugarcane growing area. Fertilizer inputs in the sugar-belt is the major contributor of high nutrients into the lower parts of the river. The river acts as recipient of industrial effluent mainly from sugar industries along the river. The semi-treated industrial load from these factories is adversely affecting the water quality of the river at its downstream. The Nyando River is one of the heavily polluted rivers, especially downstream of those industries. The river water is abstracted for domestic purpose, irrigation and livestock watering.

A3.1.6 Yala River

The Yala River is a major river in western Kenya originating in the South Nandi forest on the edge of the Kerio Valley. It is formed from two major tributaries, the Kimondi and the Sirwa. The Yala River catchment area at gauging station 1FE02 amounts to 1,577 km2 that results from 942 km2 of Remonde River, 549 km2 of Mokong River and 86 km2 of the residual basin. Agricultural and natural vegetation over about one third and two third of both sub-catchment, respectively. The agricultural vegetation consists of tea, maize and sorghum, etc.

"Kisumu Water Supply and Sanitation Study - Feasibility Study" (MOLA, 1988) (hereinafter referred to as the 1988 Study) has concentrated on Lake Victoria and the rivers located in the north of the Municipality. The 1988 Study has carried out alternative study on 15 river options as well as various lake options in the study. The river alternatives were representatively composed of the followings:

1) Kibos dam;
2) Piped diversion (22.7 km) from the Yala River to the Kibos River via the Gorsor River;
3) Piped diversion (36.7 km) from the Yala River to the Kibos River via the Awach River; and
4) Piped diversion (7 km) from the Gorsor River (A=36 km2) with dam into the Kibos River.

The 1988 Study concluded that the Kibos dam option was the cheapest and technically feasible river source option: the diversions from the Yala River were judged too expensive in comparison with the Kibos Dam. The general locations of proposed diversions are shown in Figure A3-4.

A3.1.7 Local Catchment for Rural Water Supply

The available surface water sources for rural water supply are discussed in addition to the above-mentioned sources for piped urban water supply to Kisumu Municipality. On the western rural area, there are two relatively small rivers, namely the Kisyan (52 km2) and the Awach/Mugunuk (36 km2) Rivers; falling from north to south from about EL 1,700 m to Lake Victoria. General locations of those rivers are shown in Figure A3-5. A connecting line between Maseno and Vihiga approximately gives the northern watershed; in the east, the catchment abuts on the Awach catchment, southerly bordered by the Kisyan Hill's Escarpment. In the west, the Awach/Mugunuk catchment boundary follows the alignment of the Kisyan-Darajambili-Maseno road. In the eastern rural part of the Study Area, no evident surface flow for rural water supply could be seen.

A3.1.8 Groundwater

Groundwater is also considered as one of the water sources for Kisumu Municipality. However, water yield of the groundwater is slight low against water demand of urban area. Extensive investigation were carried out in the study, "Rural Domestic Water Supply and Sanitation Programme" (LBDA, 1987-1988) conducted by Netherlands. The groundwater condition in the Study area can be summarized as follows:

On the western area, it was found that shallow groundwater of good water quality occurs throughout the area. Accordingly, it is possible to exploit the shallow ground water by hand dug wells which may range in depth from 12 to 20 m. It is also possible to develop the deeper, preferable faulted or fractured, aquifers by 40 - 60 m deep boreholes. The possibilities for ground water development in the area are rather good. However, successful ground water development will be restricted to the topographical lower areas such as valleys, inter-mountainous flats, foot slopes along mountains and escarpments. The contour lines and electrical conductivity of shallow ground water in and around the area are shown in Figures A3-6 and A3-7, respectively.

On the eastern area, the present potential of good and safe water points is very limited. Many of the developed shallow ground water resources appear to be contaminated. Accordingly, the groundwater development from deeper Pleistocene aquifers was recommended by the study. The contour lines and electrical conductivity of shallow ground water in and area are shown in

Figures A3-6 and A3-7, respectively.

A3.2 Available Intake Sites

General condition of six (6) available intake sites is described hereunder and the proposed locations are shown in Figure A3-3. The catchment area of the rivers at objective gauging stations and proposed intake sites are shown respectively in Table A3-2.

A3.2.1 Lake Victoria

In 1956, the present lake intake was established at Hippo point. The water is abstracted from the lake with the elevation of 1,134 m and is pumped up a distance of 1100 m to Lake WTW. The treated water is pumped into reservoirs at Kibuye and Watsons Bank. It is estimated that this present intake be continuously used even in the future by adding capacity by rehabilitation and/or increment works.

A3.2.2 Kibos River

The present Kajulu intake weir with the elevation of 1,273 m is considered optimum place for gravity water supply to Kibuye with the elevation of around 1,190 m. The catchment amounts to 117 km2; the distance from the intake to the proposed Kibuye is around 11 km.

A3.2.3 Awach River

The possible intake site with the elevation of about 1,300 m has been proposed by the 1988 Study. The intake has initially planned only for rural water supply; this study shall treat this river water for urban gravity water supply. The distance from the intake to Kibuye is around 11 km. The catchment area at the proposed intake amounts to 82 km2. Therefore, the hydrological data at 1HA14 is necessary to be decreased by using unit discharge. The reduction factor is 0.76 (82 km2/108 km2).

A3.2.4 Sondu River

The Sondu/Miriu Hydropower project is now on going and the Sondu-Miriu hydropower station is expected completed in 2002; some amount of discharge of the Sondu River will be diverted for power generation. There are two alternative intake sites on the Sondu River, one is located downstream of proposed Sondu-Miriu Hydropower station site, and another is located upstream of the station as described below:

(1) Downstream of the Station

The outflow from the hydropower station can be proposed as future available water source for Kisumu water supply as well as for "Kano Plain Irrigation Project" and the intake might be placed near the station. The distance from the intake to Kibuye is approximately 55 km. The catchment area at the proposed intake amounts to 3,345 km2. However, the elevation of the station is planned to be EL 1,205 m and accordingly it is completely impossible to convey water by gravity up to Kibuye with the elevation of around 1,190 m. In general, the slope of at least $3^{0/00}$ is required for the piped gravity water supply.

(2) Upstream of the Station

The feasibility study of "The Magwagwa Hydroelectric Power Development Project" was completed in August 1991, the implementation has not yet decided though. The increased Sondu flow by the outflow from the hydropower station is proposed as future available water source and the intake might be placed near the station, which will be located downstream of Sondu bridge. The distance from the intake to Kibuye is approximately 55 km. The elevation of the station is planned to be EL 1,458 m and gravity water supply might be possible. However, careful consideration on decompression should be required because the pipeline needs to be constructed via drastically undulating Kendu-Nyabondo Escarpment and then low-lying Kano plain. Besides, in view of water rights, the intake upstream of the Power Station will reduce water flow and resulting loss of power generation as envisaged in the Hydropower Project. The water right for the Hydropower Project is expected registered soon. Consequently, this alternative can be hardly allowed.

A3.2.5 Nyando River

In conclusion, Ahero bridge is proposed as the only reasonable available water intake along the Nyando River from the viewpoint of the transmission to Kisumu Municipality. The distance to Kisumu is 21 km via main road A1. However, the elevation of the intake site (EL 1,150 m) is lower than that of Kibuye (EL 1,190 m). Accordingly, pumping is required for the transmission to Kisumu Municipality. Besides, as going up along the river, many tributaries are branched off and the Nyando River loses its catchment drastically. The catchment area at the proposed intake amounts to 2,598 km2.

A3.2.6 Yala River

The possible intake site with the elevation of about 1,778 m has been proposed for gravity water supply by the 1988 Study. The diversion of the Yala River water is to supplement the flow in the Kibos River by which intake rate of the Kibos River can be increased. The distance from the intake to the discharge point to the Kibos River is around 22.7 km. The catchment area at the proposed intake amounts to 1,491 km2.

A3.3 Low Flow Condition at Proposed Intake Sites

The low flow conditions of selected water sources are compiled here to prepare the basic information for the selection of optimum water sources. The materials are prepared by quoting from various previous hydrological studies. The water level gauging stations on objective rivers are shown in Table A3-3 and the locations are shown in Figure A3-2.

A3.3.1 Lake Victoria

From the viewpoint of water resources, Lake Victoria is the second largest freshwater lake in the world and accordingly the possible yield from the lake can be considered as unlimited. The actual situation is that almost of present urban piped water supply of Kisumu Municipality rely on the lake water, which is pumped up at the present water intake at Hippo point.

A3.3.2 Kibos River

The 1988 Study has selected the gauging station 1HA04 at the present Kajulu intake weir as objective station. The reasons are that the station had the longest observation period since 1929 and the station proved to be the only reliable station in the basin through the investigation.

The 1988 study has estimated the various probable minimum flows at 1HA04 with various return periods by using daily flows for 49 years. The analyzed result is shown in Figure A3-8.

"Kisumu Water Supply Project - Short Term Measures, Final Design Report" (Municipality of Kisumu, 1990) has also estimated the probable daily minimum flows of the Kibos River at 1HA04 as follows:

- 98 % (50-year) probable daily minimum flow : 0.021 m3/s (1,800 m3/d)
- 95 % (20-year) probable daily minimum flow : 0.027 m3/s (2,400 m3/d)
- 90 % (10-year) probable daily minimum flow : 0.031 m3/s (2,700 m3/d)

The flow duration curve of the Kibos River is prepared as shown in Figure A3-9 by using the daily flow data during 1957 and 1982 (excluding 1970,1972, 1974 and 1976) in the 1988 Study.

A3.3.3 Awach River

About 1 km upstream the confluence with the Kibos River, a gauging station 1HA14 is situated, which has been observed since 1961 and is equipped with a staff gauge. According to the 1988 Study, the gauges were repeatedly washed away by flooding, this resulting in several rating curves. The measurements cover a range of 0.21 to 0.85 m, therefore the extension to very low stage is uncertain.

The 1988 Study has estimated the probable minimum flows at 1HA14 with various return periods by using daily flows for 20 years. The analyzed result is shown in Figure A3-10.

A3.3.4 Sondu River

The gauging station 1JG1 with a catchment area of 3,287 km2 located at the old Sondu bridge plays an important role for the hydrological study to select the optimum development scale of "Sondu River Multipurpose Development Project" by LBDA. Because the station is not only located near the project sites but has the longest record since 1946 in the basin.

"Detailed Design and Preparation of Tender Documents for Sondu/Miriu Hydropower Project" (Kenya Power Company Limited, 1991) has estimated the probable minimum flows at 1JG1 with various return periods by using daily flows for 43 years. The analyzed result is shown in Figure A3-11. The 1991 Study has also prepared a flow duration curve at 1JG1 for the period of 1947 to 1988 as shown in Figure A3-12.

A3.3.5 Nyando River

"Feasibility Study on Kano Plain Irrigation Project" (LBDA, 1992) has selected the gauging station 1GD04 as objective station, since the station has the longest observation period and proved to be the only reliable station in the basin through the investigation.

The 1992 Study has estimated the drought flows of the Nyando River at 1GD04 with various return periods by using annual mean flows. Typical monthly drought flows were then estimated based on the observed monthly mean flow in accordance with the above probable flows. The results are shown in Figure A3-13.

A3.3.6 Yala River

The 1988 Study has selected the gauging stations at 1FC01 on the Remonde River and 1FE02 on the Yala River as objective station, which are located near proposed intake site.

The 1988 Study has estimated the probable minimum flows of the Yala River at proposed intake site by using the daily flow records for 23 years at 1FE02 on the Yala River with various return periods. The analyzed result is shown in Figure A3-14.

A3.3.7 Local Catchment for Rural Water Supply

According to the 1988 Study, the probable low flow condition of the Kisyan and Awach/Mugumk Rivers has been estimated as shown in Table A3-4 by using the data of neighboring stations 1HB5 and 1HA14. Judging from the sparse population density in these basins, the installation of "Compact Water Treatment Unit" might be preferable method for water supply.

A4 EVALUATION OF WATER SOURCES

The following six (6) water sources are evaluated from the viewpoints of transmission, water quality and possible yield.

1) Lake Victoria;
2) Kibos River;
3) Awach River;
4) Sondu River;
5) Nyando River; and
6) Yala River

A4.1 Transmission

Assuming that water is sent from the intakes to enter of Kisumu Municipality, the distance of transmission and pumping requirement are summarized as shown in Table A4-1 based on the study result described in subsection A3.2.

A4.2 Water Quality

The water quality of all the water sources are in principle acceptable for raw water abstraction. However, the basin of Lake Victoria and the Nyando River have pollution source that will deteriorate water quality. If those sources are to be used for water supply, pollution source control shall be carried out. The details of the water quality is described in Appendix (N) "Water and Sludge Quality Survey". The summary of evaluation is shown in Table A4-2.

A4.3 Water Yield

The water yields of alternative water sources are estimated hereunder. The summary is shown in Table A4-3.

According to the "Design Manual for Water Supply in Kenya" (MOWR (former MOWD), 1986) (hereinafter referred to as the Manual), safe yield for principal towns and urban centers with a population over 10,000 is described as follows:

The 96% - probability daily low flow shall be regarded as the safe yield of a river. The flow - frequency analysis shall be made by using the lowest recorded daily flow of each calendar year for which records are available for the dry season.

The 96 % probability daily low flow defined here equals the minimum daily flow with the probability of once in 25-year (1-(1/25)=0.96). The amount of 96 % probability daily low flow is considered about only several percent of annual mean flow. If "96 % probability daily low flow" is defined as possible water amount, the amount shall be limited too strictly in spite of strong water demand in Kisumu Municipality. Consequently, a realistic concept of "Dependability 96 % Possible Water Amount" is introduced. If inhabitants in Kisumu Municipality allow water supply system to operate below the capacity for 2 weeks a year, dependability 96 % on flow duration curve, possible water development capacity becomes more than 5 times of 96 % probability daily low flow.

A4.3.1 Lake Victoria

The possible yield from Lake Victoria is can be considered as unlimited from the hydrological viewpoint; the lake is the second largest freshwater lake in the world as already mentioned in subsection A3.3.1.

A4.3.2 Kibos and Awach Rivers

(1) 96 % Probability Daily Low Flow

According to the 1990 Study described in subsection A3.3.2, the 96 % probability daily low flow of the Kibos and Awach Rivers at the proposed intake sites are roughly estimated as follows:

- Kibos River (Kajulu Intake Weir, 1HA04) : 0.025 m3/s (2,200 m3/d)
- Awach River (proposed intake site) : 0.017 m3/s (1,500 m3/d)
  < 0.025 m3/s x 82 km2 /117 km2>

The low flow of the Awach River is estimated by adopting the unit discharge of 1HA04 on the Kibos River to avoid overestimate. The probable low flows at 1HA14 on the Awach River become bigger than that of the 1HA04 although the catchment at 1HA14 is smaller than that at 1HA04 (refer to Figures A3-8 and A3-10).

