MINISTRY OF WATER AND ENVIRONMENT
THE REPUBLIC OF UGANDA
DIRECTORATE OF WATER RESOURCES
MANAGEMENT (DWRM) &
DIRECTORATE OF WATER DEVELOPMENT (DWD)

THE DEVELOPMENT STUDY
ON
WATER RESOURCES DEVELOPMENT AND MANAGEMENT FOR LAKE KYOGA BASIN
IN
THE REPUBLIC OF UGANDA

FINAL REPORT
SUPPORTING REPORT

March 2011

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

OYO INTERNATIONAL CORPORATION
IN ASSOCIATION WITH
TOKYO ENGINEERING CONSULTANTS Co., Ltd.
AND
ORIENTAL CONSULTANTS Co., Ltd.

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ABBREVIATION

ADB	African Development Bank
ADC	Austrian Development Cooperation
ASL	Above Sea Level
BADEA	Arab Bank for Economic Development in Africa
BH	Borehole
BHN	Basic Human Needs
BOD	Biochemical Oxygen Demand
CBMS	Community Based Management System
CBO	Community Based Organization
CFR	Central Forest Reserve
CMO	Catchment Management Organization
COD	Chemical Oxygen Demand
C/P	Counterpart
CRED	Centre for Research on the Epidemiology of Disasters
DANIDA	Danish International Development Agency
DEA	Directorate of Environmental Affairs
DEM	Digital Elevation Model
DHI	Danish Hydraulic Institute
DO	Dissolved Oxygen
DWD	Directorate of Water Development
DWRM	Directorate of Water Resources Management
DWSCC	District Water and Sanitation Coordination Committee
EA	Environmental Audit
EC	Electric Conductivity (mS/m)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return

EIS	Environmental Impact Statement
EM-DAT	Emergency Events Database
ETM	Enhanced Thematic Mapper
EU	European Union
FAO	Food and Agriculture Organization
FIEFOC	Farm Income Enhancement and Forestry Conservation Project
GDP	Gross Domestic Product
GFS	Gravity Flow Scheme
GIS	Geographic Information System
GoU	Government of Uganda
GPS	Global Positioning System
HH	Household
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IPCC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
ITCZ	Inter-Tropical Convergence Zone
JFP	Joint Partnership Fund
JICA	Japan International Cooperation Agency
JSR	Joint Sector Review
JTR	Joint Technical Review
LANDSAT	Land sensing Satellite
LC	Local Council
LFR	Local Forest Reserve
MAAIF	Ministry of Agriculture, Animal Industry and Fisheries
MAC	Maximum Allowable Concentration
MCM	Million Cubic Meter

MDG	Millennium Development Goals
MERECP	Mount Elgon Ecosystem Conservation Programme
MoEMD	Ministry of Energy and Mineral Development
MoES	Ministry of Education and Sports
MoFA	Ministry of Foreign Affair
MFPED	Ministry of Finance Planning and Economic Development
MGLSD	Ministry of Gender, Labour and Social Development
MoH	Ministry of Health
MoLG	Ministry of Local Government
MoWLE	Ministry of Water, Land and Environment
MoWE	Ministry of Water and Environment
MoWT	Ministry of Works and Transport
MoTTI	Ministry of Tourism, Trade and Industry
UBoS	Uganda Bureau of Statistics
NAADS	National Agricultural Advisory Services
NASA	National Aeronautics and Space Administration
NDP	National Development Plan
NEMA	National Environment Management Authority
NFA	National Forestry Authority
NGO	Non Government Organization
NGWDB	National Groundwater DataBase
NPV	Net Present Value
NSWG	National Sanitation Working Group
NWSC	National Water and Sewerage Corporation
OFDA	Office of U.S. Foreign Disaster Assistance
O&M	Operation & Maintenance
PCA	Principle Component Analysis

PEAP	Poverty Eradication Action Plan
RGC	Rural Growth Center
RWS	Rural Water Supply
RWSS	Rural Water Supply and Sanitation
SIDA	Swedish International Development Cooperation Agency
SRTM	Shuttle Rader Topography Mission
SS	Suspended Solids
SSIP	Strategic Sector Investment Plan
SWAP	Sector Wide Approach
TDS	Total Dissolved Solid
TLU	Tropical Livestock Unit
TM	Thematic Mapper
TNTC	Too Numerous To Count
TOR	Terms of Reference
TSU	Technical Support Unit
UBoS	Uganda Bureau of Statistics
UFW	Unaccounted For Water
UGX	Ugandan Shilling
UK	United Kingdom
ULGA	Uganda Local Governments Association
UNICEF	United Nations Children’s Fund
UNITAR	United Nations Institute for Training and Research
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNOSAT	UNITAR Operational Satellite Applications Programme
UNRA	Uganda National Road Authority
UO	Umbrella Organization
USA	United States of America

USGS	United States Geological Survey
UTM	Universal Transverse Mercator
UWA	Uganda Wildlife Association
UWA-FACE	UWA-Forest Absorption Carbon-dioxide Emission
UWASNET	Uganda Water and Sanitation NGO Network
UWSS	Urban Water Supply and Sanitation
VSW	Vegetation-Soil-Water
WATSUP	Water Atlas Up-date Project
WESWG	Water and Environment Sector Working Group
WfP	Water for Production
WFP	World Food Programme
WGS	World Geodetic System
WHO	World Health Organization
WMO	World Meteorological Organization
WMZ	Water Management Zone
WPC	Water Policy Committee
WRM	Water Resources Management
WRMD	Water Resources Management Department
WSDF	Water and Sanitation Development Facility
WSC	Water and Sanitation Committee
WSSB	Water Supply and Sanitation Board
WSSWG	Water and Sanitation Sector Working Group
WUC	Water User Committee

CHAPTER 1 METEOROLOGY AND HYDROLOGY

1.1 Meteorology

1.1.1 Meteorological Network and Climatological Zones

The Department of Meteorology in Uganda has been monitoring climatic changes in the country. Prior 1977, the Department originally had over 1,000 weather stations (mainly rainfall stations) spread throughout the country. Conversely, due to the political turmoil of the 1970's, most of these got damaged or were neglected. By 2001, only 60 weather stations were operational in whole Uganda. The few remaining stations have often focused their attention on obtaining data regarding only two climate variables; temperature and rainfall.

Under the severe condition, DWRM conducted a hydroclimatic study mainly based on existing rainfall data. The result was consolidated to "Hydroclimatic Study Report (2001)". A climatological zoning was undertaken in the report. The basic zones were delineated by Basalirwa et al (1993) in his study, and DWRM extended this zoning concept in "Hydroclimatic Study (2001)". The zones were delineated with monthly rainfall data at 102 rain gauges for the period 1940-1975. Therefore, following meteorological analyses in the JICA Study were conducted based on this extended climatological zoning. Table 1-1 shows the characteristics of the zones in Lake Kyoga Basin mentioned in the "Hydroclimatic Study (2001)".

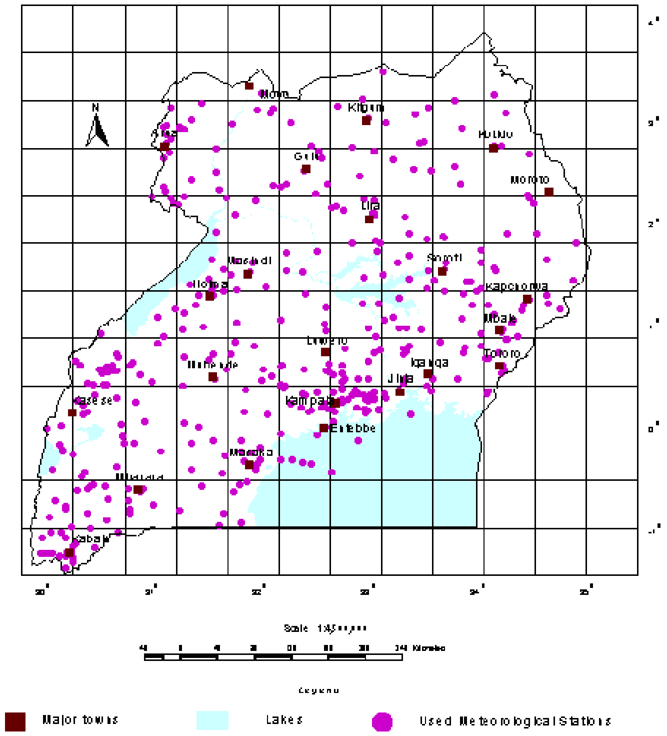


Figure 1-1 Existing Rainfall Stations in Whole Uganda

(Source; Hydroclimatic Study Report, 2001, DWRM)

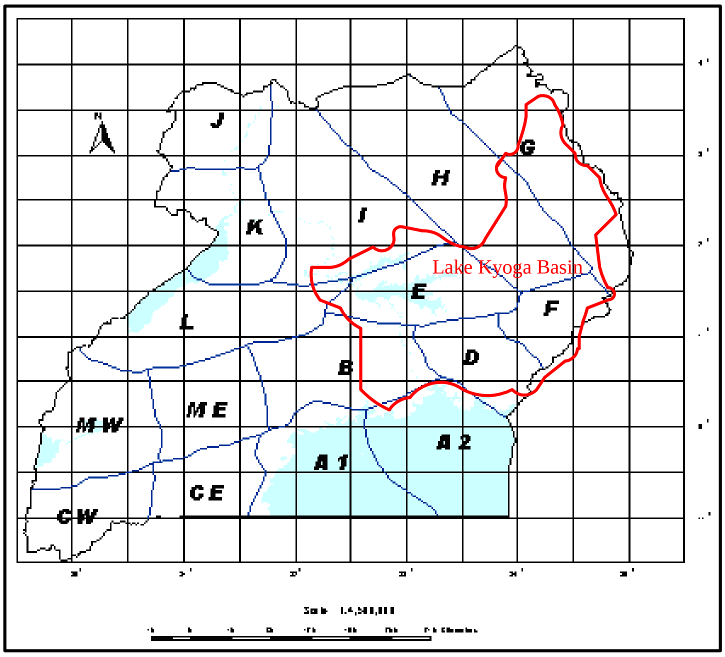


Figure 1-2 Climatological Zoning in Whole Uganda

Table 1-1 Characteristics of Climatological Zones in Lake Kyoga Basin

Zone	Annual rainfall (mm)	Main Rainy Season	Main Dry Season	Excess Months
A2	1,443	2 rainy seasons	2 dry seasons	2 months
B	1,250	2 rainy seasons	2 dry seasons	2 months
D	1,316	2 rainy seasons	2 dry seasons	3 months
E	1,215	1 rainy seasons	1 dry season	3 months
F	1,328	1 rainy seasons	1 dry season	8 months
G	745	I rainy season with 2 peaks	1 dry season	Over 10 months
H	1,197	I rainy season with 2 peaks	1 dry season	Over 10 months
I	1,340	I rainy season with 2 peaks	1 dry season	Over 10 months
L	1,270	2 rainy seasons	1 dry season	5 months

Note：Excess Months means number of months in a year while monthly evaporation is larger than monthly rainfall.