(2) **Dependability 96 % Possible Water Amount**

The analysis of the dependability is carried out based on the duration curve shown in Figure A3-9 and the result is shown in Table A4-4. Under the concept of dependability 96 %, 66,100 m3/d of water is available at proposed intake sites in the Kibos and Awach Rivers. In other words, 66,100 m3/s of water can be sent to Kisumu Municipality from those rivers in 96 % period (about 2 weeks) of a year in average.

(3) **Yield by Proposed Kibos Dam**

NWMP has proposed the construction of the Kibos dam at the site with the elevation of about 1,450 m. The proposed site was located almost the same with that proposed in the 1988 Study. NWMP has envisaged the water supply of 82,080 m3/d (0.95 m3/s) to Kisumu Municipality to meet the demand in 2010. The proposed dam with the height of 39 m will create a reservoir having 7 $m3*10^6$ of gross storage. The preliminary layout of the proposed dam is shown in Figure A4-1.

A4.3.3 Sondu River

(1) **96 % Probability Daily Low Flow**

The 96 % probability daily low flow at the proposed intake site is estimated as follows based on the probable minimum flow at 1JG01 shown in Figure A3-11:

Q=0.87 m3/s (75,100 m3/d)
<=0.85 m3/s * 3,345 km2 (at intake facility site) /3,287 km2 (at 1JG01)>

This value of 0.87 m3/s is expected increased in the future by the construction of proposed Magwagwa dam located upstream. However, the implementation of "Magwagwa Hydroelectric Power Development Project" has not yet decided, the feasibility study was completed in 1991 though.

(2) **Dependability 96 % Possible Water Amount**

The analysis of the dependability is carried out based on the duration curve shown in Figure A3-12 and the result is shown in Table A4-4. Under the concept of 96 % dependability, 345,600 m3/d of water is available at proposed intake site, Sondu Miriu Hydropower Station. The water yield of the Sondu river is considered enough to the water demand of Kisumu Municipality even in far future.

(3) Coordination with "Kano Plain Irrigation Project"

The maximum plant discharge available for the Sondu-Miriu Hydropower station has been designed to be 39.9 m3/s. On the other hand, according to "Feasibility Study on Kano Plain Irrigation Project" (LBDA 1991), the maximum intake from the hydropower station has been proposed 18.5 m3/s, the implementation of this project has also not yet decided though. Accordingly, the intake for the Kisumu water supply would not influence the irrigation project during rainy months: surplus water at the hydropower station will be 21.4 m3/s (39.9 m3/s - 18.5 m3/s). However, some coordination will be necessary on the intake during dry months between both projects. The reason is that the maximum irrigation intake of 18.5 m3/s has been determined based on the probable 5-year monthly minimum discharge regulated by proposed Magwagwa dam.

A4.3.4 Nyando River

(1) 96 % Probability Daily Low Flow

The 96 % probability daily low flow of the Nyando River is estimated to be 0.63 m3/s (54,400 m3/d) indirectly based on the following procedures, since no analysis on probable daily minimum flow of the Nyando River is available:

1) Assuming that the 10-day minimum flow of recent 25 years (1966–1987) at 1GD04 is regarded as nearly probable 96 % (25-year) 10-day minimum flow. The value will be 0.74 m3/s in February 1987 (refer to Table A2-4).

2) The probable 96 % (25-year) daily minimum flow at Ahero bridge is estimated 0.63 m3/s (0.74 m3/s * 0.85). The ratio of 0.85 is quoted from the ratio between probable daily and 10-day minimum flows of the Sondu River (refer to Figure A3-13).

(2) Dependability 96 % Possible Water Amount

The dependability of the Nyando river is estimated by applying the flow duration curve of the Sondu River, since no flow duration curve is available on the Nyando River. The estimation is shown in Table A4-4. The conversion factor of 0.78 (2,598/3,345) is adopted; the catchment of the Nyando River at the proposed intake site is 2,598 km2 against 3,345 km2 of the Sondu

River. Under the concept of the dependability 96 %, 269,600 m3/d of water is available at proposed intake site. The water yield of the Nyando River is considered enough to water demand of Kisumu Municipality. The river water can be abstracted by intake weir with no storage facilities in the upstream. Judging from the relatively big amount of the water yield, the abstraction seems not influence the present/future water abstraction permits and natural river environment located downstream.

A4.3.5 Yala River

(1) 96% Probability Daily Low Flow

According to the previous frequency analysis by the 1988 Study (refer to Figure A3-14), the 96 % probability daily low flow at the proposed intake site is estimated to be 105,400 m3/d (1.22 m3/s).

(2) Dependability 96 % Possible Water Amount

The flow duration at the intake site is estimated as shown in Table A4-5 by using the average minimum flow analyzed by the 1988 Study. Under the concept of 96 % dependability, 304,100 m3/d (3.52 m3/s) of water is available at the intake site. The summary of the analysis is shown in Table 4-4.

The water yield of the Yala River is considered enough to water demand of Kisumu Municipality. The river water can be abstracted by intake weir with no storage facilities in the upstream. Judging from the relatively big amount of the water yield, the abstraction seems not influence the present/future water abstraction permits and natural river environment located downstream.

A5 OPTIMUM WATER SOURCES FOR PRIORITY PROJECT

A5.1 Availability of Raw Water from Kibos and Awach Rivers

In the Master Plan, various available water sources are evaluated based on the review of previous study. As a result, the Kibos River, Awach Rivers and Lake Victoria are selected as optimum water sources for the priority project. Hydrological analyses based on raw hydrological data are conducted in this subsection to confirm the detailed availability of raw water from the Kibos and Awach Rivers.

A5.1.1 General River Condition

(1) Catchment

The Kibos river catchment is amounts to 117 km2 at the gauging station 1HA04 where present Kajulu Intake Weir is located. The river falls from northeast to southwest from EL 1,940 m (Kobujoi market) to EL 1,273 m at Kajulu through sparsely populated area; houses are sparsely distributed only along the roads that pass through on the watershed. The Kibos catchment is currently almost covered by forest, grassland, pastureland and cultivated land in the upstream of Kajulu. The Kibos river passes down the Nyando Escarpment and runs southwards until the Awach river, the biggest tributary, is joined. After joining the Awach river, the Kibos runs into swampy alluvial plain near Lake Victoria, cutting a deep and altering channel.

The Awach river is the biggest tributary of the Kibos river. The catchment area amounts to 108 km2 at the gauging station 1HA14, falling from EL 1,700 m (Kapsotik) in the north to EL 1,180 m at the confluence with the Kibos river. "Kisumu Water Supply and Sanitation Study" (1988, MOLG) (hereinafter referred to as the 1988 Study) has stated that the Awach River runs through a densely populated area and as a result there are dangers of pollution. However, the Study Team carried out the site reconnaissance of watershed on February 1998 and confirmed that the river runs through sparsely populated area; houses are sparsely distributed mainly along the roads that pass through on the watershed. The Awach catchment is currently almost covered by forest, grassland, pastureland and cultivated land in the upstream of proposed intake site. It can be concluded that the watershed currently shows satisfactory condition as a water source. The catchment of the Kibos and Awach Rivers are shown in Figure A5-1.

(2) Intake Site

On the Kibos River, present Kajulu intake weir with the elevation of 1,273 m is considered optimum for the intake site by gravity water supply; the distance from the intake site to Kibuye reservoir is around 11 km.

On the Awach River, the possible intake site with the elevation of about 1,300 m has been preliminary proposed by the 1988 Study. The Study Team carried out the site reconnaissance along the Awach River on February 1998 and found that the location with the elevation of 1,255 m will be optimum place for the intake site by gravity water supply. The optimum site is located just downstream the abandoned weir constructed by MOWR and the distance from the site to Kibuye reservoir is around 11 km. The catchment at the intake amounts to 82 km2. Geomorphologically, the optimum intake sites on both rivers are located at the top of the alluvial fan.

A5.1.2 Reliability of Discharge Rating Curve

The objective gauging stations under operation on both rivers are shown in Table A5-1. The hydrological data such as 1) daily water levels, 2) discharge measurement records and 3) discharge rating equations at both stations were collected from the database system in the headquarter of MOWR in Nairobi and the Provincial Water Engineer's Office, MOWR in Kisumu. The water level data after 1994 are excluded from the analysis, since the availability of these data are proved quite low through examination; especially the raw data of water level at 1HA04 seems to be scattered and lost after 1995.

The Study Team carried out field reconnaissance from 9 to 13 February 1998 to examine the condition of these stations. The Study Team also intended to carry out some discharge measurements at both stations on 12th with the collaboration of the Provincial Water Engineer's Office, MOWR to examine the reliability of rating equations at very low stage during dry season. However, as the flow condition during the field reconnaissance was found that of typical rainy season because of abnormal weather condition at that period, the measurement was not carried out. The observed water level at 1HA04 was 1.60 feet (0.48 m) (4.36 m3/s), while the level at 1HA14 was 0.37 m (1.15 m3/s) on 12 February.

The collected discharge measurement records for both stations are plotted together with discharge rating curves as shown in Figure A5-2. The discharge measurements record of both station s are shown in Table A5-2. On the gauging station 1HA04, the station is located at present Kajulu intake weir and the stable weir section gives invariable equations. The width of the weir is 9.90 m (6.85 m + 3.05 m), the drawing of the weir could no be found, though. The regular discharge measurements for 1HA04 have been carried out at the river section located downstream the weir, the water level have been read at the weir, though. On the gauging station 1HA14, four (4) equations have been prepared in spite of relatively stable river channel around the station, since the staff gauges have been washed away several times by floods before 1971. It can be judged that the rating equations established by MOWR for both stations are reliable within the range of the discharge measurements or the range supplemented by weir formulae. Consequently, the rating equations by MOWR are adopted for the conversion from water level into discharge in the Study.

A5.1.3 General Flow Condition

The daily mean flows for the Kibos and Awach Rivers during 1974 and 1993 are shown in Figure A5-3. The average daily flows for both rivers during the same period are shown in Figure A5-4. As can be seen in Figure 4-8, drought period generally appears from the end of December until the middle of February on both rivers; the minimum flow tends to appear in the end of January in average. The Kibos and Awach catchment adjoin and are relatively small. Therefore, both hydrographs show the similar pattern and the annual runoff volumes of both rivers show almost the linear relationship as shown in Figure A5-5. The total runoff volume of the Awach River is around 60 % as that of the Kibos River.

A5.1.4 River Maintenance Flow

Maintenance of the minimum flow in perennial rivers is not mentioned in "Design Manual for Water Supply in Kenya" (MOWR (former MOWD), 1986) (hereinafter referred to as the Manual). However, it is necessary to maintain a certain amount of water for conservation of the natural river environment as recommended by "The Study on the National Water Master Plan" (MOWR, 1992) (hereinafter referred to as NWMP). The river maintenance flow is assumed equivalent to the recorded minimum daily flow by NWMP.

According to the concept by NWMP, the river maintenance flows of the Kibos and Awach Rivers are assumed as shown in Table A5-3 by the daily flow record and the discharge measurement results. The values for the Awach intake site is estimated by applying the conversion factor of 0.76*1HA14 (82 km2/ 108 km2 = 0.76).

The total amount of the water abstraction permits as of 1997 is 2,294 m3/d (0.027 m3/s) along the Kibos river (refer to Table A5-4). Among those, the permission numbers 12870 and 12871 are the abstraction from present Kajulu WTW. Accordingly, the abstraction permits located downstream the intakes are only 786 m3/d (0.009 m3/s). On the other hand, the river maintenance flow along the Kibos downstream is assumed approximately 0.11 (0.07 + 0.04) m3/s (9,600 m3/s). Consequently, it is concluded that the river maintenance flow assumed here does not affect to the water abstraction permits.

A5.1.5 Frequency and Flow Duration Analyses

The frequency and flow duration analyses are conducted here for the basis of the evaluation of raw water availability of the Kibos and Awach Rivers.

(1) Frequency Analysis for Average Minimum Flow

The frequency of average minimum flows is analyzed for the duration of 1, 7 and 30 days. The average minimum flows for each year are shown in Table A5-5 and Figure A5-6. The data length for the analysis is 39 and 31 years on 1HA04 (Kibos River) and 1HA14 (Awach River), respectively. The data before 1954 at 1HA04 are excluded from the analysis, since these low flow become suddenly unnaturally low. The frequency analysis is conducted in accordance with "minimum distribution method" and the results are shown in Figure A5-7. The values for the Awach intake site is estimated by applying the conversion factor of 0.76*1HA14.

(2) Flow Duration Analysis

The flow duration of daily mean flows is analyzed by applying the series method for the recent 20 years (1974-1993). Two (2) types of flow duration curve are prepared, namely, 1) average flow duration curve and 2) sequential flow duration curve. The average flow duration curve is prepared by taking the average of each annual duration curve in order to comprehend the average flow duration condition. The results are shown in Figure A5-8. On the other hand, the sequential flow duration curve, which is commonly used, is prepared by applying the series method throughout the available data period in order to grasp the absolute low flow condition throughout the objective period. The results are shown in Figure A5-9. The curves for the Awach intake site is estimated by applying the conversion factor of 0.76*1HA14 (82 km2/108 km2 = 0.76). The data at 1HA04 from 1983 to 1986 and that at 1HA14 from 1984 to 1986 are excluded from the analysis, since frequent data missing and/or incompleteness during these period are not adequate for the duration analysis.

A5.1.6 Evaluation of Availability

(1) 96% Probability Daily Low Flow

According to the Manual by MOWR, safe yield for principal towns and urban centers with a population over 10,000 is described as follows:

> The 96% - probability daily low flow shall be regarded as the safe yield of a river. The flow - frequency analysis shall be made by using the lowest recorded daily flow of each calendar year for which records are available for the dry season.

The 96 % probability daily low flow defined here equals the minimum daily flow with the probability of once in 25-year (1-(1/25)=0.96). According to the frequency analysis shown in Figure A5-7, the 96 % low flow at the intake sites on the Kibos and Awach Rivers are estimated as shown in Table A5-6.

The safe yield, the 96 % low flow, is assumed to be 15,500 m3/s (0.18 m3/s) in total. As already mentioned in (4), it is necessary to maintain a certain amount of water for conservation of the natural river environment, there is no description on the river maintenance flow in the Manual, though. If safe yield is defined as a balance between 96 % probability daily low flow and maintenance flow, the safe yield will be only 7,700 m3/s (0.09 m3/s) in total. In all cases, the safe yields fall far short of the water amount of 45,500 (42,500 + 3,000) m3/d in Phase I at year 2005. As already made clear in the Master Plan stage, under that concept of safe yield, possible water development amount is limited too strictly in spite of strong water demand in Kisumu Municipality. Consequently, a realistic concept of dependability 96 % is introduced hereunder.

(2) Dependability 96 % Possible Water Amount

If habitants in the municipality allow water supply system to operate below the capacity for 2 weeks a year (dependability 96 % on flow duration curve), possible water development capacity will considerably increase. According to the flow duration analysis shown in Figures 4-12 and 4-13, under the concept of dependability 96 %, the possible water amount at the intake sites on the Kibos and Awach Rivers are estimated as shown in Table A5-7.

(3) Water Amount in Phase I and II

The total water amount in Phase II is proposed 88,000 (85,000 + 3,000) m3/d. The water sources in Phase II will be the combination of the Kibos and Awach Rivers, and Lake Victoria. The basic concept is that the surplus water will be abstracted from the Kibos and Awach Rivers during rainy months, and the shortage during dry months is supplemented by Lake Victoria. The ratio and period of water amounts from the intakes on both rivers during rainy months are determined as shown in Table A5-8 by using the average flow duration curves (refer to Figure A5-8). It is not necessary to mention about the dependability in Phase II, since the shortage of river water during dry months will be fully supplemented by alternative water source, Lake Victoria.

The total water amount in Phase I is proposed 45,500 (42,500 + 3,000) m3/d. The ratio of water amount from the intakes on both rivers in Phase I is determined in accordance with the abstraction ratio in Phase II. As there is no alternative water source to supplement the shortage in Phase I, it is necessary to evaluate the dependability by using the sequential flow duration curves (refer to Figure A5-9). The result is shown in Table A5-9. Under the concept of dependability 96 % possible water amount, the dependability 94.9 % falls slightly low of 96 %. However, the 94.9 % might occur only in year 2005, since the water demand is lower than 45,500 m3/s until year 2004 and the water intake capacity will be increased after year 2006. Moreover, as shown in Table A5-7, the amount of 44,000 m3/d by dependability 96 % amounts to 97 % of 45,500 m3/d. Consequently, the water yield of 45,500 m3/s in Phase I from both rivers is considered practically satisfy the water demand of Kisumu Municipality up to year 2005.

A5.2 Availability of Raw Water from Lake Victoria

Lake Victoria is the second largest freshwater lake in the world. The availability capacity of raw water from Lake Victoria is in principle unlimited. In 1956, the present lake intake was established at Hippo point. The water is abstracted from the lake with the elevation of 1,134 m and is pumped up to Kibuye with the elevation of 1,190 m; the distance from the intake to Kibuye reservoir is around 5 km. This water source will be very important either as single source or as a combined source with the Kibos/Awach Rivers. Due to its proximity to supply area, combination of this source with the Kibos/Awach Rivers will increase the reliability of water supply system.

A5.3 Recommendations

On the abstraction of the river water from the Kibos and Awach Rivers, it is required to make an application to MOWR for water abstraction permit. The application form, "Application for a

Water Permit (Surface Water)" is available at the headquarters of MOWR. The water amount to be abstracted from both rivers is summarized in Table A5-10.

Through the field reconnaissance in February 1998, the Study Team found that no daily water level has been recorded since 1998 at 1HA04 on the Kibos River, and the data of 1995 and 1996 was scattered and lost. The Kibos River is selected as one of the optimum water sources for the water supply to Kisumu Municipality, and accordingly the data at 1HA04 becomes increasingly important for various hydrological analyses to be carried out in future. It is recommended that the continuous daily gauge reading at the station be carried out. It is also recommended to replace present old feet gauge with metric gauge, since some confusion and/or wrong conversion could be found even in the recent data.

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TABLE

Table A2-1 Meteorological Condition in Kisumu

Month	Temperature				Relative Humidity		Daily Sunshine Hours (hrs)	Daily Wind Run (km)	Monthly Mean Evaporation (mm)	Monthly Mean Rainfall (mm)	Nos. of Rainy Days (days)
	Daily Max. (°C)	Daily Min. (°C)	Extreme High (°C)	Extreme Low (°C)	Daily Max. (%)	Daily Min. (%)					
Jan	30.6	17.0	36.0	9.0	60	41	9.3	155.2	221	62	7
Feb	30.8	17.3	36.9	12.2	62	42	9.0	164.5	208	88	10
Mar	30.4	17.7	36.6	12.0	67	44	8.7	162.7	220	158	11
Apr	28.8	17.9	36.0	13.3	75	53	8.0	142.4	180	216	17
May	28.2	17.3	32.2	13.3	76	54	7.9	119.0	170	173	13
Jun	27.9	16.4	31.4	12.4	74	52	8.1	119.7	160	88	8
Jul	27.7	16.1	31.4	11.8	74	49	7.6	125.2	162	66	7
Aug	28.2	16.1	33.1	11.4	71	48	7.6	136.9	175	98	8
Sep	29.4	16.2	34.5	10.6	65	46	7.9	141.7	191	79	8
Oct	30.5	17.1	34.7	10.2	61	42	8.3	149.4	209	75	10
Nov	30.1	17.2	34.4	12.8	63	45	7.9	146.6	190	120	13
Dec	29.9	17.0	35.7	12.0	63	44	9.0	155.3	204	100	9
Total									2290	1323	121
Max.	30.8	17.9	36.9	13.3	76	54	9.3	164.5	221	216	17
Min.	27.7	16.1	31.4	9.0	60	41	7.6	119.0	160	62	7
Ave.	29.4	16.9	34.4	11.8	68	47	8.3	143.2	191	110	10

Station No. : 9034025 Recording Period : 1931 - 1980

Station Name : Kisumu Airport Meteorological Station Altitude : EL. 1149 m

Location : Latitude; 0:6S, Longitude; 34:35E

Source: MOWR (1992, July) "The Study on the National Water Master Plan - Data Book (DB.1) Hydrological Data (Study Supporting Data)". JICA.

Table A2-2 Monthly Rainfall in Kisumu

Station No. 9034025

(Unit : 0.1mm)

Year	Month Mean												Annual
	Jan.	Feb.	Mar.	Apr.	May	Jun	Jul.	Aug.	Sep	Oct.	Nov.	Dec.	Mean
1959			2024	1090	1055	143	400	801	922	283	1478	730	
1960	526	673	2642	2457	1593	997	741	577	761	716	555	746	12984
1961	10		1670	1923	1734	401	569	1434	1437	859	4494	2928	
1962	1150	102	1765	2491	3580	1082	644	533	1258	816	1251	871	15543
1963	1501	1251	1423	2852	2210	718	295	912	188	581	1689	1327	14947
1964	425	2197	1629	3093	1129	1190	1012	604	1010	519	735	1272	14815
1965	867	221	1842	2645	2275	373	559	202	1394	1432	1512	704	14026
1966	407	2578	2275	2310	993	540	719	1407	600	647	541	86	13103
1967	149	313	1017	1609	1971	462	162	177	1432	886	3350	729	12257
1968	315	1852	1962	3407	961	1731	512	721	813	1951	1556	2129	17910
1969	1123	1931	1458	942	1598	501	484	632	511	1103	1389	509	12181
1970	2043	704	2239	1930	1040	658	133	667	543	804	689	1376	12826
1971	125	114	741	3454	2890	447	591	967	477	1700	920	1531	13957
1972	119	1225	708	2282	1936	1055	757	1552	930	1515	2255	620	14954
1973	1322	1023	138	2153	2336	340	155	773	681	132	1040	198	10291
1974	114	277	1493	3057	708	1044	1351	687	879	402	1309	637	11958
1975	192	526	2800	1645	1680	346	385	1597	795	864	638	1056	12524
1976	822	674	329	3313	713	405	888	1134	1441	524	1398	1120	12761
1977	714	830	1492	2959	2874	896	934	1090	199	1011	1817	844	15660
1978	1465	1772	2395	2119	1959	925	882	1232	1138	1042	1434	1294	17657
1979	619	2339	2168	1621	1424	570	612	886	818	238	1633	1760	14688
1980	442	454	1777	2235	1177	662	885	388	735	899	749	660	11063
1981	393	305	3060	952	1687	781	756	1126	541	154	707	722	11184
1982	485	690	607	1127	813	1703	914	807	1523	1694	3181	938	14482
1983	154	464	396	2536	1202	1004	273	880	425	1409	1913	794	11450
1984	447	506	341	1432	1256	571	1946	1193	930	669	2287	733	12311
1985	968	850	2472	2209	2268	1108	872	569	632	415	474	689	13526
1986	680	883	2284	2747	1455	721	1026	386	1049	689	948	896	13764
1987	609	1360	1643	1279	1211	1626	322	282	1132	1878	1192	410	12944
1988	1752	99	1519	3972	827	571	1316	271	1034	458	1616	796	14231

Source;
MOWD (1992, July) "The Study on the National Water Master Plan - Data Book (DB.1) Hydrological Data (Study Supporting Data)". JICA.

Table A2-3 Monthly Mean Flow and Runoff Coefficient

unit: m3/s

River	Kibos	Awach	Sondu	Nyando	Yala
Station	1HA04	1HA14	1JG01	1GD04	1FE02
Period	1952 - 1988	1961 - 1988	1947 - 1988	1956 - 1988	-
Jan	1.10	0.68	16.11	6.03	8.50
Feb	1.05	0.61	13.18	5.69	7.00
Mar	1.20	0.92	17.57	6.13	7.10
Apr	2.49	2.46	50.83	14.71	10.80
May	3.16	2.63	102.60	19.24	17.60
Jun	2.24	1.76	57.72	13.61	15.30
Jul	1.74	1.22	44.35	13.70	20.30
Aug	1.97	1.18	51.34	18.39	31.80
Sep	2.01	1.22	56.28	15.93	29.70
Oct	1.74	1.05	35.61	9.96	20.50
Nov	1.85	1.30	34.55	9.97	17.90
Dec	1.61	1.00	32.19	8.89	12.90
Annual Mean	1.85	1.34	42.69	11.85	16.60
Catchment Area (km2)	117	108	3,287	2,520	1,577
Annual Mean Runoff (mm)	499	391	410	148	332
Basin Mean Rainfall (mm)	1,860	1,800	1,500	1,460	1,570
Runoff Coefficient	0.27	0.22	0.27	0.10	0.21

Source:

1: LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes, Annex I Meteorology and Hydrology". JICA.

2: MOWR (1992, July) "The Study on the National Water Master Plan - Data Book (DB.1) Hydrological Data (Study Supporting Data)". JICA

Table A2-4 Discharge Record of Rivers (1/6)