1.1.2 Meteorological Data Analyses

At first, the Study Team collected existing meteorological data from DWRM. However, the period of collected data were mainly prior 1998 and had many large or short gaps in observation period (see Chapter 13, Figure A13-1). In addition, other observation items except rainfall are few. This made it difficult to study the regional characteristics of climate due to not being able to compare them under the same condition (same period). Therefore, the new weather data were collected to make up for the shortage from the Department of Meteorology such as monthly records on rainfall, air temperature, sunshine hours, pan evaporation and relative humidity of the stations covering period since 1999 to 2008.

Figure1-3 shows the distribution of the meteorological stations where data collected. Those are operated by Department of Meteorology and other governmental organizations in and adjacent to the study area. The numbers of the stations are a few by

Figure 1-3 Distribution of the Weather Stations where Data Collected

comparison with the largeness of the study area.

(1) Monthly rainfall

Uganda has a tropical climate characterized by strong seasonality in rainfall as a consequence of the influence of the seasonal latitudinal movement of the equatorial low-pressure trough and Inter-Tropical Convergence Zone (ITCZ). Mean annual rainfall for the country is **1,300 mm** but shows great spatial variability. In the study area, mean annual rainfall varies 989 mm (Kakooge) to 2,477 mm (Buginyanya) spatially and the average is 1,466 mm. However, it is necessary to beware of lack of data in north-eastern parts of the study area, called Karamoja because of the destruction of weather stations by vandalism. This area seems to have semi-arid climate.

The rainfall data (Figure 1-4) shows that the study area experiences typically two annual rainfall maxima between March to May and September to November. However, in the drier parts, rainfall between the two maxima is not strikingly different thereby producing a uni-modal type of distribution. These parts are characterised by one long dry season followed by one long wet season.

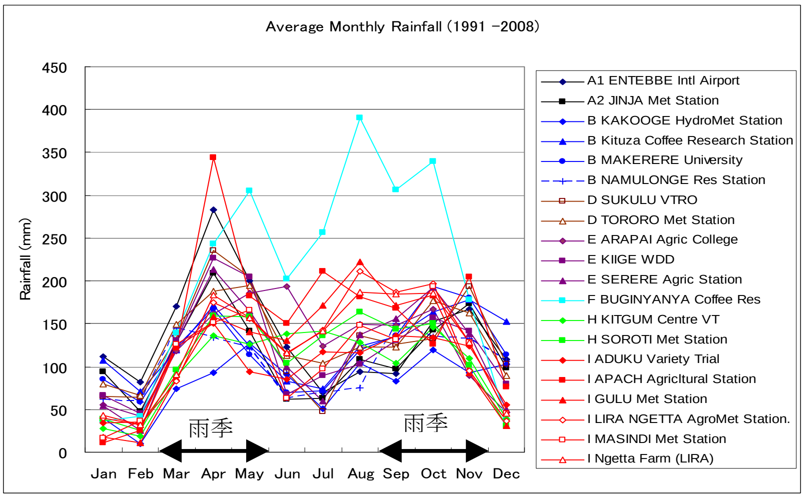


Figure 1-4 Average Monthly Rainfall

(2) Air Temperature

Air temperature of the several stations in the study area and the surrounding areas was analyzed as Figure 1-5. This figure presents mean maximum and minimum temperature for each month at the stations. Annual variation and difference of maximum temperature among the stations are bigger than those of minimum temperature. The temperatures are higher on January and February and lower on June or July.

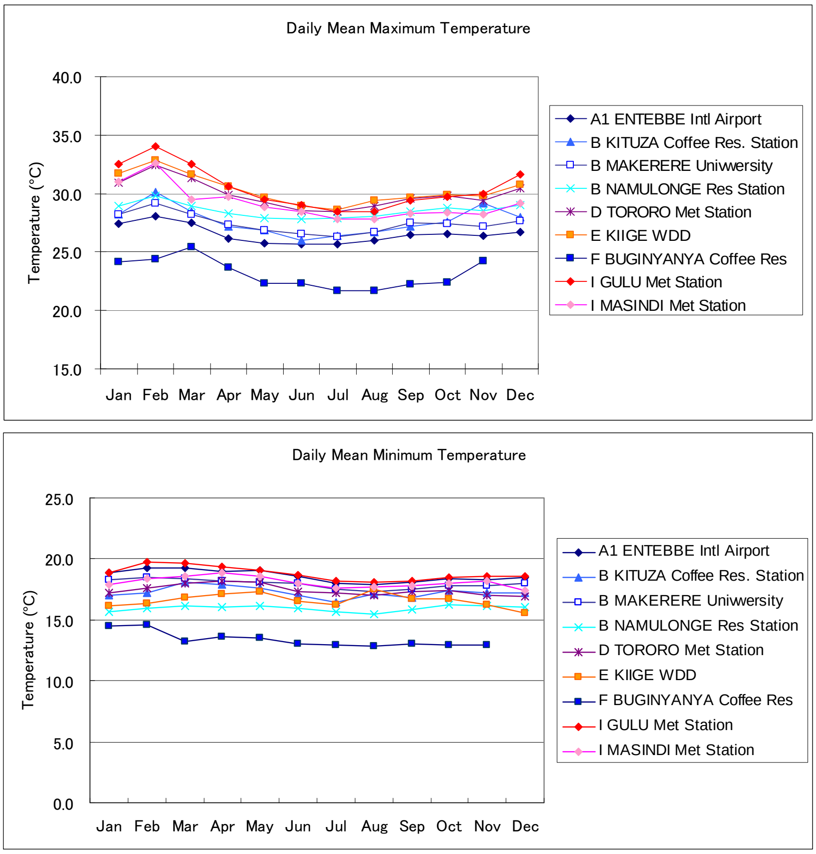


Figure 1-5 Averaged Maximum and Minimum Temperature

(3) Sunshine Hours

The Department of Meteorology has not enough records for sunshine hours during 1999 to 2008 so that the records between 1961 and 1971 are provided instead of them. Sunshine hours of the several stations in the study and the surrounding areas were analyzed as Figure 1-6. This figure presents daily mean sunshine hours for every month. Annual variation patterns of sunshine hours among the stations are the longest on January and the shortest on April, July or October. Daily mean sunshine hour is longer in central and northern area than southern area except Tororo. Daily mean sunshine hour in a year is 6.8 hours in the study area.

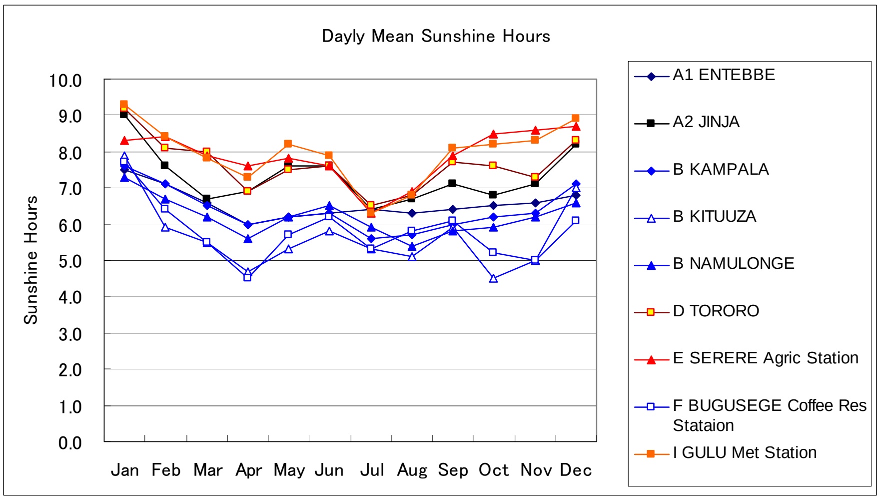


Figure 1-6 Daily Mean Sunshine Hours

(4) Pan Evaporation

The Department of Meteorology has not enough records of pan evaporation during 1999 to 2008 so that the records between 1969 and 1978 are provided instead of them. Pan evaporation data of the several stations in the study area and the surrounding area was analyzed as Figure 1-7. The figure presents daily mean pan evaporation for each month at the stations. Many stations show their highest value on February, and a few on January or December. The annual mean pan evaporation is 1,751 mm. The value exceeds annual mean rainfall in the study area. The highest value was recorded at Nakapiripirit station on January. The record of Nakapiripirit station shows more remarkable seasonal change than those of the other stations. The seasonal change of pan evaporation seems to follow the temperature.

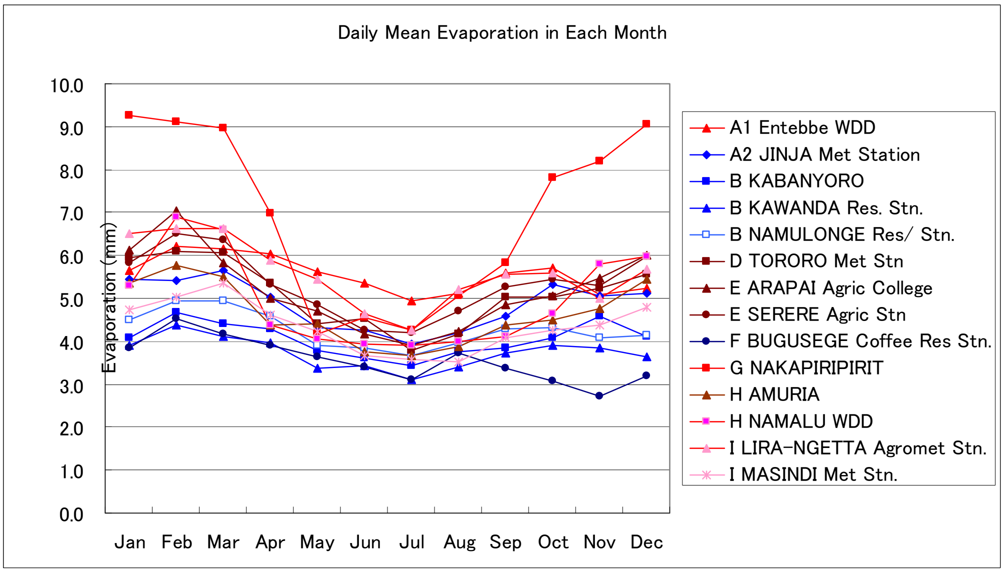
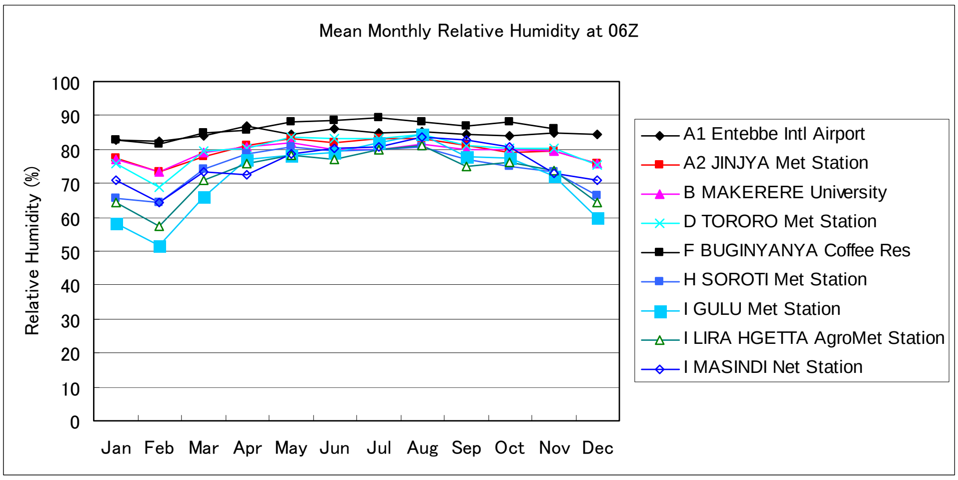