Monthly and Annual Mean Kibos Flow (in m3/sec) at 1HA04, 1933 - 88

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1933	0.46	0.76	0.24	0.29	1.04	0.89	0.75	0.98	1.63	0.55	0.29	0.43	0.69
1934	0.50	0.02	0.35	0.64	2.06	0.56	0.61	0.67	0.52	0.39	0.38	0.18	0.57
1935	0.07	0.43	0.59	1.09	2.30	3.23	1.23	0.85	0.93	0.75	0.32	0.36	1.01
1936	0.32	1.42	1.88	3.01	1.98	2.83	2.98	1.92	1.21	0.84	0.79	0.67	1.65
1937	0.39	0.45	0.83	4.76									
1938													
1939													
1940	0.18	0.37	1.12	0.86		1.47	1.76	1.03	0.67	0.43	0.98	1.26	0.92
1941	0.37	0.22	0.37	0.84	2.15	1.91	1.02	1.15	1.05	0.75	1.78	4.15	1.31
1942	1.26	0.82	1.11	2.12	4.97	2.49	1.30	2.74	2.37	0.78	0.52	0.37	1.74
1943	0.10	0.39	0.20	0.40	1.57	1.02	0.72	0.90	0.84	0.49	0.21	0.42	0.61
1944	0.39	0.29	0.37	0.62	0.98	0.59	0.24	0.33	0.55	0.32	1.43	1.69	0.65
1945	0.27	0.34	0.40	0.36	0.72	0.91	1.07	1.42	0.78	0.58	0.55	0.66	0.67
1946	0.38		0.11	0.12	0.66	1.20	0.65	2.26	2.91	0.80	1.15	2.24	
1947	0.83	0.57	1.01	2.51	6.31	3.72	2.34	2.60	2.80	1.46	0.69	0.76	2.13
1948	0.28	0.44	0.53	0.58	0.29	0.96	0.58	0.47	0.62	0.47	0.40	0.48	0.51
1949	0.34	0.27		0.73	0.76	1.43	0.89	1.16	0.75	0.62	0.51	0.39	
1950	0.58	0.40	0.74	1.18	0.79	0.97	1.64	1.03	1.54	0.70	0.64	0.54	0.90
1951													
1952	2.57	1.17	0.89	2.28	6.03	3.03	2.21	3.44	3.14	1.95	1.46	0.76	2.41
1953	0.28	0.40	0.59	1.55	0.97	1.20	0.59	0.53	0.77	0.48	0.70	0.64	0.73
1954	0.41	0.49	0.50	0.80	2.10	2.03	1.11	1.29	0.92	0.64	0.50	0.51	0.94
1955	0.60	0.80	0.59	1.18	3.15	1.03	1.90	1.64	3.24	3.09	1.14	1.83	1.68
1956	1.58	1.10	0.61	1.58	2.65	1.95	1.40	1.40	2.09	2.68	1.04	0.59	1.56
1957	0.52	0.59	0.69	1.16	3.82	2.44	1.64	2.03	1.31	0.84	0.79	0.75	1.38
1958	0.62	0.70	0.81	0.59	0.86	0.99	2.03	1.59	0.80	0.82	0.48	1.46	0.98
1959	0.79	0.80	1.23	1.13	2.19	0.71	0.43	0.75	0.83	1.69	2.69	0.98	1.19
1960	0.51	0.81	1.77	3.69	2.97	1.87	1.34	0.90	1.39	1.13	1.30	0.51	1.52
1961	0.65	0.75	0.80	0.90	1.40	0.77	0.50	0.43	1.30	4.56	9.24	10.56	2.66
1962	6.27	1.70	2.22	4.54	4.96 *	6.20	3.45	3.28	2.57	2.80	2.30	1.73	3.50
1963	1.70	1.53	1.14	4.10	7.70	3.90	1.95	1.36	1.11	0.82	2.00	4.29	2.63
1964	1.05	1.10	1.67	4.80	4.25	2.88	2.03	3.70	2.08	4.22	1.58	1.32	2.56
1965	0.98	0.57	0.95	1.37	1.90	0.74	0.67	0.73	0.92	1.07	2.99	1.41	1.19
1966	0.63	0.77	1.80	4.57	3.19	1.53	1.37	1.35	1.42	0.86	1.74	0.57	1.65
1967	0.79	0.68	0.83	1.11	1.98	1.36	1.12	0.89	1.47	1.09	2.14	3.26	1.39
1968	0.92	4.17	3.02	3.43	4.30	5.33	1.89	1.82	2.06	1.58 *	1.36 *	3.81 *	2.81
1969	1.13 *	1.91 *	1.38 *	0.99	3.15	2.00	1.29	1.53	1.61	0.86 *	0.84	0.45	1.43
1970	1.47	1.14	1.91	2.44	3.19	1.98	1.12	0.99	1.13	0.83 *	1.58	1.32	1.59
1971	0.63	0.70	0.67	1.69	3.01	1.35	1.24	2.22	2.44	1.41	0.87	0.85	1.42
1972	0.48	0.54	0.52	0.47	2.71	2.14 *	1.81	2.85	2.04	2.81 *	3.07 *	1.61 *	1.75
1973	2.26	1.54	0.70	1.03	1.84	1.49	1.03	1.31	2.37	1.52	2.02	0.83	1.50
1974	0.49	0.11 *	1.03	4.20	1.93	2.54	4.18	1.50	4.81	3.41	1.24	0.79	2.19
1975	0.39	0.37	0.62	1.50	1.53	1.66	2.51	2.98	3.22	2.79	1.07	0.74	1.62
1976	0.52	0.38	0.41	1.45	1.01	1.34	0.66 *	1.46	1.69	0.67	0.60	0.47	0.89
1977	0.67	1.56	0.99	3.81	4.18	4.02	3.26	1.95	2.64	1.37	5.58	2.63	2.72
1978	3.09	1.79	4.41	5.48	6.62	2.43	1.70	1.61	2.15	2.62	2.15	2.57	3.05
1979	1.34	3.73	2.97	3.74	3.41	3.27	1.90	3.33	2.64	1.13	1.15	1.03	2.47
1980	0.78	0.80	0.64	1.15	3.75	3.41	3.75	1.93	3.01	2.55	1.83	1.26	2.07
1981	0.59	0.99	2.57	6.14	4.44	2.53	4.27	2.18	2.81	2.18	1.28	0.87	2.57
1982	1.52	1.06	1.44	2.69	3.64	3.92	1.80	2.79	2.98	2.53	5.18	4.86	2.87
1983	1.35	0.86	0.69	3.00	3.14	0.92	2.43	8.66	4.00	1.88 *	0.86 *	0.57 *	2.36
1984	0.30 *	0.20 *	0.11 *	0.62 *	0.56 *	0.88 *	1.65 *	1.86 *	0.89 *	0.57 *	1.23 *	0.98 *	0.82
1985	0.23 *	0.44 *	0.44 *	5.34 *	4.49 *	2.07 *	0.87 *	1.17 *	1.77 *	0.95 *	0.51 *	0.36 *	1.55
1986	0.34 *	0.28 *	0.50 *	1.10 *	1.45 *	1.42	1.23	1.17	1.07	0.80	1.04	1.12	0.96
1987	0.99	1.14	1.16	0.81	3.19	3.80	1.08	0.68 *	0.75	0.98	1.65	0.67	1.41
1988	1.40	1.12	1.19	5.82	5.27	1.90	1.14	3.41	2.76	2.27	1.19	0.62	2.34
Mean (1952-88)	1.10	1.05	1.20	2.49	3.16	2.24	1.74	1.97	2.01	1.74	1.85	1.61	1.85

Note: *. These figures are estimated based on the monthly mean flow table of 1HA14 using catchment area proportion.
The calculation of mean flow in this Table does not imply flow records are complete within any month.

Source;

LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes. Annex I Meteorology and Hydrology", JICA.

Table A2-4 Discharge Record of Rivers (2/6)

Monthly and Annual Mean Awach Flow (in m3/sec) at 1HA14, 1961 - 88

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1961	0.58 *	0.67 *	0.71 *	0.80 *	1.24 *	0.68 *	0.62	0.68	0.96	4.05 *	8.21 *	1.53	1.73
1962	5.57 *	1.51 *	1.97 *	4.04 *	4.41 **	5.51 *	3.07 *	2.92 *	2.28 *	2.49 *	1.31	1.00	3.01
1963	1.05	0.99	1.04	3.23	5.14	2.25	0.97	0.76	0.49	0.32	1.38	2.11	1.64
1964	0.62	0.46	1.22	5.52	3.15	1.98	1.44	1.90	0.76	0.96	1.02	0.55	1.63
1965	0.39	0.23	0.22	1.19	2.66	0.66 *	0.71	0.52	0.49	0.47	0.86	1.62	0.84
1966	0.64	1.12	1.63	7.91	2.72	1.63	1.18	0.76	1.14	0.60	1.49	0.62	1.79
1967	0.36	0.21	0.42	1.94	3.05	1.21	1.06	0.79	0.77	0.61	1.21	3.14	1.23
1968	0.70	0.90	2.76	3.55	4.66	3.94	1.80	1.64	2.03	1.40	1.21	3.39	2.33
1969	1.00	1.70	1.23	1.28	2.23	1.76	1.24	1.75	1.14	0.76	0.74	0.40	1.27
1970	0.42	0.38	0.57	1.29	1.47	1.37	0.63	0.94	0.82	0.74	0.52	0.49	0.80
1971	0.21	0.12	0.08	2.17	2.64	1.50	1.15	1.14	1.91	0.81	0.52	0.64	1.07
1972	0.37	0.39	0.78	0.43	3.18	1.90	1.19	1.59	0.96	2.50	2.73	1.43	1.45
1973	1.61	0.95	0.58	1.00	4.16	1.91	0.78	1.38	2.02	1.15	0.95	0.35	1.40
1974	0.28	0.10	0.36	2.26	1.41	1.58	3.97	1.16	2.15	1.67	0.84	0.44	1.35
1975	0.26	0.36	0.51	2.27	1.39	1.51	1.02	2.57	2.35	1.31	0.58	0.46	1.22
1976	0.29	0.21	0.14	1.21	0.95	0.98	0.59	0.65	0.90	0.35	0.31	0.39	0.58
1977	0.65	0.67	1.05	4.21	3.36	3.42	2.30	1.11	1.30	0.65	1.74	0.93	1.78
1978	0.92	1.07	3.78	3.65	5.92	1.43	0.90	0.81	0.75	0.58	0.59	0.61	1.75
1979	0.49	2.32	1.60	1.65	1.25	1.45	1.13	0.79	0.61	0.31	0.58	0.57	1.06
1980	0.22	0.15	0.35	1.31	2.52	2.59	2.04	0.76	0.98	0.79	0.56	0.33	1.05
1981	0.15	0.24	1.03	3.02	1.71	0.93	1.20	1.07	1.36	0.80	0.47	0.24	1.02
1982	0.20	0.16	0.19	0.53	0.98	1.44	0.73	1.08	2.65 *	0.72	3.32	3.30	1.28
1983	0.68	0.40	0.61 *	1.88	2.51	0.92	0.63	1.12	0.99	1.67	0.76	0.51	1.06
1984	0.27	0.18	0.10	0.55	0.50	0.78	1.47	1.65	0.79 **	0.51	1.09	0.87 **	0.73
1985	0.20 **	0.39 **	0.39	4.75	3.99	1.84	0.77	1.04	1.57	0.84 **	0.45	0.32	1.38
1986	0.30	0.25	0.44	0.98	1.29	0.60	0.37	0.54	0.84	0.71 *	0.92 *	1.00 *	0.69
1987	0.24	0.25	1.01	1.57	1.74	2.68	0.69	0.60	0.47	1.05	1.73	0.51	1.05
1988	0.44	0.76	1.04	4.63	3.51	0.93	0.52	1.45	0.79	0.60	0.43	0.23	1.28
Mean (1961-88)	0.68	0.61	0.92	2.46	2.63	1.76	1.22	1.18	1.22	1.05	1.30	1.00	1.34

Note: *. These figures are estimated based on the monthly mean flow table of 1HA04 using catchment area proportion.
**. Based on 1HA01 using catchment area proportion.
The calculation of mean flow in this Table does not imply flow records are complete within any month.

Source:
LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes, Annex I Meteorology and Hydrology", JICA.

Table A2-4 Discharge Record of Rivers (3/6)

Monthly and Annual Mean Sondu Flow (in m3/sec) at 1JG01, 1946 - 89

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
1946					14.12	48.26	37.46	83.08	82.50	33.22	16.95	10.04	
1947	13.16	11.83	15.58	99.60	264.97	79.78	52.07	56.27	59.93	53.99	13.44	8.50	60.76
1948	5.30	3.46	2.79	5.17	9.61	25.33	26.59	57.29	64.40	19.03	10.30	2.78	19.34
1949	3.49	2.78	1.74	4.15	5.53	13.46	15.77	36.09	57.62	23.48	10.85	9.31	15.36
1950	6.58	3.89	5.72	14.07	20.89	22.62	35.44	44.78	57.90	24.23	10.47	6.96	21.13
1951	4.50	4.67	4.23	110.48	920.02	87.55	35.21	45.12	28.54	31.42	45.78	123.48	120.08
1952	60.32	14.73	8.72	44.83	201.45	66.52	29.04	52.92	46.56	25.71	15.73	10.62	48.10
1953	5.49	3.17	2.31	6.16	9.86	10.75	9.85	11.96	9.73	7.05	6.65	6.45	7.45
1954	3.32	1.72	1.58	5.89	45.75	75.33	39.00	34.10	56.07	25.91	13.32	11.00	26.08
1955	5.92	5.55	3.10	6.81	16.26	10.25	16.51	45.16	86.04	63.39	25.04	19.21	25.27
1956	41.62	31.56	14.51	36.77	104.10	75.25	48.16	54.04	86.63	40.64	27.72	16.73	48.14
1957	8.58	6.95	6.57	47.67	113.96	149.81	63.26	53.37	45.54	15.27	10.62	9.40	44.25
1958	6.47	9.71	9.70	9.76	66.99	33.78	34.66	32.82	45.29	27.77	13.87	11.52	25.20
1959	8.64	6.64	11.68	37.04	69.75	35.22	16.09	18.21	28.56	22.84	23.27	14.49	24.37
1960	9.74	6.20	17.90	70.06	62.60	55.34	36.56	40.10	78.78	43.50	23.21	13.08	38.09
1961	6.76	4.54	4.32	9.72	24.06	15.55	12.92	33.03	46.28	56.62	258.81	227.19	58.32
1962	85.56	26.66	12.65	32.71	182.56	111.75	88.55	45.75	86.22	73.18	31.11	18.04	66.23
1963	31.95	24.98	21.17	74.05	264.96	118.43	34.96	51.32	37.63	10.98	12.69	88.08	64.27
1964	33.83	13.38	25.37	183.64	108.52	49.04	69.10	71.89	60.73	75.29	22.12	11.40	60.36
1965	10.03	6.37	4.01	32.45	72.74	23.59	15.38	16.38	17.01	11.81	31.57	22.14	21.96
1966	11.02	11.29	32.36	89.45	80.88	33.29	26.36	24.60	71.05	24.10	22.88	11.86	36.60
1967	6.55	4.35	3.64	19.93	99.09	64.22	75.48	40.09	30.81	17.02	21.22	57.12	36.63
1968	15.32	17.18	51.35	122.92	160.99	92.59	57.35	93.56	46.83	17.75	29.27	93.28	66.53
1969	22.83	48.94	39.46	29.85	37.46	23.70	14.16	16.94	34.87	14.15	9.58	6.89	24.90
1970	14.33	22.60	66.73	126.23	115.65	82.58	42.54	79.93	79.54	59.12	27.14	11.90	60.69
1971	10.54	6.86	4.61	11.21	41.77	66.50	64.14	100.38	93.93	46.17	16.84	10.38	39.44
1972	10.25	9.19	7.44	7.66	32.37	41.38	45.88	44.40	26.74	19.83	74.63	47.23	30.58
1973	43.61	32.63	20.06	12.45	33.23	80.71	31.40	48.67	62.91	36.59	30.01	13.36	37.14
1974	7.11	4.50	5.71	72.24	51.20	56.58	130.91	67.00	55.03	42.84	24.24	11.02	44.03
1975	6.21	4.42	5.50	28.79	33.33	50.50	42.40	94.43	136.64	81.90	36.79	14.41	44.61
1976	8.89	6.17	5.39	8.42	22.84	41.59	58.00	50.89	73.24	21.65	11.29	9.07	26.45
1977	11.65	24.01	13.92	89.55	163.96	81.02	109.92	78.33	55.35	26.12	109.91	78.31	70.17
1978	31.26	28.15	168.06	198.19	153.49	46.46	58.52	55.92	70.46	73.79	40.71	28.57	79.47
1979	21.22	69.63	48.07	69.45	92.72	75.23	56.32	63.41	35.35	15.33	10.08	7.65	47.04
1980	5.87	5.22	7.70	14.76	39.42	55.90	64.56	33.42	32.28	14.00	13.23	10.36	24.73
1981	5.69	6.26	12.53	142.07	93.51	33.41	40.33	79.29	62.33	56.68	22.00	13.11	47.27
1982	7.57	4.48	2.66	4.82	44.02	72.24	36.89	65.10	50.18	35.82	122.30	163.90	50.83
1983	26.80	11.74	7.50	16.96	48.94	50.50	42.83	55.15	107.71	80.22	51.82	24.52	43.72
1984	15.84	8.71	6.25	11.75	14.19	10.18	10.71	29.10	32.29	19.59	15.44	30.52	17.05
1985	9.20	9.40	10.13	104.33	107.73	77.88	46.80	77.65	62.56	22.04	22.96	15.44	47.18
1986	8.43	7.31	7.25	14.20	38.42	36.48	26.02	33.54	32.50	19.22	12.83	15.87	21.01
1987	9.88	7.20	20.87	26.46	68.37	131.46	49.19	24.48	21.01	16.70	35.66	25.65	36.41
1988	15.10	14.39	17.26	82.32	170.86	60.68	52.66	99.32	90.85	82.86	83.78	21.10	65.93
1989	12.20	13.61	14.18	66.66	119.36	54.81	32.07	49.70	80.46				
Mean (1947-88)	16.11	13.18	17.57	50.83	102.60	57.72	44.35	51.34	56.28	35.61	34.55	32.19	42.69

Note: Above figures are summarized after interpolation conducted by the D/D Team of the Sondu/Miriu Hydropower Project.

Source:
LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes, Annex I Meteorology and Hydrology". JICA.

Table A2-4 Discharge Record of Rivers (4/6)

10-Day, Monthly and Annual Mean Nyando Flow (in m3/sec) at 1GD04, 1956 - 88 (1 of 3)

Year: 1956

Month	First	Middle	Last	Mean
1	11.32	8.49	27.05	15.62
2	7.79	8.43	9.35	8.52
3	3.64	2.63	10.05	5.44
4	13.14	9.34	29.49	17.32
5	16.07	31.04	28.64	25.25
6	15.08	7.78	24.98	15.95
7	21.13	11.53	33.07	21.91
8	29.06	40.60	42.83	37.50
9	45.38	20.95	14.63	26.99
10	15.50	14.66	10.23	13.46
11	7.28	5.47	3.86	5.54
12	8.32	3.54	2.67	4.84
Mean	16.14	13.71	19.74	16.53

1958

Month	First	Middle	Last	Mean
1	2.04	0.79	1.75	1.53
2	1.85	9.04	2.19	4.36
3	1.58	5.74	4.08	3.80
4	1.39	1.32	4.06	2.26
5	11.81	27.55	6.24	15.20
6	9.84	6.47	10.13	8.81
7	18.37	35.40	14.99	22.92
8	11.05	22.24	27.53	20.27
9	20.97	17.42	10.04	16.14
10	7.91	11.07	5.18	8.05
11	3.42	2.78	2.31	2.84
12	1.44	3.23	4.79	3.15
Mean	7.64	11.92	7.77	9.11

1960

Month	First	Middle	Last	Mean
1	1.42	1.49	1.80	1.57
2	1.05	1.08	1.03	1.05
3	3.29	3.95	19.82	9.02
4	25.59	25.50	16.31	22.47
5	19.60	15.65	24.84	20.03
6	10.37	7.25	5.62	7.75
7	6.65	5.21	5.07	5.64
8	4.81	8.23	15.26	9.43
9	19.65	16.58	10.76	15.66
10	8.82	5.75	3.69	6.09
11	3.90	10.14	3.59	5.88
12	1.98	1.36	2.16	1.83
Mean	8.93	8.52	9.16	8.87

1957

Month	First	Middle	Last	Mean
1	2.85	1.66	2.43	2.31
2	2.34	1.75	1.84	1.98
3	1.51	3.38	2.15	2.35
4	5.43	10.20	28.05	14.56
5	25.40	11.56	24.21	20.39
6	53.46	18.45	34.41	35.44
7	17.58	13.26	13.63	14.82
8	21.01	19.46	17.78	19.42
9	18.24	9.18	5.37	10.93
10	4.46	3.25	3.61	3.77
11	3.47	3.12	2.35	2.98
12	2.91	1.82	2.63	2.45
Mean	13.22	8.09	11.54	10.95

1959

Month	First	Middle	Last	Mean
1	2.04	1.43	2.13	1.87
2	1.91	1.52	1.16	1.53
3	2.48	0.85	5.75	3.03
4	2.41	6.40	9.17	5.99
5	7.41	7.99	14.85	10.08
6	5.29	3.10	2.41	3.60
7	3.14	2.07	2.18	2.46
8	4.93	3.42	3.98	4.11
9	10.93	11.49	5.56	9.33
10	7.52	4.18	4.39	5.36
11	15.53	4.49	4.28	8.10
12	4.47	3.27	2.11	3.28
Mean	5.67	4.18	4.83	4.90

1961

Month	First	Middle	Last	Mean
1	0.90	0.45	0.56	0.64
2	1.02	0.62	0.41	0.68
3	0.47	2.17	2.31	1.65
4	7.08	3.39	3.02	4.50
5	7.06	7.84	3.10	6.00
6	2.53	3.37	1.92	2.61
7	2.26	2.24	3.08	2.53
8	11.38	32.13	29.41	24.31
9	29.55	20.98	13.93	21.49
10	15.51	11.77	8.17	11.82
11	19.13	67.86	64.98 *	50.66
12	45.81	70.15 *	57.78 *	57.91
Mean	11.89	18.58	15.72	15.40

Year: 1962

Month	First	Middle	Last	Mean
1	57.66 *	40.31 *	26.77 *	41.58
2	12.74 *	9.48 *	8.86 *	10.36
3	10.40 *	16.03	21.38	15.94
4	25.26	32.41	57.14	38.27
5	74.97	87.07	48.76	70.27
6	32.56	30.76	55.24	39.52
7	27.13	34.08	32.60	31.27
8	37.31	42.68	34.11	38.03
9	36.50	43.22	33.22	37.65
10	21.16	22.20	27.57	23.64
11	15.81	11.45	12.59	13.28
12	14.78	9.71	13.79	12.76
Mean	30.52	31.62	31.00	31.05

1964

Month	First	Middle	Last	Mean
1	12.21	9.50	8.38	10.03
2	8.73	6.98	8.55	8.09
3	11.57	6.73	12.37 *	10.22
4	8.63	28.48	68.95	35.35
5	22.46	29.85	18.48	23.60
6	17.70	13.93	15.32	15.65
7	31.19	27.20	26.70	28.36
8	48.50	37.74	27.44	37.89
9	35.40	34.17	30.44	33.34
10	31.98	29.11	16.35	25.81
11	11.29	9.81	8.69	9.93
12	7.54	7.34	8.65	7.84
Mean	20.60	20.07	20.86	20.51

1966

Month	First	Middle	Last	Mean
1	4.49 *	3.82 *	3.51 *	3.94
2	5.91	5.46	6.39	5.92
3	4.50	17.00	10.76	10.75
4	3.70	20.78	46.48	23.65
5	17.07	9.22	8.06	11.45
6	7.58	12.20	8.13	9.30
7	7.31	11.20	11.71	10.07
8	8.71	9.50	17.36	11.86
9	24.99	19.47	10.71	18.39
10	6.99	6.73	5.98	6.57
11	7.60	6.61	5.17	6.46
12	3.93	4.56	3.26	3.92
Mean	8.57	10.55	11.46	10.19

1963

Month	First	Middle	Last	Mean
1	11.32	11.45	12.98	11.92
2	10.18	15.00	8.65	11.28
3	9.66	14.57	12.45	12.23
4	7.87	19.97	64.42	30.75
5	94.34	86.86	47.13	76.11
6	78.00	25.01	18.39	40.47
7	18.76	16.21	15.39	16.79
8	16.44	34.98	37.29	29.57
9	29.00	14.22	11.22	18.15
10	9.52	9.00	8.20	8.91
11	7.29	7.88	27.89	14.35
12	60.76	26.86	19.15	35.59
Mean	29.43	23.50	23.60	25.51

1965

Month	First	Middle	Last	Mean
1	8.28	6.47	5.00	6.58
2	5.37	4.57	3.85	4.60
3	4.77	3.39	5.02	4.39
4	4.13	5.30	11.04	6.82
5	7.96	6.30	5.88	6.71
6	4.26	3.32	3.80	3.79
7	3.58	4.02	3.78	3.79
8	4.25	4.55	4.90	4.57
9	3.78	3.25	3.93	3.65
10	2.99	3.57 *	6.63	4.40
11	6.71	7.45	4.40	6.19
12	4.28	5.95	4.33	4.85
Mean	5.03	4.85	5.21	5.03

1967

Month	First	Middle	Last	Mean
1	2.89	2.46	2.61	2.65
2	3.87	2.71	2.26	2.95
3	2.87	2.69	2.53	2.70
4	7.79	11.08	9.36	9.41
5	17.86	30.87	30.42	26.38
6	12.90	10.98	16.38	13.42
7	26.51	29.22	36.19	30.64
8	20.63	16.79	25.16	20.86
9	17.40	11.85	11.39	13.55
10	7.92	6.77	9.36	8.02
11	5.98	9.95	31.39	15.77
12	32.81	18.78	12.42	21.34
Mean	13.29	12.85	15.79	13.97

Source;
LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes. Annex I Meteorology and Hydrology". JICA.

Table A2-4 Discharge Record of Rivers (5/6)

10-Day, Monthly and Annual Mean Nyando Flow (in m3/sec) at 1GD04, 1956 - 88 (2 of 3)

Year: 1968

Month	First	Middle	Last	Mean
1	6.56	5.12	5.30	5.66
2	4.88	9.15	25.92	13.32
3	13.09	16.16	15.65	14.97
4	23.22	18.05	67.38	36.22
5	34.94	27.86	25.86	29.55
6	20.59	24.22	20.31	21.71
7	15.97	15.11	23.19	18.09
8	25.75	30.57	30.49	28.94
9	15.31	12.13	9.14	12.19
10	8.10	6.98	8.77	7.95
11	8.01	5.63	8.19	7.28
12	19.14	6.94	4.98	10.35
Mean	16.30	14.83	20.43	17.19

1970

Month	First	Middle	Last	Mean
1	2.54	9.53	10.80	7.62
2	8.96	5.68	4.53	6.39
3	8.06	11.39	9.98	9.81
4	13.53	12.05	26.74	17.44
5	20.93	25.59	12.66	19.73
6	15.68	12.97	15.18	14.61
7	15.39	13.52	10.35	13.09
8	13.94	27.69	33.84	25.16
9	22.35	21.40	17.25	20.33
10	12.56	12.97	8.61	11.38
11	7.52	5.81	5.19	6.17
12	4.27	4.95	4.04	4.42
Mean	12.14	13.63	13.26	13.01

1972

Month	First	Middle	Last	Mean
1	5.16	5.29	3.53	4.66
2	7.38	7.03	4.57	6.33
3	3.46	3.48	3.20	3.38
4	2.50	3.51	3.48	3.16
5	16.06	10.08	11.57	12.57
6	11.11	7.94	12.25	10.43
7	15.15	12.91	11.62	13.23
8	10.08	11.24	14.53	11.95
9	8.83	6.91	7.67	7.80
10	5.22	7.25	17.55	10.01
11	26.11	31.27	14.99	24.12
12	10.64	12.05	7.35	10.01
Mean	10.14	9.91	9.36	9.80

1969

Month	First	Middle	Last	Mean
1	4.19	3.74	9.49	5.81
2	9.10	10.43	15.12	11.55
3	6.16	5.58	15.66	9.13
4	4.31	4.70	3.73	4.25
5	7.08	10.05	7.73	8.29
6	4.55	5.78	5.71	5.35
7	4.54	5.17	5.33	5.01
8	6.58	8.93	7.59	7.70
9	7.90	10.63	6.13	8.22
10	4.22	5.16	4.24	4.54
11	4.21	3.71	3.41	3.78
12	3.50	2.31	2.09	2.63
Mean	5.53	6.35	7.19	6.35

1971

Month	First	Middle	Last	Mean
1	3.29	3.73	3.67	3.56
2	2.63	2.09	2.09	2.27
3	2.17	2.67	2.37	2.40
4	5.03	8.87	16.36	10.09
5	15.13	21.21	15.02	17.12
6	13.99	11.70	18.18	14.62
7	17.35	17.69	24.74	19.93
8	16.71	25.61	30.72	24.35
9	32.01	19.19	15.94	22.38
10	17.96	12.19	10.23	13.46
11	7.78	6.96	5.85	6.86
12	4.74	4.57	7.99	5.77
Mean	11.57	11.37	12.76	11.90

1973

Month	First	Middle	Last	Mean
1	6.13	12.37	7.33	8.61
2	4.83	9.40	13.00	9.08
3	6.72	4.52	3.67	4.97
4	3.04	5.86	4.58	4.49
5	9.72	9.50	11.97	10.40
6	14.22	10.32	9.45	11.33
7	8.04	6.38	7.05	7.16
8	12.19	19.39	18.35	16.64
9	17.43	14.40	20.78	17.54
10	12.46	9.04	6.95	9.48
11	7.83	7.01	6.48	7.11
12	4.52	3.26	3.70	3.83
Mean	8.93	9.29	9.44	9.22

Year: 1974

Month	First	Middle	Last	Mean
1	4.05	3.34	2.40	3.26
2	2.11	2.24	2.03	2.13
3	3.49	2.19	4.50	3.39
4	18.10	17.60	12.69	16.13
5	9.39	9.08	10.28	9.58
6	15.03	7.23	9.13	10.46
7	21.45	28.12	23.59	24.39
8	14.05	11.30	11.53	12.29
9	14.48	11.03	11.97	12.49
10	9.71	7.72	7.20	8.21
11	5.82	4.94	4.38	5.05
12	3.55	3.82	3.12	3.50
Mean	10.10	9.05	8.57	9.24

1976

Month	First	Middle	Last	Mean
1	4.32	3.59	2.86	3.59
2	2.86	3.40	2.85	3.04
3	2.58	2.17	2.88	2.54
4	3.42	5.03	4.24	4.23
5	4.47	6.20	12.04	7.57
6	10.06	6.97	9.19	8.74
7	8.60	16.41	11.75	12.25
8	11.22	13.88	11.78	12.29
9	17.04	12.30	7.74	12.36
10	6.19	4.69	3.97	4.95
11	3.50	3.48	5.60	4.19
12	4.93	2.35	3.04	3.44
Mean	6.60	6.71	6.50	6.60

1978

Month	First	Middle	Last	Mean
1	9.58	12.20	14.16	11.98
2	8.59	8.39	13.72	10.23
3	13.25	20.23	23.39	18.96
4	20.70	29.71	17.93	22.78
5	27.32	28.89	15.32	23.84
6	11.17	11.79	12.53	11.83
7	18.51	17.30	15.51	17.11
8	19.11	16.85	20.23	18.73
9	23.53	17.99	17.20	19.57
10	19.87	14.67	12.94	15.83
11	11.49	9.66	8.32	9.82
12	6.67	10.81	12.94	10.14
Mean	15.82	16.54	15.35	15.90

1975

Month	First	Middle	Last	Mean
1	2.73	2.46	2.13	2.44
2	2.11	3.72	2.61	2.81
3	2.34 *	4.63	4.79	3.92
4	3.08	16.02	9.03	9.38
5	3.85	5.59	11.05	6.83
6	13.62	12.32	11.34	12.43
7	6.24	12.62	24.01	14.29
8	22.37	30.99	31.76	28.37
9	55.07	31.25	20.75	35.69
10	26.43	18.80	16.73	20.65
11	10.40	8.12	6.86	8.46
12	10.50	5.65	4.34	6.83
Mean	13.23	12.68	12.12	12.68

1977

Month	First	Middle	Last	Mean
1	4.52	2.78	3.83	3.71
2	7.62	3.66	5.82	5.70
3	4.32	2.91	3.57	3.60
4	16.04	14.69	8.63	13.12
5	32.83	28.84	29.06	30.24
6	23.80	21.77	19.98	21.85
7	23.87	21.09	18.54	21.17
8	24.52	20.88	18.93	21.44
9	15.63	16.06	17.34	16.34
10	10.18	8.85	12.23	10.42
11	17.19	25.05	48.51	30.25
12	21.84	14.84	13.05	16.58
Mean	16.86	15.12	16.62	16.20

1979

Month	First	Middle	Last	Mean
1	6.96	5.84	10.53	7.78
2	22.13	36.85	23.78	27.59
3	12.30	17.88	11.46	13.88
4	17.08	18.05	11.85	15.66
5	14.03	16.81	12.08	14.31
6	12.14	20.48	19.39	17.34
7	18.88	14.12	12.64	15.21
8	21.13	25.83	18.08	21.68
9	13.11	11.20	12.14	12.15
10	9.61	7.33	6.61	7.85
11	8.81	6.34	6.04	7.06
12	5.49	4.83	4.89	5.07
Mean	13.47	15.46	12.46	13.80

Source;
LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-1 Annexes, Annex I Meteorology and Hydrology", JICA.