Figure 1-7 Daily Mean Evaporation

(5) Relative humidity

Relative humidity of the several stations in the study and the surrounding areas was analyzed as Figure 1-8. The figure presents monthly mean relative humidity at 6 A.M. and 12 A.M. at major weather stations in the study area and its surroundings. The relative humidity at 6 A.M. shows higher value than that at 12 A.M. at each station. The spatial distribution of relative humidity varies wider during dry season than rainy season.

Annual variation patterns of relative humidity among the stations are similar.



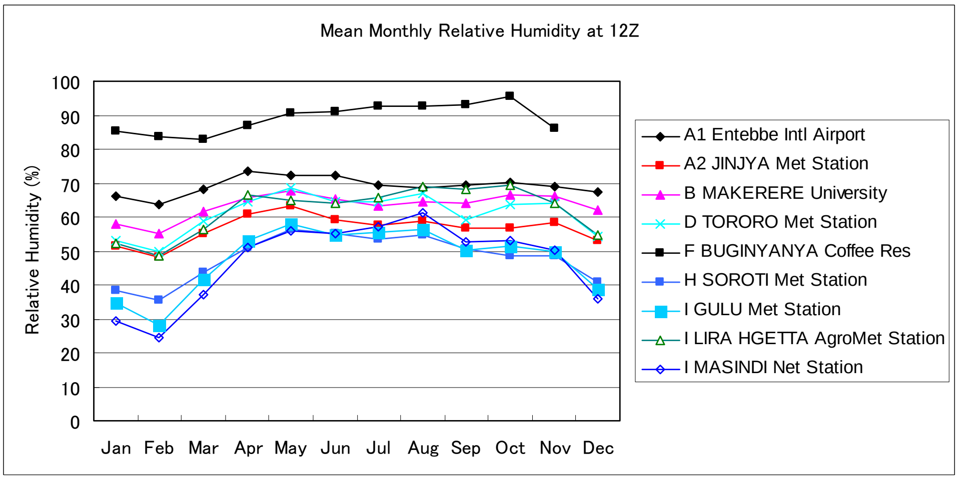


Figure 1-8 Averaged Relative Humidity

(upper: 6;00AM, lower: 12;00AM)

1.2 Hydrology

1.2.1 River Network and Gauging Stations

(1) Sub Basins in the Lake Kyoga Basin

River network was generated newly by using DEM (Digital Elevation Model) data and sub-basins (river catchments) also were defined for convenience by SRTM (Shuttle Radar Topographic Mission) data as illustrated in the Figure 1-9. The area and name of each sub-basin are shown in Table 1-2. The sub-basins are named after main rivers in each sub-basin.

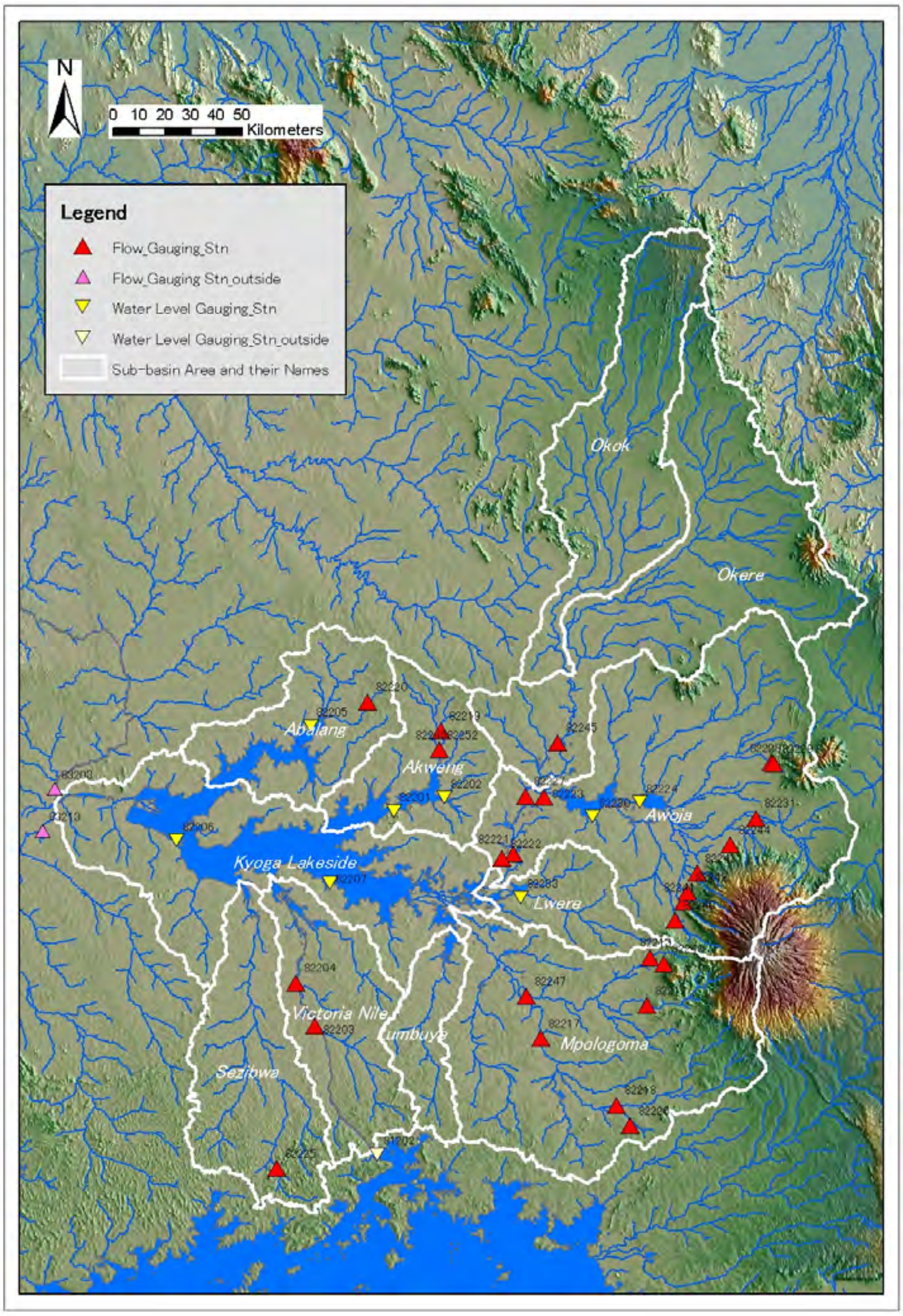


Figure 1-9 River Network, Sub-basins and River Gauging Stations

Table 1-2 List of Lake Kyoga Sub-basins

No	Name of Sub-basin	Land Area (km2)	Water Area (km2)	Total Area (km2)
1	Okok	5,512	0	5,512
2	Okere	8,199	8	8,207
3	Awoja	10,717	270	10,987
4	Lwere	1,618	58	1,676
5	Akweng	2,504	343	2,847
6	Abalang	2,908	386	3,294
7	Kyoga Lakeside Zone	5,206	2,173	7,379
8	Mpologoma	7,862	1,127	8,989
9	Lumbuye	1,478	42	1,520
10	Victoria Nile	3,456	126	3,582
11	Sezibwa	4,225	20	4,245
Total		53,685	4,553	58,238

Source: JICA Study Team

(2) Monitoring Network of River Discharge

There are some gauging stations located at not suitable points for monitoring total river discharge of each river. This is mainly due to the geomorphological characteristics of Lake Kyoga Basin. The Study Team and the counterpart visited as many gauging stations as possible, and checked their effectiveness. The result is summarized in Table 1-3.

The survey result pointed that some existing gauging stations have following disadvantages

- The rivers ordinarily have no embankments so that some gauging stations located in lower land can not measure discharges during high water and flooding.
- Some gauging stations installed at wide wetland do not measure total river discharge because there are number of river channels without gauges.
- Some gauging stations have effect of back water so that the water level of down stream affects the discharge. This means that rating curve method can not apply to such stations.
- Some gauging stations are installed at bent sides of rivers.
- Gauging stations with growing grass around the riverfront may have different quantity of river discharge for same river water level.

Monitoring of river discharge has been implemented continuously, but the monitoring data is not necessary to represent real river discharge at some gauging stations. In such a case, the effort of taking monitoring data will be no use for estimation of surface water resources. Therefore, it is strongly recommended to review install points and observation method of monitoring river discharge and their distribution. Our proposed future situation of each gauging station were added to Table 2-3. Some gauging stations will be recommended to continue their observation in spite of their weakness for measuring river water discharge. This is because the influence of the weakness to their river flow observation is small and the benefit of continuous observation (data accumulation) is more than the deficit. This recommendation is reflected in the Basin Plan.

Table 1-3 Result of Site Survey on the Existing Gauging Stations

Sub-basin	Station Name	Station ID	Characteristics of River Gauging Stations							Wet-land	Current Observation Status	Proposed Future Situation
			Linear-ity	Cross Section	Bed Slope	Obsta-cle	Over-flow	Single course	Back Water			
Okere	R. Akokorio at Soroti - Katakwi Road	82245	X	X	---	---	---	X	---	X	Cessation	Not use
Awoja	R. Agu at Kumi - Serere Road	82221	---	X	---	X	X	---	X	X	Operating	Not use due to Back water
Awoja	R. Abuket at Kumi - Serere Road	82222	curve	---	---	---	X	---	---	---	Operating	Not use: it cannot measure total discharge
Awoja	R. Kapiri at Kumi - Soroti Road	82227	Pond	X	---	X	X	---	X	---	Operating	Not use due to Back water.
Awoja	R. Kelim (Greek) at Mbale - Moroto Road	82231	---	---	---	---	X	---	---	---	Operating	Use
Awoja	R. Sironko at Mbale - Moroto Road	82240	curve	---	---	---	X	---	---	---	Operating	Use
Awoja	R. Simu at Mbale - Moroto Road	82241	---	---	---	---	X	---	---	---	Cessation	Not use
Awoja	R. Sipi at Mbale - Moroto Road	82243	---	---	---	---	---	---	---	---	Cessation	Not use
Abalang	R. Enget at Bata - Dokolo Road	82220	curve	X	---		X	---	---	X	Operating	Not use due to unsuitable location.
Mpologoma	R. Manafwa at Mbale - Tororo Road	82212	curve	---	---	---	---	---	---	---	Operating	Use
Mpologoma	R. Mpologoma at Budumba	82217	---	X		X	X	---	---	X	Operating	Use after Rehabilitation
Mpologoma	R. Malaba at Jinja - Tororo Road	82218	---	X	---	X	X	---	---	---	Operating	Use after Rehabilitation
Mpologoma	R. Namatsyo at Busamaga	82247	X	X	---	X	X	X	---	X	Cessation	Not use
Victoria Nile	R. Victoria Nile at Mbulamuti	82203	---.	---	---	---	---.	---	---	---	Operating	Use
Sezibwa	R. Sezibwa at Falls	82225	curve	---	---	---	X	---	---	---	Operating	Looking for another suitable point at the periphery
Outside	R. Kyoga Nile at Masindi Port	83203	---	---	---	---	---	---	---	---	Operating	Use

Note: “X” points out that the station has a disadvantage corresponded to the item.

1.2.2 River Flow Regime

Flow regime of rivers in sub-basins was studied for all gauging stations where data obtained. The periods of the data coverage are shown in Chapter 12 (see Figure A12-2). The characteristics of the sub-basins were summarized into Table 1-4 and 1-5. As stated above, some gauging stations may not measure proper river discharge so that the tables contain information on the applicability for water resources estimation. Furthermore, the tables also include the analysis results of Masindi Port gauging station (83202) and Kafu gauging station (83213) for reference. The gauging station at Masindi Port measures whole river discharge from the study area including river flow discharge from Kafu river and the rest of the other own catchment area.

The analysis results are summarized in followings:

- In the northern area of the study area, it has annual average discharge, but no low and drought water discharges. It is difficult to do stable surface water use. This result should be reviewed by other methods due to reliability of the gauging stations. JICA Study Team has checked this results using Mike Basin in the report (see Chapter 12).
- In the southern area of the study area, it has some low and drought water discharges
- In the sub-basins having Mount Elgon area, the duration curves decrease more rapidly as the locations of the gauging stations approach to Mount Elgon (the catchment areas are getting smaller). It means that the station usually has small discharge, but sometimes has high water condition (flooding), and the station far from Mount Elgon has stable discharge.
- In Awoja sub-basin located at north of Mount Elgon, the gauging station has low water discharge, but no drought discharge.
- In Mpologoma sub-basin located at southwest of Mount Elgon, the flow regimes are more stable than the other sub-basin, and it has low and drought water discharges.
- The flow regime of a gauging station with wider catchment is getting more stable than those with smaller catchments (see the duration curves of Victoria Nile and Masindi Port sub-basins, for example).

Note) Low water discharge: 275th discharge from the greatest daily discharge.

Drought water discharge: 355th discharge from the greatest daily discharge.

The periods of the discharge observation data used for the analysis are different at each gauging stations. This is because the analysis requests longer complete observation data with no gap in each hydrological year, however this extremely reduce the numbers of available gauging stations.

Table 1-4 Summary of the River Discharge Duration Curves Analyses (1)

Sub-Basin		Gauging Station No.	Suitability for Analysis	River Discharge				Discharge Ratio	
				Maximum (m^3/s)	Average (m^3/s)	Low water (m^3/s)	Drought water (m^3/s)	Low water / Average	Drought water / Average
1	Okok	No Data	Ina						
2	Okere	82245	S	48.03	2.28	0	0	0%	0%
3	Awoja	82221	Ina	125.37	7.7	1.3	0.04	17%	1%
		82222	G	246.30	3.98	0.01	0	0%	0%
		82223	G	292.96	14.16	0.9	0.07	6%	0%
		82227	G	381.67	13.35	0.58	0	4%	0%
		82228	G	19.81	0.43	0.08	0.04	19%	9%
		82229	?	4.53	0.36	0.05	0	14%	0%
		82231	VG	118.63	6.02	0.54	0.01	9%	0%
		82240	G	107.07	4.53	1.29	0.3	28%	7%
		82241	G	43.72	3.92	1.27	0.63	32%	16%
		82242	G	12.40	3.14	0.7	0.01	22%	0%
		82243	G	59.82	3.9	0.25	0	6%	0%
		82244	G	21.77	3.23	0.77	0.15	24%	5%
4	Lwere	No Data							
5	Akwenge	82219	G	21.66	3.07	1.72	0.18	56%	6%
		82246	Ina	12.26	1.08	0%	0	0%	0%
		82252	Ina	2.97	0.74	30%	0	40%	0%
6	Abalang	82220	G	5.89	0.44	0.13	0.02	30%	5%
7	Kyoga Lakeside Zone	No Data							
8	Mpologoma	82212	G	92.22	7.75	2.72	0.81	35%	10%
		82213	G	56.65	2.4	1.04	0.32	43%	13%
		82217	?	233.68	25.36	9.69	0.19	38%	1%
		82218	S	74.79	14.34	4.69	0.96	33%	7%
		82226	S	38.70	1.14	0.27	0.05	24%	4%
		82247	Ina	0.94	0.24	0.14	0.08	58%	33%
		82248	S	1.69	0.87	0.76	0.61	87%	70%
9	Lumbuye	No Data							
10	Victoria Nile	82203	G	1,810.89	1128.94	943.4	609.17	84%	54%
		82204	G	2,048.78	1068.58	614.1	516.25	57%	48%
11	Sezibwa	82225	S	18.77	1.48	0.72	0.32	49%	22%
other	Masindi	83203	G	1,784.35	968.16	729.6	466.12	75%	48%
	Kafu	83213	G	190.27	16.43	4.43	1.04	27%	6%

Note: Suitability VG: Very Good G: Good S：Satisfactory Ina：Inadequate ?: Unknown

Table 1-5 Summary of the River Discharge Duration Curves Analyses (2)

Sub-Basin		Gauging Station No.	Suitability for Analysis	Catchment area of the Station (Km^2)	Runnoff Depth			Specific Runnoff (m^3/s/km^2)
					Average (mm/day)	Low water (mm/day)	Drought water (mm/day)	
1	Okok	No Data	Ina					
2	Okere	82245	S	12,658	0.02	0.00	0.00	0.00018
3	Awoja	82221	Ina	25,385	0.03	0.00	0.00	0.00030
		82222	G	1,403	0.25	0.00	0.00	0.00284
		82223	G	24,485	0.05	0.00	0.00	0.00058
		82227	G	14,123	0.08	0.00	0.00	0.00095
		82228	G	37	1.00	0.19	0.09	0.01162
		82229	?	36	0.86	0.12	0.00	0.01000
		82231	VG	1,403	0.37	0.03	0.00	0.00429
		82240	G	265	1.48	0.42	0.10	0.01709
		82241	G	165	2.05	0.67	0.33	0.02376
		82242	G	136	1.99	0.44	0.01	0.02309
		82243	G	92	3.66	0.23	0.00	0.04239
		82244	G	70	3.99	0.95	0.19	0.04614
4	Lwere	No Data						
5	Akwenge	82219	G	693	0.38	0.21	0.02	0.00443
		82246	Ina	608	0.15	0.00	0.00	0.00178
		82252	Ina	696	0.09	0.03	0.00	0.00106
6	Abalang	82220	G	104	0.37	0.11	0.02	0.00424
7	Kyoga Lakeside Zone	No Data						
8	Mpologoma	82212	G	486	1.38	0.48	0.14	0.01596
		82213	G	124	1.68	0.73	0.22	0.01942
		82217	?	3,502	0.63	0.24	0.00	0.00724
		82218	S	1,513	0.82	0.27	0.05	0.00948
		82226	S	92	1.07	0.25	0.05	0.01239
		82247	Ina	16	1.30	0.76	0.43	0.01500
		82248	S	47	1.60	1.40	1.12	0.01851
9	Lumbuye	No Data						
10	Victoria Nile	82203	G	265,727	0.37	0.31	0.20	0.00425
		82204	G	266,342	0.35	0.20	0.17	0.00401
11	Sezibwa	82225	S	172	0.74	0.36	0.16	0.00862
Other	Masindi	83203	G	339,779	0.25	0.19	0.12	0.00285
	Kafu	83213	G	15,365	0.09	0.02	0.01	0.00107

Note: Suitability VG: Very Good G: Good S：Satisfactory Ina：Inadequate ?: Unknown

1.2.3 Lake Water Level Change

Lake Kyoga Basin has many lakes such as Lake Kyoga, Lake Kwania, Lake Bisina and Lake Opeta, and their water level observations have been done. However, most of them have stopped their observation by the beginning of 1980s. Only one gauging stations at Bugondo Pier in Lake Kyoga has been working by now.

The lake water level changes of Lake Victoria and Lake Kyoga are summarized in Figure 1-10. The values of each water level show the heights of the lake waters from the each control point due to large difference between those control point levels. The difference reaches about 102.2m.

The figure shows the water level of Lake Kyoga is closely linking to that of Lake Victoria. This result corresponds to the fact that the discharge from Lake Kyoga is nearly equal the discharge from Lake Victoria. This means that the lake hydrology is governed by the discharge from the Victoria Nile. In rough order of magnitude, the variations between high and low lake water levels can be seen to vary 0.5-1.0 m from year to year between extreme events. The 1962-1964 floods and the 1997-1998 floods added 1-2 m to these levels. It is said that the causes are record rainfalls in the years.