10-Day, Monthly and Annual Mean Nyando Flow (in m3/sec) at 1GD04, 1956 - 88 (3 of 3)

Year: 1980

Month	First	Middle	Last	Mean
1	4.44	3.50	4.30	4.08
2	4.39	2.95	2.56	3.30
3	3.88	3.70	2.70	3.43
4	3.99	10.82	9.21	8.01
5	9.63	24.04	13.97	15.88
6	9.71	10.02	15.50	11.74
7	14.62	13.61	8.42	12.22
8	9.11	7.33	9.74	8.73
9	9.28	7.35	6.32	7.65
10	4.70	5.11	3.88	4.56
11	3.39	4.72	4.82	4.31
12	3.48	3.02	2.66	3.05
Mean	6.72	8.01	7.01	7.25

1982

Month	First	Middle	Last	Mean
1	3.29	2.82	2.28	2.80
2	2.34	5.17	2.29	3.27
3	2.24	2.33	2.60	2.39
4	2.73	5.10	13.90	7.24
5	12.25	18.44	15.51	15.40
6	14.70	9.87	10.97	11.85
7	8.94	6.87	6.47	7.43
8	10.44	15.27	20.95	15.55
9	11.38	8.13	7.90	9.14
10	6.10	7.81	9.33	7.75
11	13.11	13.67	23.35	16.71
12	39.42	16.33	11.68	22.48
Mean	10.58	9.32	10.60	10.17

1984

Month	First	Middle	Last	Mean
1	5.37	4.98	3.93	4.76
2	3.77	2.65	2.71	3.04
3	2.61	2.44	2.25	2.43
4	4.92	5.75	8.02	6.23
5	4.04	3.57	3.18	3.60
6	3.94	4.05	3.67	3.89
7	3.07	3.25	7.26	4.53
8	7.20	8.73	6.49	7.47
9	8.30	5.40	4.00	5.90
10	4.65	4.35	2.60	3.87
11	2.47	3.26	5.37	3.70
12	4.73	5.30	2.50	4.18
Mean	4.59	4.48	4.33	4.47

1981

Month	First	Middle	Last	Mean
1	2.74	2.21	2.89	2.61
2	6.46 *	2.94	2.05	3.82
3	2.30	6.63	8.18	5.70
4	14.77	30.92	25.09	23.59
5	14.83	24.22	11.69	16.91
6	7.93	6.28	6.96	7.06
7	6.29	11.30	17.45	11.68
8	20.12	22.23	18.19	20.18
9	16.80	14.95	19.83	17.19
10	17.00	12.46	9.15	12.87
11	7.64	7.07	5.42	6.71
12	4.12	5.20	4.42	4.58
Mean	10.08	12.20	10.94	11.08

1983

Month	First	Middle	Last	Mean
1	9.17	6.87	6.40	7.48
2	5.63	4.90	5.25	5.26
3	3.14	4.64	2.84	3.54
4	3.40	5.30	10.42	6.37
5	7.03	7.59	8.40	7.67
6	7.85	10.91	10.71	9.82
7	8.32	7.61	10.21	8.71
8	11.24	18.16	24.95	18.12
9	24.07	20.55	18.51	21.04
10	17.18	22.69	15.45	18.44
11	12.85	10.42	8.24	10.50
12	6.49	3.22	5.04	4.92
Mean	9.70	10.24	10.54	10.16

1985

Month	First	Middle	Last	Mean
1	2.21	2.57	3.50	2.76
2	4.15	2.40	2.18	2.91
3	2.37	2.84	6.15 **	3.79
4	27.21 **	64.40 **	41.29 **	44.30
5	34.67 **	38.96 **	37.93 **	37.19
6	25.54 **	15.28 **	10.53 **	17.12
7	7.27 **	6.99 **	7.27 **	7.18
8	7.46 **	14.23	15.49	12.39
9	15.08	12.86	9.75	12.56
10	7.64	7.23	5.79	6.89
11	5.68 **	4.38 **	2.61 **	4.22
12	4.88	4.27	4.40	4.52
Mean	12.01	14.70	12.24	12.99

Year: 1986

Month	First	Middle	Last	Mean
1	2.12	1.98	1.69	1.93
2	2.33	1.59	1.16	1.69
3	1.61	1.91	1.84	1.79
4	2.29	3.00	7.15	4.15
5	11.46	9.42	10.75	10.54
6	10.49	11.18	7.17	9.61
7	6.38	31.69	5.60 *	14.56
8	6.37	6.68	6.25	6.43
9	4.50	6.22	7.56	6.09
10	5.48	2.97	2.36	3.60
11	2.71	2.88	1.48	2.36
12	1.93	1.75	1.14	1.61
Mean	4.81	6.77	4.51	5.36

1988

Month	First	Middle	Last	Mean
1	1.54	2.68	3.38	2.53
2	2.11	1.82	1.34	1.76
3	0.92	0.88	5.15	2.32
4	2.71	13.80	26.04	14.18
5	21.28	24.43	10.33	18.68
6	6.46	5.45	3.91	5.27
7	8.31 *	7.57 *	10.03 *	8.64
8	27.22	30.68	25.59	27.83
9	28.51	19.44	16.31	21.42
10	24.77	18.45	10.84	18.02
11	8.80	8.61	6.89	8.10
12	3.91	3.52	3.27	3.57
Mean	11.38	11.44	10.26	11.03

1987

Month	First	Middle	Last	Mean
1	0.87	1.16	1.25	1.09
2	0.96	0.74	1.24	0.98
3	2.78	7.41	3.15	4.45
4	2.37	3.62	3.56	3.18
5	4.43	8.76	9.71	7.63
6	16.13	23.34	7.37	15.61
7	7.82	4.35	2.76	4.98
8	1.87	3.64	2.97	2.83
9	2.40	2.50	1.93	2.28
10	1.91	2.35	1.76	2.01
11	8.92 *	13.72 *	7.88 *	10.17
12	2.95	2.17	1.56	2.23
Mean	4.45	6.15	3.76	4.79

(Mean 1956-88)

Month	Mean
1	6.03
2	5.69
3	6.13
4	14.71
5	19.24
6	13.61
7	13.70
8	18.39
9	15.93
10	9.96
11	9.97
12	8.89
Mean	11.85

Note: * These figures are estimated based on the measured of 1HA04 using catchment area propotion and and mean annual discharge ratio of 3.5

** Based on the measured discharges of 1HA14 using catchment area propotion and annual discharge ratio of 2.6

Other figures come from the measured discharges of 1GD04. The calculation of mean flow in this Table does not imply flow records are complete within any 10-day period.

Source:
LBDA (1992, January) "Feasibility Study on Kano Plain Irrigation Project - Vol. II-I Annexes, Annex I Meteorology and Hydrology". JICA.

Table A3-1 General Information of Water Sources

Name of Water Sources	Catchment Area at Objective Gauging Station (km2)	Annual Mean Basin Rainfall (mm)	Annual Mean Flow (m3/d)
Lake Victoria	180,950	500 - 2,000	-
Kibos River	117	1,860	160,000
Awach River	108	1,800	116,000
Sondu River	3,287	1,500	3,688,000
Nyando River	2,520	1,460	1,024,000
Yala Rive	1,577	1,570	1,434,000

Table A3-2 Catchment Area at Intake Sites

Name	Objective Gauging Station (km2)	Proposed Intake Site (km2)
Kibos	117	117
Awach	108	82
Sondu	3,287	3,345
Nyando	2,520	2,598
Yala	1,577	1,491

Table A3-3 Water Level Gauging Stations on Objective Rivers

River System	River Name	MOWR Station Code	Location		Elevation	Catchment Area	Observation Type	Observation Period	
			Latitude	Longitude	(EL m)	(km2)		Open	Close
Kibos	Kibos	1HA04	00:00:10S	34:48:15	1,273	117	SW	1929	-
and	Awach	1HA14	00:02:50S	34:48:15	1,180	108	S	1961	-
Awach	Kibos	1HA15	00:04:05S	34:48:50	1,170	248	-	1967	1972
Sondu	Sondu	1JG01	00:23:35S	35:00:30	1,500	3,287	SR	1946	-
Nyando	Nyando	1GD01	00:09:50S	34:55:10	1,160	2,598	-	1948	1962
	Nyando	1GD03	00:08:00S	34:59:25	1,140	2,625	SR	1967	-
	Nyando	1GD04	00:06:05S	35:02:40	1,190	2,520	S	1955	-
Yala	Kimondi	1FC01	00:12:00N	35:02:55		909	S	1925	-
	Yala	1FE02	00:11:00N	34:56:10		1,577	S	1961	-

Note: S= Staff Gauge, W= Weir, R = Recorder.

Table A3-4 Low Flow Condition of Local Catchment

unit: m3/s

Name	Return Period	Duration	
		1 day	30 days
Kisyan	20-year (95%)	0.018	0.040
	10-year (90%)	0.025	0.050
Awach/Muguruk	20-year (95%)	0.012	0.028
	10-year (90%)	0.017	0.035

Table A4-1 Evaluation on Transmission from Water Sources

Name of Intake	Elevation of Proposed Intake (m)	Distance to Center of Municipality (Kibuye) (km)	Pump Requirement
Lake Victoria	1,134	5	necessary
Kibos	1,273	11	no
Awach	1,300	11	no
Sondu (1)	1,210	55	necessary
Sondu (2)	1,460	55	no
Nyando	1,150	21	necessary
Yala	1,778	22.7 (to Kibos River)	no

Table A4-2 Evaluation on Water Quality of Water Sources

Name of Water Source	Water Quality	
	Present	Future
Lake Victoria	acceptable	acceptable
Kibos River	good	good
Awach River	good	good
Sondu River	good	good
Nyando River	acceptable	acceptable
Yala River	good	good

Table A4-3 Evaluation on Water Yield of Water Sources

unit: m3/d

Name of Water Source	Annual Mean Flow	96 % Probability Daily Low Flow	Dependability 96 % Possible Water Amount
Lake Victoria	-	-	-
Kibos River	160,000	2,200	38,900
Awach River	116,000	1,500	27,200
Sondu River	3,688,000	75,100	345,600
Nyando River	1,024,000	54,400	*269,600
Yala River	1,434,000	105,400	304,100

Note: ** denotes estimated value based on the data of Sondu River

- 96 % Probability daily low flow: Minimum daily flow with the probability of once in 25-year

Table A4-4 Result of Dependability Analysis (1/4)

unit: m3/d

Dependability	Kibos (1)	Awach (1) * 82/117	Total
80	92,400	64,700	157,100
90	64,800	45,400	110,200
96	38,900	27,200	66,100
99	22,500	15,700	38,200

Table A4-4 Result of Dependability Analysis (2/4)

Dependability	Water Amount of Sondu River (m3/d)
90	527,900
96	345,600
99	207,400

Table A4-4 Result of Dependability Analysis (3/4)

Dependability	Water Amount of Nyando River (m3/d)
90	411,800
96	269,600
99	161,700

Table A4-4 Result of Dependability Analysis (4/4)

Dependability	Water Amount of Yala River (m3/d)
96	304,100
97	279,900
98	257,400
99	236,700
100	210,800

Table A4-5 Average Minimum Flows of Yala River at Proposed Intake Site

unit: m^3/s

Year	Duration of Low Flow Period (day)							
	30	21	14	9	7	5	3	1
1962	8.20	8.08	6.55	5.87	5.60	5.38	5.25	5.18
1963	6.02	4.33	4.10	3.73	3.61	3.52	3.46	3.39
1964	4.88	4.81	4.42	4.25	3.96	3.73	3.62	3.35
1965	2.66	2.58	2.44	2.39	2.38	2.38	2.35	2.33
1966	1.94	1.90	1.83	1.77	1.69	1.60	1.55	1.51
1967	1.59	1.50	1.36	1.25	1.21	1.17	1.14	1.12
1968	3.36	3.24	3.21	3.18	3.12	3.06	3.00	2.87
1969	2.88	2.51	2.37	2.25	2.14	1.97	1.82	1.69
1970	2.75	2.69	2.38	2.21	2.14	2.03	1.98	1.87
1971	1.71	1.69	1.53	1.45	1.42	1.39	1.35	1.31
1972	2.35	2.21	2.20	2.06	2.05	1.86	1.62	1.20
1973	2.78	2.65	2.52	2.49	2.49	2.48	2.43	2.38
1974	2.83	2.65	2.51	2.35	2.26	2.15	2.13	2.06
1975	2.42	2.42	2.38	2.30	2.27	2.16	2.07	1.86
1976	2.76	2.58	2.41	2.38	2.36	2.33	2.32	2.15
1977	3.04	2.83	2.48	2.38	2.41	2.30	2.17	2.10
1978	-	-	-	-	-	-	-	-
1979	7.67	7.03	6.07	5.49	5.24	5.03	4.82	4.67
1980	3.70	3.00	2.70	2.52	2.45	2.39	2.32	2.26
1981	2.59	2.17	2.05	2.01	2.01	1.99	1.94	1.91
1982	2.66	2.50	2.42	2.33	2.31	2.25	2.17	2.05
1983	5.14	4.79	4.72	4.41	4.28	4.12	3.96	3.83
1984	3.44	3.18	2.96	2.88	2.86	2.88	2.74	2.60
Average (m^3/s)	3.52	3.24	2.98	2.82	2.74	2.64	2.56	2.44
(m^3/day)	304,100	279,900	257,400	243,600	236,700	228,000	221,100	210,800
Average Dependability on Flow Duration	95.9%	97.1%	98.1%	98.8%	99.0%	99.3%	99.6%	100.0%

Note: The discharges in this table are calculated based on the low flow study result at 1FE2 on the Yala river in "Kisumu Water Supply and Sanitation Study (1988, MOLG)". The conversion factor of 0.945*1FE2 (1,491km2/1,577km2=0.945) is adopted. Relatively big flows in 1978 are excluded to avoid overestimation.