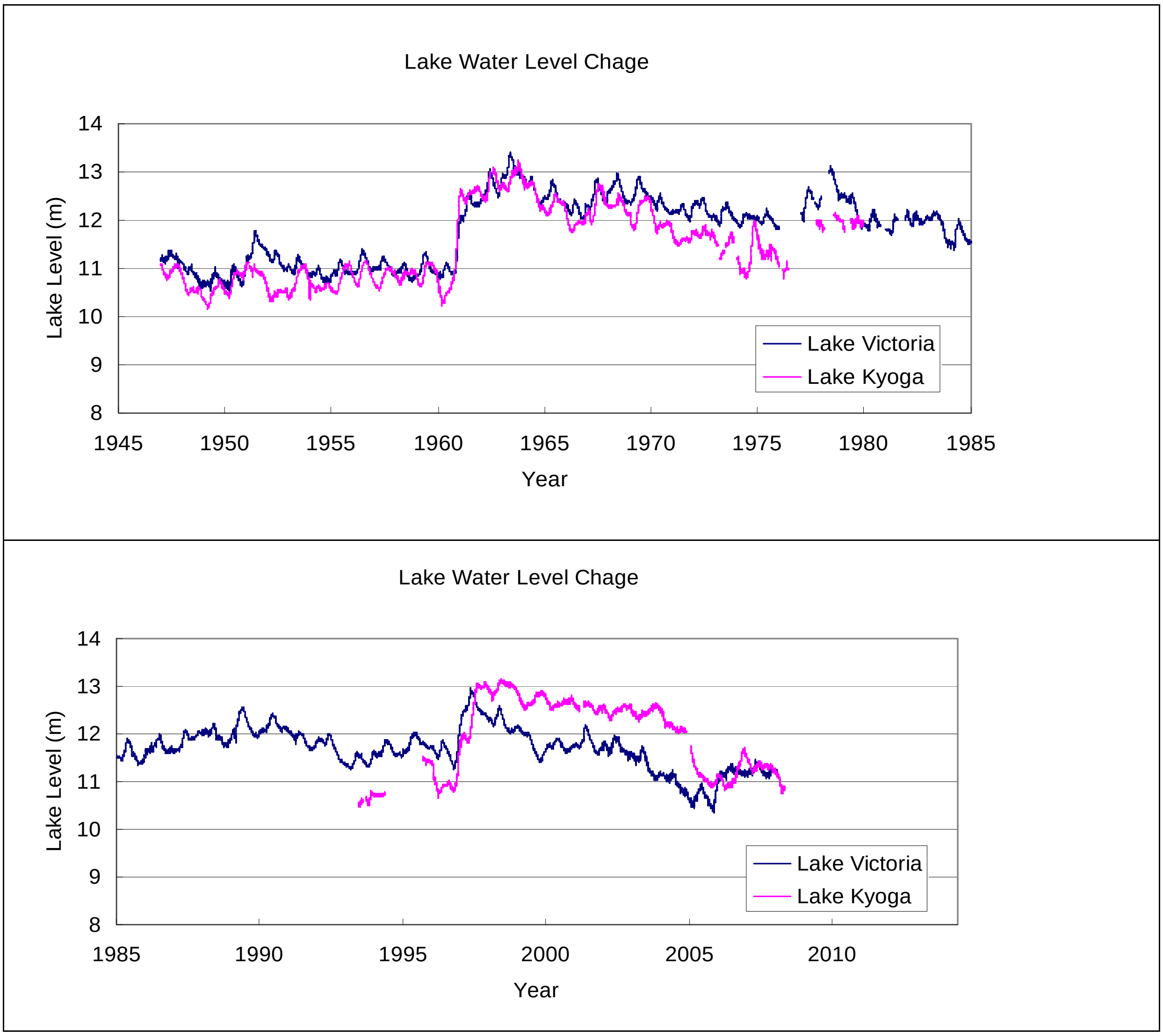


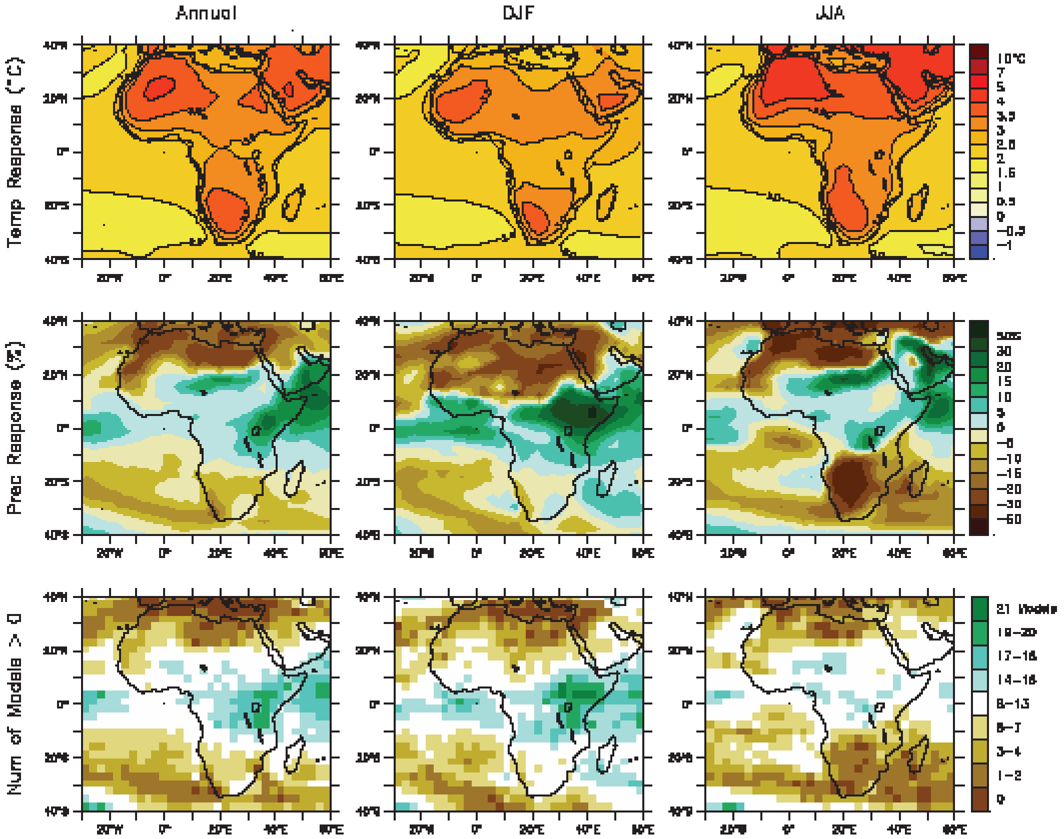
Figure 1-10 Water Level Changes of Lake Kyoga and Lake Victoria

1.3 Climatic Change

1.3.1 Climate Change Projection in IPCC Fourth Assessment Report

Increasingly reliable regional climate change projections are now available for many regions of the world due to advances in modeling and understanding of the physical processes of the climate system. IPCC (Intergovernmental Panel on Climate Change) Fourth Assessment Report contains projection of regional climate change in future using a method of comparison between model simulation results and climate observation data.

The estimation on regional change of rainfall was implemented based on the result that global model and down-scaling model have given the same projections under physical consideration of climatic system.



source : IPCC Fourth Assessment Report WG1 Page 869

Figure 1-11 Temperature and Precipitation Changes from the MMD-AIB Simulations

Figure 1-11 is an example of climate change simulation results over Africa. Figures in above line show temperature change and figures in middle line shows precipitation change. This simulation result shows that annual rainfall around Uganda is likely to increase in the 21st century. The simulation result for December to February and June to August also show that the precipitations in those periods are likely to increase.

The figures in bottom line shows number of simulation models those projections have a tendency of precipitation increase. Most models in the 21 models say that precipitation will increase around

Uganda.

In addition to this, IPCC Fourth Assessment Report pointed out following matters with high certainty.

- All of Africa is very likely to warm during this century. The warming is very likely to be larger than the global, annual mean warming throughout the continent and in all seasons, with drier subtropical regions warming more than the moister tropics.
- Annual rainfall is likely to decrease in much of Mediterranean Africa and northern Sahara, with the likelihood of a decrease in rainfall increasing as the Mediterranean coast is approached.
- Rainfall in southern Africa is likely to decrease in much of the winter rainfall region and on western margins.
- There is likely to be an increase in annual mean rainfall in East Africa.
- It is uncertain how rainfall in the Sahel, the Guinean Coast and the southern Sahara will evolve in this century.

1.3.2 Climate Change Prediction of the Government of Uganda

In 2006, the government of Uganda issued a report, “Climate Change: Uganda National Adaptation Programmes of Action”. The report studied rainfall data from 1943 to 1999. The key points stated are summarized below.

- There is increasing variability in most regions of Uganda other than the central region; however, rainfall variability does not show any significant trends.
- On the other hand there is clear increase of frequency of droughts in recent years,
- Although it is predicted (IPCC Assessment Reports 1995/2001) that precipitation will increase in some areas of East Africa as a result of climate change, evapotranspiration will also increase due to a rise in temperatures thus reducing the benefit of the increase.

1.3.3 Rainfall Variability Based on Existing Rainfall Data

The effect of climate change for surface water resources may come out as increase of droughts. The Study Team selected twelve reliable rainfall stations with long-term data and the distribution covering the whole Kyoga Basin, and analyzed their deviations from each average annual rainfall with taking moving average in 3 years. This is because that simple deviation has no tendency like a random walk. The results are shown in Figure 1-13 to Figure 1-15. The figures are set out from north to south and east to west depending on the location of each rainfall station.

These figures say that:

- Sometimes flooding and droughts happens at the same time in the wide area of Lake Kyoga basin. For example, annual rainfall in 2003 showed following result;
  Annual Rainfall > Average rainfall: Lira, Soroti, (Masindi), Mpigi, Mukono, (Entebbe)
  Annual Rainfall < Average rainfall:: (Kitugum), (Gulu), Apach, Kamuli, Tororo
  Parenthetic station means that the station is located outside of Lake Kyoga basin.
- Droughts continued more than ten years at some rainfall stations, on the other hands, rainfall harvest also continued more than ten years at other rainfall stations. However, those stations

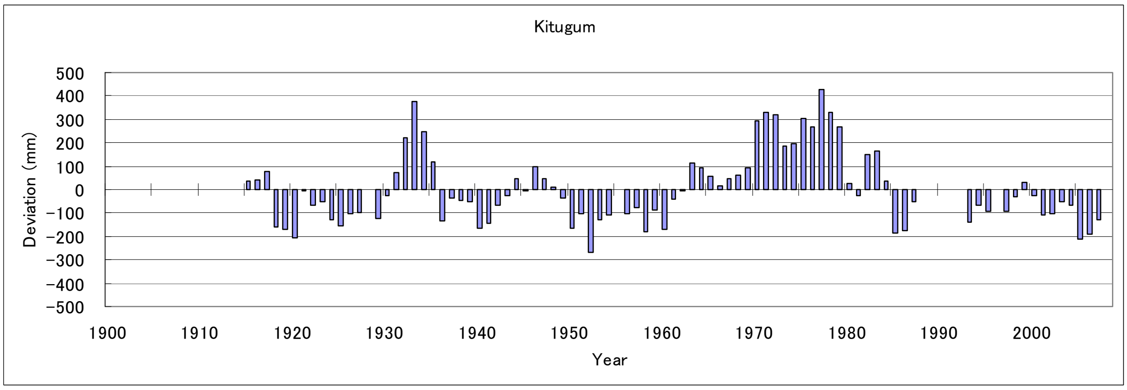
also have experienced opposite rainfall phenomenon in the past. For example, Jinja station has experienced rain harvest during recent ten years, and experienced poor rainfall before 1960.