Table A5-1 Objective Water Level Gauging Stations

MOWR Station Code	River	Latitude	Longitude	Elevation (EL m)	Catchment Area (km2)	Observation Type	Observation Period Open	Observation Period Close
1HA04	Kibos	00:00:10S	34:48:15	1,273	117	S (feet), W	1929	-
1HA14	Awach	00:02:50S	34:48:15	1,180	108	S (metric)	1961	-

Notes: S = Staff Gauge, W = Weir

Table A5-3 River Maintenance Flows

River	Objective Gauging Station			Proposed Intake Site		
	(m3/s)	(m3/d)	Area(km2)	(m3/s)	(m3/d)	Area (km2)
Kibos	0.07	6,100	117 (1HA04)	0.07	6,100	117
Awach	0.04	3,500	108 (1HA14)	0.03	2,600	82
Total	0.11	9,600	225	0.10	8,700	199

Table A5-4 Water Abstraction Permits along Kibos/Awach Rivers

Permit No.	Permit Holder	Use	Nogroabs (m3/d)	Flodgros (m3/d)	Isuedate	Expdate
12585	Director of Agriculture	Gen. Irr.	0.00	768.22	04/03/75	11/30/79
12870	Municipal Council of Kisumu	Public (Kajulu)	1370.08	0.00	02/18/70	09/05/94
12871	Municipal Council of Kisumu	Public (Kajulu)	137.01	0.00	09/20/70	06/05/95
2190	Director of Agriculture	Minor Irr.	9.00	0.00	-	-
P16969	Commissioner of Prisons	Gen. Irr.	0.00	0.91	06/23/76	-
P22812	Channah Agricultural Constructors	Dom/Minor Irr.	454.35	18.18	05/06/85	-
-	Kibos Industries	Industrial	315.00	0.00	-	-
-	Joseph M. Ochieng	Dom/Minor Irr.	7.65	0.00	-	-
Total		(m3/d)	2293.09	787.31		
		(m3/s)	0.027	0.009		

Source: MOWR and Data Center, LBDA.

Note: Norgroabs; Amount abstracted when the river is flowing normally,

Flodgros; Amount abstracted when the river is under floods,

Isuedate; Date when the permit was issued, Expdate; Date when the permit will expire.

Table A5-2 Discharge Measurements Record (1/3)

- Kibos River at 1HA14 -

No.	Date	Mean Velocity (m/s)	Water Stage H (m)	Discharge Q (m3/s)
1	05-APR-53	0.070	0.06	0.077
2	27-APR-53	0.460	0.16	1.527
3	17-JAN-55	0.210	0.19	0.118
4	28-JUL-55	0.408	0.35	2.078
5	11-OCT-56	0.271	0.33	2.062
6	11-OCT-56	0.265	0.33	2.024
7	02-JAN-57	0.113	0.19	0.668
8	30-OCT-62	0.902	0.42	3.858
9	12-MAY-66	0.725	0.37	2.574
10	20-MAY-66	0.497	0.33	2.109
11	11-AUG-66	0.366	0.24	0.842
12	27-SEP-66	0.512	0.31	0.887
13	24-JAN-67	0.302	0.32	1.037
14	24-APR-67	0.317	0.20	0.663
15	27-JUN-67	0.472	0.28	1.586
16	26-AUG-68	0.482	0.30	1.649
17	10-SEP-68	0.451	0.28	1.512
18	04-OCT-68	0.518	0.29	1.555
19	08-JAN-69	0.384	0.25	1.057
20	12-FEB-69	0.768	0.48	4.602
21	02-APR-69	0.354	0.24	1.032
22	06-MAY-69	0.457	0.31	1.674
23	27-MAY-69	0.866	0.39	3.600
24	25-JUN-69	0.442	0.30	1.594
25	14-AUG-69	0.399	0.29	1.561
26	02-FEB-70	0.445	0.33	1.147
27	28-APR-70	0.573	0.36	2.546
28	08-JUL-70	0.360	0.27	1.206
29	11-AUG-70	0.305	0.24	0.797
30	09-SEP-70	0.256	0.20	0.631
31	23-SEP-70	0.357	0.24	0.852
32	06-OCT-70	0.390	0.25	1.093
33	28-OCT-70	0.332	0.23	0.761
34	17-NOV-70	0.408	0.27	1.185
35	19-DEC-70	0.280	0.21	0.676
36	03-MAR-71	0.128	0.21	0.167
37	11-JUN-71	0.296	0.29	1.063
38	10-MAY-72	0.311	0.27	1.090
39	20-NOV-73	0.482	0.32	2.081
40	05-NOV-74	0.370	0.31	1.553
41	18-APR-83	0.620	0.41	2.755
42	18-APR-83	0.620	0.41	2.755
44	19-MAR-84	0.250	0.16	0.304
43	24-APR-84	0.290	0.16	0.300
45	16-MAY-84	0.310	0.22	0.771

Source : Database System in the Headquarter of MOWR

No.	Date	Mean Velocity (m/s)	Water Stage H (m)	Discharge Q (m3/s)
46	24-JUN-84	0.370	0.26	1.173
47	06-JUL-84	0.490	0.32	1.887
48	29-AUG-84	0.580	0.46	4.046
49	13-SEP-84	0.380	0.35	2.145
50	10-OCT-84	0.350	0.27	1.501
51	17-NOV-84	0.400	0.33	2.021
52	15-DEC-84	0.450	0.33	2.145
53	31-DEC-84	0.330	0.23	0.842
54	26-JAN-85	0.280	0.27	0.609
55	09-FEB-85	0.530	0.25	0.947
56	23-FEB-85	0.200	0.16	0.286
57	14-MAY-85	0.730	0.46	5.711
58	13-JUN-85	0.490	0.40	3.157
59	15-JUL-85	0.330	0.31	1.310
60	19-AUG-85	0.380	0.27	1.244
62	14-SEP-85	0.350	0.29	1.273
61	08-OCT-85	0.350	0.24	0.978
63	09-NOV-85	0.380	0.26	1.133
64	07-APR-86	0.360	0.18	0.444
65	25-JUN-86	0.240	0.24	0.951
66	16-JUL-86	0.340	0.24	0.966
67	27-JUL-86	0.180	0.23	0.555
68	12-AUG-86	0.270	0.21	0.792
69	17-SEP-86	0.290	0.25	0.877
70	28-OCT-86	0.210	0.22	0.512
71	23-JAN-87	0.210	0.23	0.213
72	20-FEB-87	0.260	0.34	0.848
74	14-MAY-87	0.360	0.29	1.365
75	10-JUL-87	0.370	0.27	1.254
73	26-JUL-87	0.210	0.21	0.469
76	31-JUL-87	0.310	0.25	0.872
77	28-AUG-87	0.290	0.28	0.973
78	29-SEP-87	0.230	0.21	0.617
79	06-OCT-87	0.420	0.33	2.220
80	26-FEB-88	0.190	0.27	0.425
81	02-MAR-89	0.200	0.25	0.442
82	07-NOV-89	0.410	0.37	1.860
83	06-DEC-89	0.340	0.36	1.359
84	18-SEP-90	0.340	0.32	0.991
85	08-SEP-92	0.530	0.38	1.990
86	17-FEB-95	0.420	0.41	1.783
87	16-FEB-96	0.300	0.30	0.712
Weir Formulae			0.03	0.031
			0.06	0.085
			0.09	0.156
			0.12	0.235
			0.18	0.481

Table A5-2 Discharge Measurements Record (2/3)

- Awach River at 1HA14 (1/2) -

No.	Date	Mean Velocity (m/s)	Water Stage H (m)	Discharge Q (m3/s)
1	26-JUN-61	0.411	0.32	0.636
2	28-SEP-62	0.433	0.41	0.998
3	02-OCT-62	0.570	0.38	0.959
4	18-OCT-62	0.628	0.48	1.613
5	30-OCT-62	0.738	0.57	2.429
6	13-NOV-62	0.515	0.37	0.998
7	11-JAN-63	0.555	0.47	1.623
8	14-MAR-63	0.424	0.33	0.680
9	10-APR-63	0.418	0.31	0.627
10	02-MAY-63	0.783	0.85	5.664
11	23-MAY-63	0.664	0.68	3.410
12	07-JUN-63	0.658	0.62	2.819
13	14-JUN-63	0.692	0.52	2.196
14	21-JUN-63	0.546	0.45	1.607
15	28-JUN-63	0.588	0.48	1.758
16	20-AUG-63	0.442	0.30	0.686
17	19-SEP-63	0.387	0.27	0.417
18	17-OCT-63	0.314	0.21	0.271
19	30-OCT-63	0.360	0.26	0.383
20	19-NOV-63	0.591	0.41	1.261
21	07-JAN-64	0.442	0.33	0.732
22	09-JUN-64	0.536	0.46	1.692
23	18-AUG-64	0.539	0.45	1.691
24	25-AUG-64	0.533	0.37	1.269
25	17-NOV-64	0.436	0.28	0.630
26	13-JAN-65	0.378	0.24	0.449
27	12-MAR-65	0.293	0.13	0.159
28	17-JUN-65	0.497	0.24	0.604
29	09-JUL-65	0.439	0.26	0.569
30	30-NOV-65	0.396	0.26	0.542
31	10-JAN-66	0.442	0.26	0.583
32	23-FEB-66	0.619	0.38	1.354
34	23-MAR-66	0.695	0.46	1.811
33	12-MAY-66	0.750	0.53	2.492
35	20-MAY-66	0.640	0.45	1.897
36	21-JUL-66	0.494	0.34	0.966
37	11-AUG-66	0.460	0.28	0.625
38	24-JAN-67	0.475	0.31	0.657
39	16-MAY-67	0.573	0.55	2.310
40	07-JUN-67	0.357	0.39	1.397
41	27-JUN-67	0.497	0.35	1.085
42	18-SEP-67	0.567	0.42	1.512
43	26-AUG-68	0.576	0.45	1.595
44	10-SEP-68	0.533	0.41	1.284
45	04-OCT-68	0.732	0.48	2.054
46	15-NOV-68	0.561	0.34	1.020
47	08-JAN-69	0.536	0.34	0.975
48	12-FEB-69	0.716	0.61	3.122
49	02-APR-69	0.591	0.43	1.641
50	06-MAY-69	0.536	0.43	1.479
51	27-MAY-69	0.613	0.52	2.248
52	25-JUN-69	0.506	0.39	1.168
53	14-AUG-69	0.442	0.57	1.869
54	04-NOV-69	0.256	0.33	0.696
55	19-DEC-69	0.137	0.21	0.270
56	02-FEB-70	0.219	0.30	0.566
57	28-APR-70	0.512	0.44	1.558
58	08-JUL-70	0.256	0.33	0.707
59	11-AUG-70	0.274	0.39	0.830
60	09-SEP-70	0.326	0.29	0.634
61	23-SEP-70	0.287	0.33	0.743
62	06-OCT-70	0.287	0.33	0.812
63	28-OCT-70	0.171	0.28	0.442
64	17-NOV-70	0.210	0.42	0.578
65	19-DEC-70	0.079	0.21	0.167
66	06-MAY-71	0.387	0.42	1.130
67	11-JUN-71	0.509	0.42	1.501
68	16-JUL-71	0.378	0.29	0.716
69	21-SEP-71	0.661	0.39	1.394
70	02-DEC-71	0.277	0.22	0.450
71	17-FEB-72	0.314	0.27	0.530
72	10-MAY-72	0.628	0.49	1.953
75	08-SEP-72	0.482	0.39	1.450
73	15-NOV-72	0.655	0.61	3.041
74	07-MAR-73	0.475	0.31	0.910
76	23-OCT-73	0.216	0.25	0.573
77	06-FEB-74	0.019	0.10	0.040
78	24-OCT-74	0.332	0.32	1.041
79	18-JUL-75	0.344	0.28	0.619
80	14-NOV-75	0.463	0.29	0.747
81	16-DEC-75	0.326	0.28	0.587
82	13-JAN-76	0.326	0.21	0.423
83	03-FEB-76	0.155	0.10	0.134
84	17-FEB-76	0.180	0.17	0.220
85	09-MAR-76	0.162	0.10	0.156
86	18-MAY-76	0.351	0.22	0.397
87	07-JUL-76	0.366	0.27	0.579
88	31-JAN-77	0.448	0.28	0.664
89	16-MAY-77	0.866	0.56	2.782
90	02-JUN-77	0.677	0.52	1.960
91	17-NOV-77	0.649	0.42	1.573
92	17-JAN-78	0.317	0.34	1.007
93	07-FEB-78	0.347	0.22	0.481
94	20-MAY-78	0.774	0.79	5.218
95	19-JUN-78	0.558	0.39	1.286
96	31-JUL-78	0.357	0.29	0.671
97	26-AUG-78	0.442	0.32	0.851
98	12-SEP-78	0.302	0.25	0.550
99	15-JAN-79	0.238	0.21	0.294
100	27-FEB-79	0.588	0.50	2.282

Source : Database System in the Headquarter of MOWR

Table A5-2 Discharge Measurements Record (3/3)