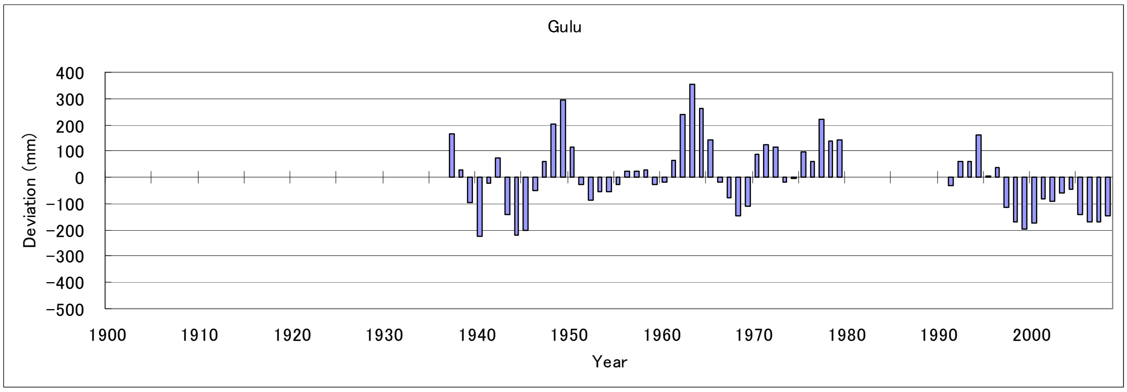
These tendencies above mentioned have continued to recent years. Therefore, it is hard to point out that the climate change will results in increase of droughts.

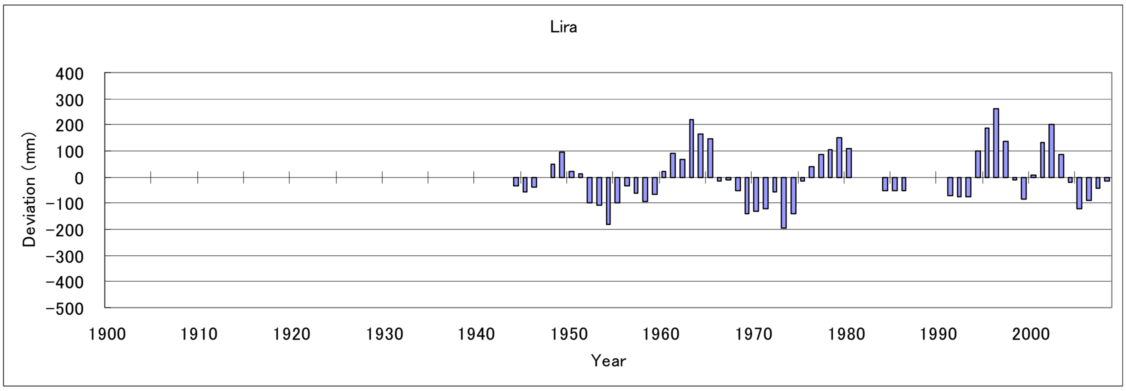
Table 1-6 Selected Rainfall Stations for Drought Analysis

District	Rainfall Station ID	Station Name
Kitugum	86320000	Kitugum Centre VT
Gulu	87320000	Gulu Meteorological Station
Lira	87320020	Ngetta Farm
Apac	88320110	Aduku Variety Trial
Soroti	88330060	Soroti Meteorological Station
Masindi	88310030	Masindi Meteorological Station
Kamuli	88330470	Kiige WDD
Tororo	89340190	Tororo Meteorological Station
Mpigi	89320670	Namullonge Research Station
Jinja	89330430	Jinja Meteorological Station
Mukono	89321040	Kituza Coffee Research Station
Entebbe	89320660	Entebbe International Airport

Figure 1-12 Distribution of Selected Rainfall Stations for Drought Analysis







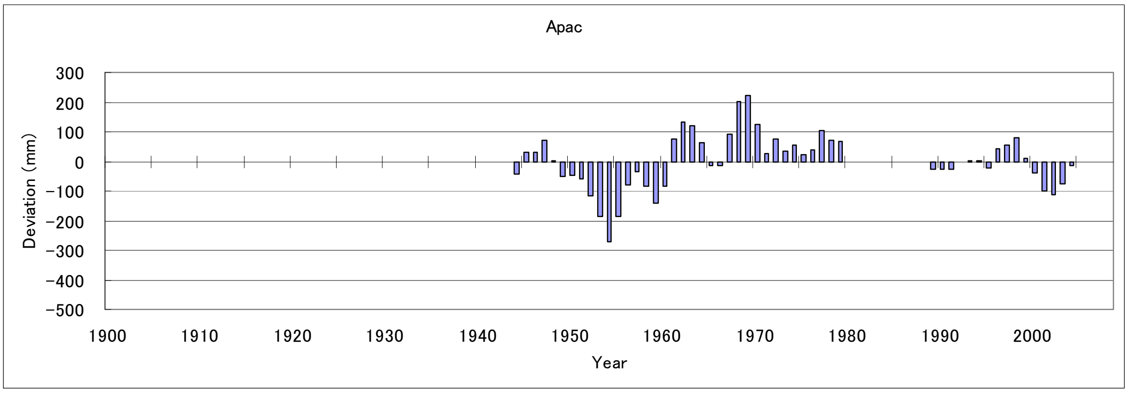
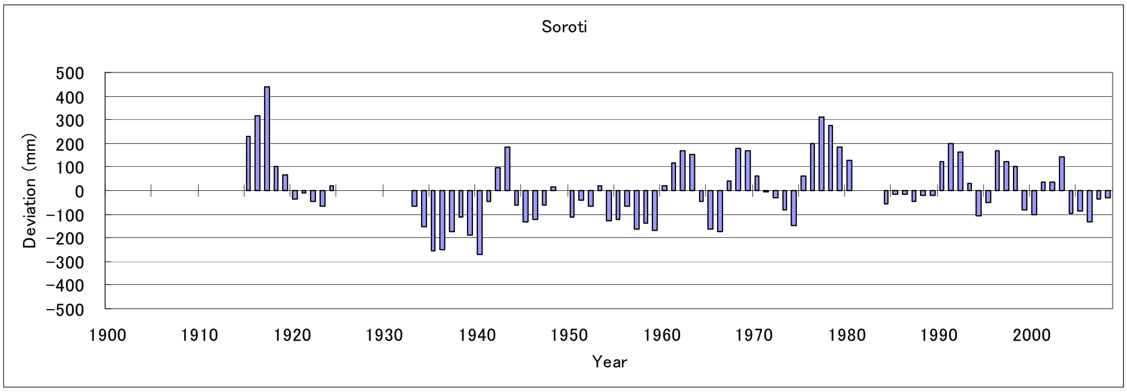
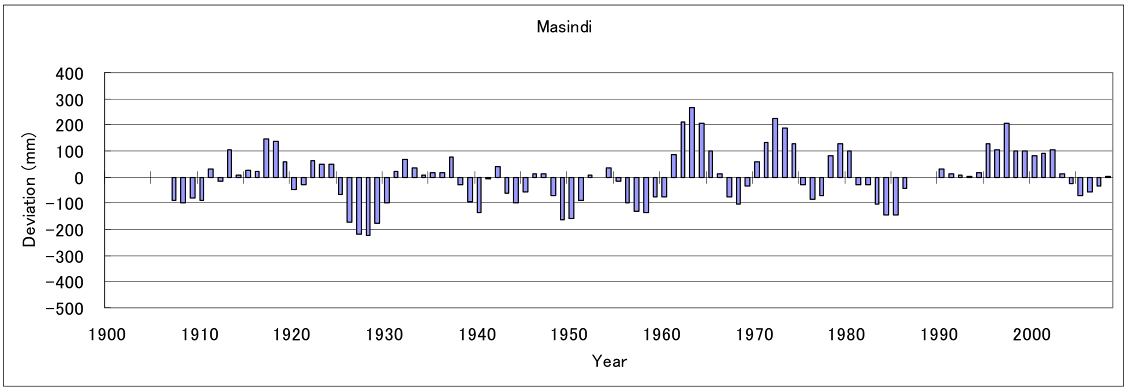
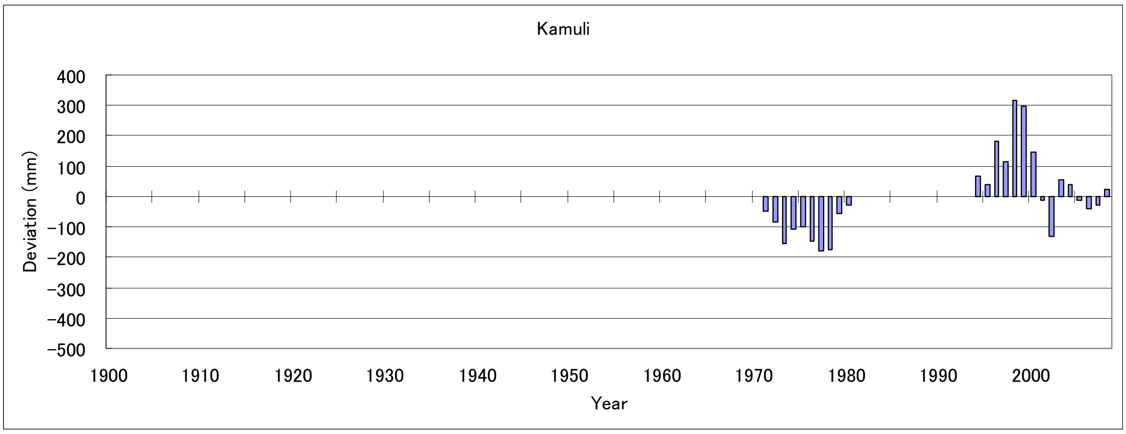


Figure 1-13 Deviation from the Average of Annual Rainfall of Representative Gauging Stations (1) - Moving Average in 3 years -







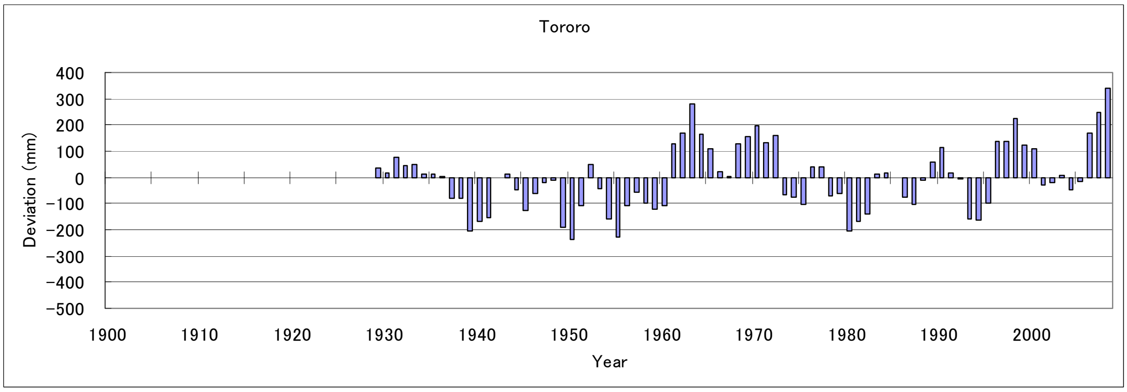
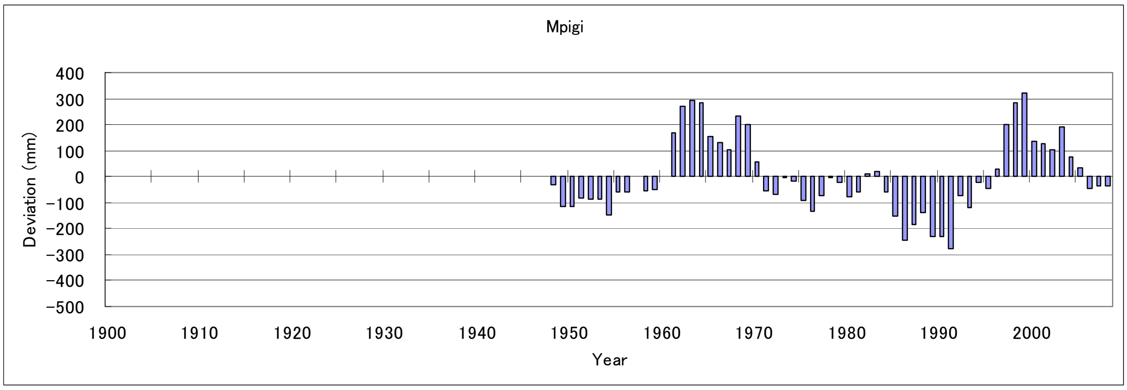
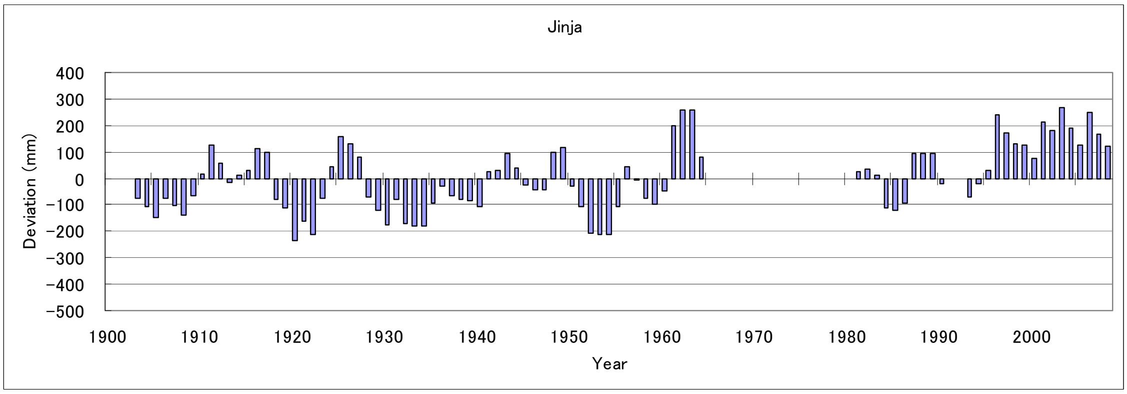
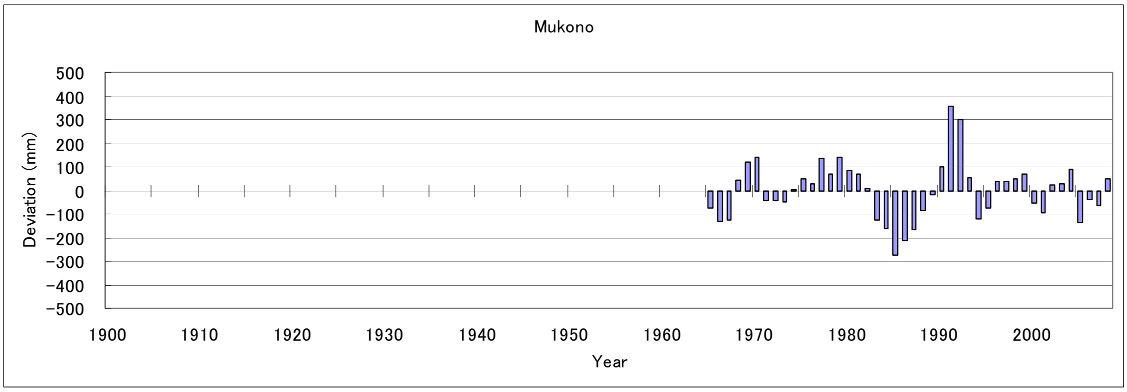


Figure 1-14 Deviation from the Average of Annual Rainfall of Representative Gauging Stations (2) - Moving Average in 3 years -







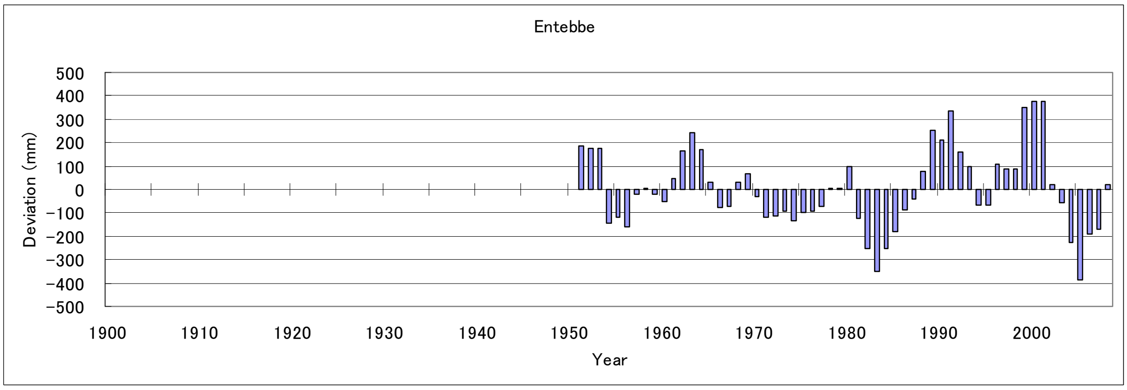


Figure 1-15 Deviation from the Average of Annual Rainfall of Representative Gauging Stations (3) - Moving Average in 3 years -

CHAPTER 2 GEOMORPHOLOGY AND GEOLOGY

2.1 Geomorphology

2.1.1 General Geomorphology of Uganda

The geomorphologic of Uganda is expressed roughly that facing Lake Victoria in the south, surrounded by rises of the Great Rift Valleys in the east and west, huge plain which is lying between the rises is tilting towards to the north gradually, and the River Nile which is flowing down from Lake Victoria as a water source is flowing to the Republic of Sudan via Lake Kyoga.

African Great Rift Valley continues from the Republic of Djibouti and Ethiopia in the north to the Republic of Mozambique, is divided into Eastern and Western Rift Valleys. Uganda is located in the area surrounded by these two rift valleys. Boundary with Kenya is the west rim of the Eastern Rift Valley (Gregory Rift Valley). Mt. Elgon (4,321m, the highest peak of Uganda) is dominated at the south end of the boundary. Western boundary is facing to the Democratic Republic of Congo, and Western Rift Valley (Albertine Rift Valley) is consisted the boundary. In the rift valley, Rwenzori Mountains (5,109m, the highest peak is in Congo) pushed up by crustal movement are dominated, and Lake Albert and Lake Edward are in the bottom of the valley. Virungas Mountains (4,507m, the highest peak is in Rwanda) are at the South-western boundary between Uganda, Rwanda and Congo. Lake Victoria formed by the activity of Eastern and Western Rift Valleys is the largest lake in the Africa (the third largest in the world). Intermediated area between the rift valleys is forming a peneplain which has gentle topographic change with the elevation between 1,000 to 1,200m. The elevation is decreasing from southern east to northern west gradually. Lake Kyoga (elevation of lake water is 1,034m) is located in the middle of the peneplain, the water from Lake Victoria (elevation of lake water is 1,034m) is flowing down into Lake Kyoga, and flowing out to Lake Albert (elevation of lake water is 615m) from Lake Kyoga.