- Awach River at 1HA14 (2/2) -

No.	Date	Mean Velocity (m/s)	Water Stage H (m)	Discharge Q (m3/s)
101	27-MAR-79	0.628	0.39	1.337
102	04-APR-79	0.399	0.32	1.106
103	19-MAY-79	0.555	0.35	1.064
104	29-JUN-79	0.533	0.35	0.996
105	04-JUL-79	0.695	0.46	1.821
106	22-AUG-79	0.287	0.29	0.658
107	19-SEP-79	0.262	0.24	0.422
108	06-OCT-79	0.277	0.27	0.715
109	11-DEC-79	0.271	0.25	0.522
110	05-MAR-80	0.280	0.18	0.321
111	17-APR-80	0.649	0.41	1.269
112	14-MAY-80	0.777	0.39	1.694
113	06-JUN-80	0.527	0.52	1.956
114	05-AUG-80	0.329	0.35	0.783
116	16-SEP-80	0.469	0.41	1.287
115	08-OCT-80	0.293	0.28	0.632
117	19-NOV-80	0.299	0.25	0.645
118	09-DEC-80	0.210	0.28	0.414
119	18-FEB-81	0.207	0.24	0.474
120	10-MAR-81	0.152	0.17	0.124
121	26-FEB-82	0.280	0.14	0.321
123	24-AUG-82	0.713	0.35	1.367
122	01-SEP-82	0.564	0.32	0.903
124	12-JAN-83	0.497	0.28	0.630
125	18-APR-83	0.713	0.43	1.608
126	12-SEP-83	0.683	0.43	1.829
127	13-SEP-83	0.582	0.42	1.671
128	19-NOV-83	0.543	0.39	1.633
129	22-FEB-84	0.207	0.10	0.123
130	24-FEB-84	0.158	0.10	0.118
131	19-MAR-84	0.152	0.10	0.106
132	17-MAY-84	0.317	0.18	0.319
133	24-MAY-84	0.372	0.24	0.574
134	20-JUN-84	0.616	0.36	1.214
135	06-JUL-84	0.387	0.22	0.621
136	13-AUG-84	0.646	0.39	1.208
137	29-AUG-84	0.671	0.42	1.725
138	13-SEP-84	0.381	0.29	0.800
139	10-OCT-84	0.451	0.28	0.740
140	17-NOV-84	0.375	0.35	0.954
141	26-NOV-84	0.384	0.34	0.950
142	09-DEC-84	0.369	0.59	2.799
143	15-DEC-84	0.625	0.41	1.516
144	31-DEC-84	0.491	0.24	0.649
145	26-JAN-85	0.372	0.27	0.624
146	09-FEB-85	0.430	0.35	1.028
147	23-FEB-85	0.229	0.20	0.327
148	02-MAR-85	0.271	0.25	0.447
149	16-MAR-85	0.168	0.14	0.135
150	23-MAR-85	0.296	0.32	0.692
151	28-APR-85	0.622	0.70	4.623
152	14-MAY-85	0.765	0.63	3.532
153	29-MAY-85	0.808	0.60	3.340
154	13-JUN-85	0.564	0.42	1.580
155	26-JUN-85	0.369	0.35	0.912
156	05-JUL-85	0.344	0.32	0.800
157	15-JUL-85	0.341	0.31	0.673
158	02-AUG-85	0.296	0.29	0.657
159	10-AUG-85	0.314	0.29	0.809
160	19-AUG-85	0.479	0.35	1.141
162	14-SEP-85	0.390	0.36	1.092
161	08-OCT-85	0.271	0.32	0.747
163	09-NOV-85	0.247	0.27	0.547
164	23-DEC-85	0.119	0.20	0.182
165	26-FEB-86	0.064	0.10	0.055
166	15-MAR-86	0.070	0.13	0.064
167	22-MAR-86	0.344	0.42	1.111
168	07-APR-86	0.280	0.20	0.268
169	28-APR-86	0.314	0.36	0.828
170	25-JUN-86	0.143	0.21	0.372
171	16-JUL-86	0.271	0.20	0.343
172	27-JUL-86	0.216	0.05	0.254
173	12-AUG-86	0.280	0.18	0.285
174	28-AUG-86	0.162	0.20	0.230
175	17-SEP-86	0.283	0.32	0.804
176	28-OCT-86	0.223	0.25	0.509
177	27-NOV-86	0.201	0.24	0.459
178	16-DEC-86	0.347	0.21	0.359
179	22-DEC-86	0.287	0.24	0.493
180	23-JAN-87	0.149	0.11	0.168
181	20-FEB-87	0.314	0.31	0.608
182	26-MAR-87	0.238	0.29	0.615
183	21-APR-87	0.317	0.34	0.853
184	14-MAY-87	0.427	0.32	0.956
185	10-JUL-87	0.247	0.32	0.618
186	31-JUL-87	0.351	0.28	0.784
187	28-AUG-87	0.280	0.32	0.573
188	29-SEP-87	0.201	0.22	0.459
189	06-OCT-87	0.262	0.28	0.646
190	26-FEB-88	0.067	0.15	0.136
191	18-MAR-88	0.259	0.27	0.584
192	05-JUL-88	0.189	0.27	0.420
193	12-JUL-88	0.247	0.25	0.471
194	19-AUG-88	0.561	0.56	2.535
195	25-OCT-88	0.198	0.21	0.418
196	05-JAN-89	0.274	0.28	0.709
197	02-MAR-89	0.244	0.28	0.603
198	16-APR-89	0.536	0.57	2.670
199	18-AUG-89	0.485	0.46	1.953
200	07-NOV-89	0.335	0.28	0.719
201	06-DEC-89	0.323	0.31	1.162
202	18-SEP-90	0.271	0.31	0.823
203	08-SEP-92	0.460	0.35	1.065
204	09-DEC-92	0.185	0.21	0.414
205	16-AUG-93	0.200	0.14	0.476
206	21-JUL-94	0.369	0.39	0.996

Source : Database System in the Headquarter of MOWR

Table A5-5 Average Minimum Flows

(Kibos River at 1HA04)

No.	Year	1-day	Q (m3/s)	7-day	Q (m3/s)	30-day	Q (m3/s)
1	1955	6-Jan	0.21	1-Jan	0.36	10-Dec	0.40
2	1956	19-Mar	0.40	14-Mar	0.45	26-Feb	0.59
3	1957	16-Feb	0.25	15-Jan	0.36	18-Jan	0.45
4	1958	23-Feb	0.25	18-Feb	0.32	7-Nov	0.50
5	1959	18-Feb	0.21	12-Mar	0.32	4-Jul	0.50
6	1960	8-Feb	0.36	3-Feb	0.45	11-Jan	0.54
7	1961	27-Apr	0.32	24-Apr	0.36	13-Jul	0.50
8	1962	25-Dec	0.84	23-Dec	1.02	10-Feb	1.59
9	1963	11-Nov	0.59	19-Oct	0.65	14-Oct	0.70
10	1964	2-Feb	0.65	29-Jan	0.65	24-Jan	0.93
11	1965	12-Apr	0.36	7-Apr	0.40	31-Jan	0.59
12	1966	21-Dec	0.40	21-Dec	0.45	11-Jan	0.59
13	1967	2-Jan	0.45	26-Dec	0.50	18-Dec	0.54
14	1968	27-Nov	0.21	26-Nov	0.28	7-Nov	0.28
15	1969	13-Feb	0.21	12-Feb	0.28	27-Jan	0.28
16	1970	1-Jan	0.36	31-Dec	0.40	7-Dec	0.45
17	1971	13-Dec	0.45	12-Oct	0.50	9-Jan	0.59
18	1972	1-Apr	0.25	1-Apr	0.25	15-Mar	0.40
19	1973	2-Apr	0.45	2-Apr	0.45	14-Mar	0.54
20	1974	17-Mar	0.18	12-Mar	0.21	29-Jan	0.34
21	1975	21-Feb	0.25	18-Feb	0.28	9-Jan	0.40
22	1976	11-Mar	0.21	5-Mar	0.25	10-Feb	0.36
23	1977	1-Jan	0.45	1-Mar	0.53	1-Jan	0.69
24	1978	11-Dec	0.84	5-Dec	1.01	31-Dec	1.39
25	1979	1-Nov	0.59	21-Dec	0.64	20-Dec	0.64
26	1980	17-Mar	0.40	5-Jan	0.50	10-Mar	0.62
27	1981	21-Jan	0.40	17-Jan	0.48	1-Jan	0.61
28	1982	13-Mar	0.65	12-Mar	0.74	18-Feb	1.01
29	1983	3-Feb	0.40	3-Mar	0.42	11-Feb	0.68
30	1984		*0.12		*0.15		*0.24
31	1985		*0.50		*0.56		*0.65
32	1986		*0.27		*0.27		*0.65
33	1987	29-Mar	0.40	23-Dec	0.52	2-Dec	0.71
34	1988	4-Apr	0.50	14-Dec	0.53	4-Dec	0.61
35	1989	2-Jan	0.54	7-Jan	0.60	1-Jan	0.82
36	1990	10-Oct	1.02	4-Dec	1.07	31-Dec	1.34
37	1991	18-Feb	0.65	4-Mar	0.65	9-Feb	0.83
38	1992	14-Mar	0.50	11-Mar	0.56	28-Feb	0.67
39	1993	9-Apr	0.65	7-Apr	0.69	26-Mar	0.81

(Awach River at 1HA14)

No.	Year	1-day	Q (m3/s)	7-day	Q (m3/s)	30-day	Q (m3/s)
1	1963	25-Oct	0.21	20-Oct	0.26	30-Sep	0.32
2	1964	31-Oct	0.30	14-Feb	0.35	24-Jan	0.45
3	1965	20-Mar	0.10	17-Mar	0.12	24-Feb	0.19
4	1966	21-Oct	0.33	20-Oct	0.33	10-Jan	0.44
5	1967		*0.15		*0.17		*0.18
6	1968	12-Feb	0.37	6-Feb	0.40	14-Jan	0.48
7	1969	31-Dec	0.16	25-Dec	0.22	2-Dec	0.36
8	1970	6-Jan	0.14	31-Dec	0.18	9-Dec	0.27
9	1971	8-Mar	0.05	4-Mar	0.06	16-Feb	0.07
10	1972	25-Jan	0.13	19-Jan	0.22	9-Jan	0.31
11	1973	7-Apr	0.17	4-Apr	0.22	2-Dec	0.38
12	1974	28-Feb	0.04	23-Feb	0.06	28-Jan	0.10
13	1975	29-Dec	0.11	19-Feb	0.15	15-Feb	0.21
14	1976	17-Mar	0.04	11-Mar	0.05	18-Feb	0.11
15	1977	1-Jan	0.25	28-Feb	0.34	5-Jan	0.57
16	1978	11-Dec	0.28	5-Dec	0.33	22-Nov	0.50
17	1979	1-Nov	0.22	27-Oct	0.25	7-Feb	0.25
18	1980	27-Feb	0.06	23-Feb	0.07	2-Feb	0.14
19	1981	31-Jan	0.06	2-Feb	0.06	14-Jan	0.09
20	1982	29-Jan	0.07	6-Feb	0.08	14-Jan	0.13
21	1983	8-Apr	0.17	5-Apr	0.18	30-Dec	0.31
22	1984	26-Mar	0.04	22-Mar	0.05	3-Mar	0.08
23	1985	14-Mar	0.17	13-Mar	0.19	20-Dec	0.22
24	1986	26-Feb	0.09	25-Feb	0.09	4-Feb	0.22
25	1987	7-Feb	0.13	3-Feb	0.14	13-Jan	0.22
26	1988	3-Mar	0.09	27-Feb	0.17	4-Feb	0.25
27	1989	31-Jan	0.19	28-Jan	0.21	7-Jan	0.29
28	1990	15-Feb	0.41	15-Aug	0.46	31-Dec	0.52
29	1991	4-Dec	0.13	3-Dec	0.16	31-Dec	0.18
30	1992	28-Jan	0.13	26-Jan	0.14	20-Feb	0.15
31	1993	24-Dec	0.15	21-Dec	0.16	30-Nov	0.21

note: The values with * are estimated by using the correlation coefficient of minimum flows between both stations.

Table A5-6 96 % Probability Daily Low Flow

River	Area	96 % Probability Daily Low Flow (1)		Maintenance Flow (refer to Table A5-3) (2)		(1) - (2)	
	(km2)	(m3/s)	(m3/d)	(m3/s)	(m3/d)	(m3/s)	(m3/d)
Kibos	117	0.16	13,800	0.07	6,100	0.09	7,700
Awach	82	0.02	1,700	0.03	2,600	0.00	0.00
Total	199	0.18	15,500	0.10	8,700	0.09	7,700

Table A5-7 Dependability 96 % Possible Water Amount

Type of Flow Duration Curve	River	Area	Dependability 96 % Possible Water Amount (1)		Maintenance Flow (refer to Table A5-3) (2)		(1) - (2)		Ratio against 45,500 m3/d in Phase I
		(km2)	(m3/s)	(m3/d)	(m3/s)	(m3/d)	(m3/s)	(m3/d)	(%)
Average	Kibos	117	0.65	56,100	0.07	6,100	0.58	50,100	-
(1974-1993)	Awach	82	0.16	13,800	0.03	2,600	0.13	11,200	-
	Total	199	0.81	69,900	0.10	8,700	0.71	61,300	135
Sequential	Kibos	117	0.50	43,200	0.07	6,100	0.43	37,100	-
(1974-1993)	Awach	82	0.11	9,500	0.03	2,600	0.08	6,900	-
	Total	199	0.61	52,700	0.10	8,700	0.51	44,000	97

Table A5-8 Water Amount and Supply Period in Phase II

River	Area	Water Amount		Ratio of Time on Average Duration Curve		
	(km2)	(m3/s)	(m3/d)	(day)	(month)	(%)
Kibos**	117	0.85	73,000	300	10	82
Awach	82	0.18	15,000	329	11	90
Total	199	1.03	88,000			

**: 73,000 m3/s = 70,000 m3/d +3,000 m3/d (Kajulu Intake)

Table A5-9 Water Amount and Dependability in Phase I

River	Area	Water Amount		Dependability on Sequential Duration Curve	
	(km2)	(m3/s)	(m3/d)	(%)	(day)
Kibos**	117	0.45	38,600	94.9	19
Awach	82	0.08	6,900	96.0	15
Total	199	0.53	45,500		

**: 38,600 m3/s = 35,600 m3/d +3,000 m3/d (Kajulu Intake)

Table A5-10 Summary of Water Abstraction Amount

unit: m3/d

River	Phase I (up to year 2005)	Phase II (up to year 2015)
Kibos	38,600	73,000
Awach	6,900	15,000
Total	45,500	88,000