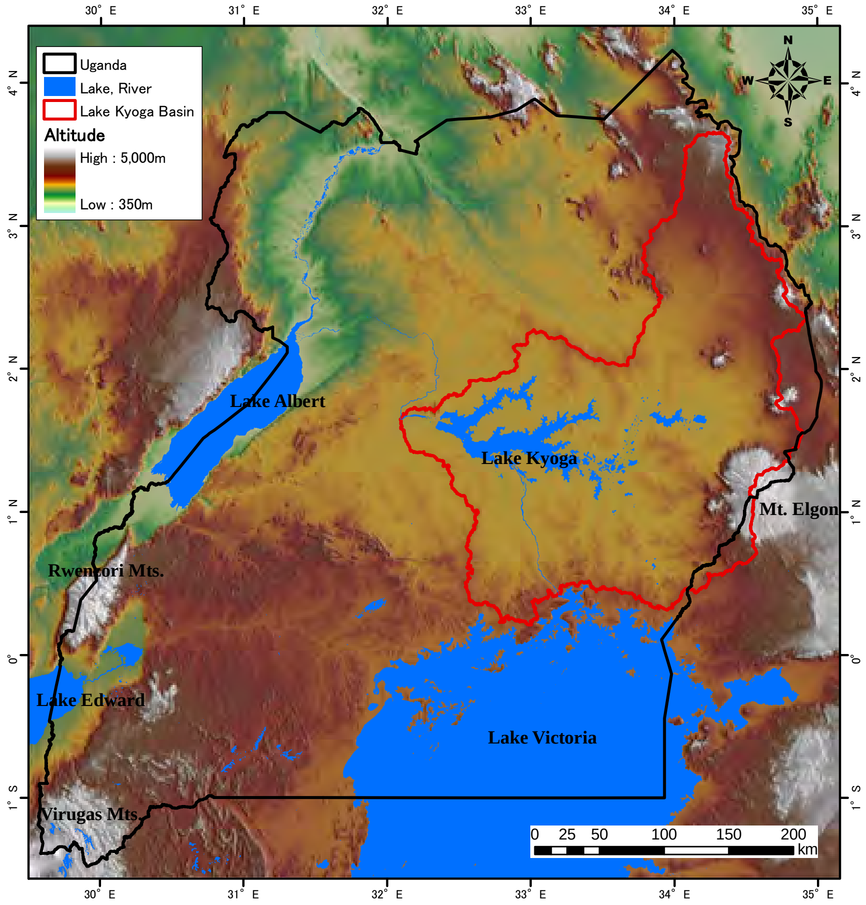


Figure 2-1 Geomorphology of Uganda

2.1.2 Topographic Characteristics of Lake Kyoga Basin

The study area is located in the eastern part of Uganda, and borders Kenya to the east and Sudan to the north. The study area consists principally of peneplanes, hills and mountains and its altitude ranges from 1,030m as the exit of Lake Kyoga to 4,321m as the peak of Mt. Elgon. Topography of the study area is roughly tilted from east to west. Peneplain is the last step of cycle of erosion; geomorphologic surface was eroded down nearly to the base level of erosion by the process of erosion, and the plain was formed with very gentle relief .

Because of gentle slope, most of rivers have swamps. Lake Kyoga (water area is 1,720m^2) itself has very shallow, maximum 6m depth approximately.

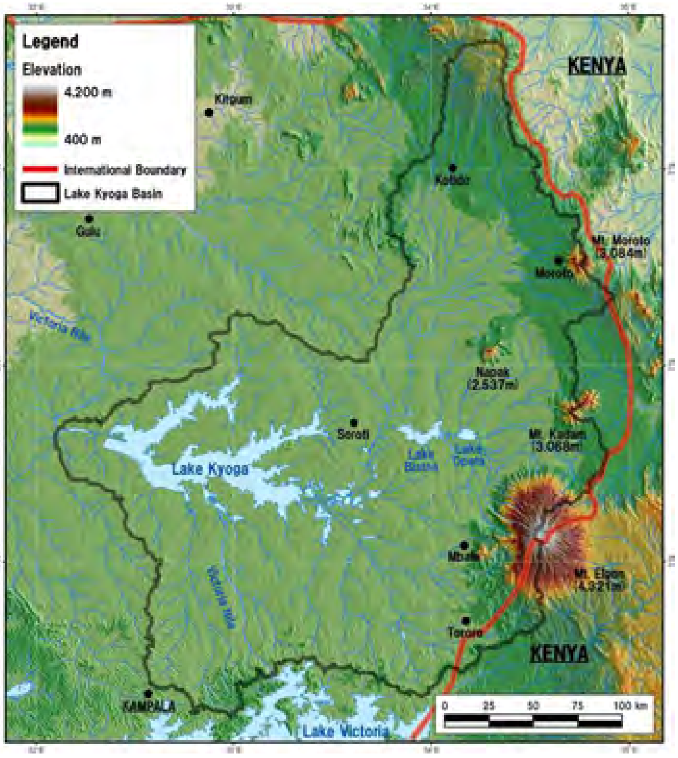
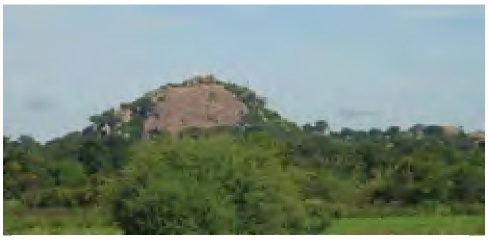


Figure 2-2 Location Map of the Survey Area



Inselberg in peneplain

Swamp is covered by papyrus
(River is flowing from left to right in this picture)

Mt. Elgen is the one of oldest volcano in East Africa, the area of skirts of the mountain is 3,500km2. And along the east rim of Lake Kyoga Basin, some volcanoes are ranging from south to north, Mt. Kadam (3,068m), Mt. Napak (2,537m), Mt. Motoro (3,084m), etc. Lake Kyoga Basin boundary from Moroto to Kitido is overlapping the rim of Eastern Rift Valley, and the national boundary is also taking along.

Satellite image data taken from earth observatory satellite were used to grasp topographic and surface condition. First, Lake Kyoga Basin was extracted by drainage analysis result analysed by Digital Elevation Model (DEM). Lake Kyoga Basin boundary shown in Figure 2-2 is the result of analysis. The area of catchment was estimated to be approximately 58,230 km^2, of which approximately 57,080 km^2 (98.0 % of the catchment) belongs to Uganda, and the remaining 1,150 km^2 (2.0 % of the catchment) belongs to Kenya.

Additionally, data processing of DEM data was performed to extract information regarding geomorphology and geology. Figure 2-3 shows the shaded relief image. Shade relief is known to be effective for observation of geomorphologic features.

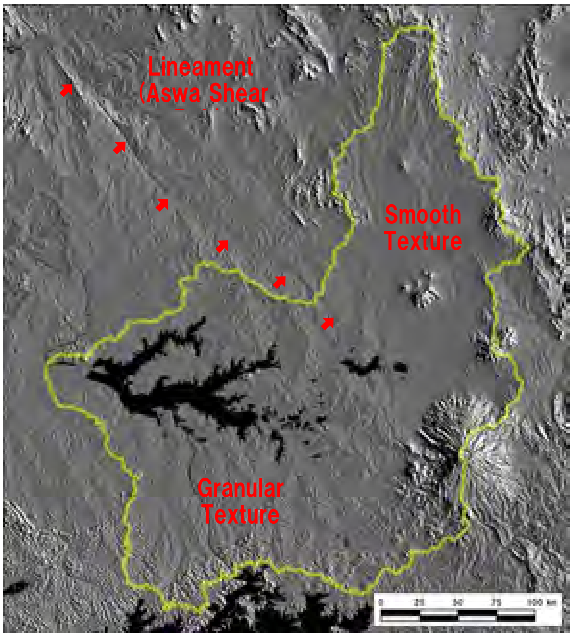


Figure 2-3 Shaded Relief Image

The clear lineament structures (Aswa Shear Belt) extended from the northwestern part to central part of the processed image could be clearly extracted. But, it becomes unclear in the Lake Kyoga Basin. Concerning the surface textures of plane which assume a dominant position in the study area, the northern part with smooth textures differs from the southern west part with well-developed granular textures. These differences are concerning to the geology and surface soil.

The results of elevation classification and slope classification are sown in Figure 2-4 and Figure 2-5, respectively.

The altitude of these terrains ranges mainly from 900 to 1,150 m (shown as light brown color in the left image of Figure 2-4) as plain area, but a small part of these terrains distributed in the northern part ranges from 1,150 to 1,600 m (light green color) as hilly area, and more than it (blue to dark blue color) as mountainous area. The largest part of the study area is classified as a plain or a gentle hilly terrain with less than 3 degrees of slope (shown as light yellow color in Figure 2-5). The hilly terrains are mainly distributed in the southern to southwestern part of study area. Their altitude ranges mainly from 1,150 to 1,600 m and have 3 to 10 degrees of slope. These terrains form the southern borders of study area, corresponding to watershed between the Lake Kyoga Basin and the Lake Victoria Basin, and are composed of Precambrian metamorphic rocks (mainly phylites and schists) and metavolcanics. The linear structures, being clearly observed in the slope classification map,

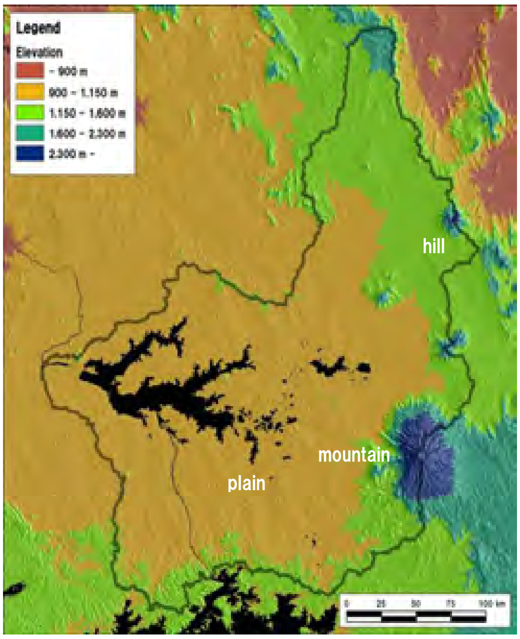


Figure2-4 Elevation Classification Map

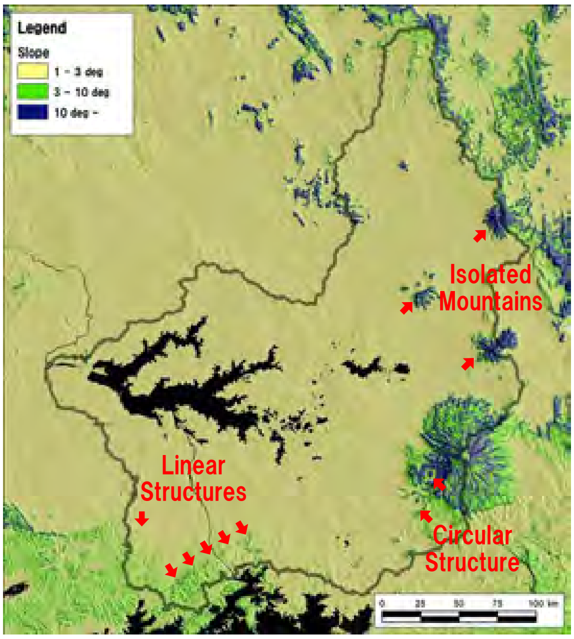


Figure 2-5 Slope Classification Map

correspond to the narrow and steep mountains composed of silicified metamorphic rocks.

The mountainous areas are mainly distributed in the eastern and northern part and the shapes of mountains vary depending on their location and geology. In the eastern part, there are the isolated mountains composed of Tertiary volcanic rocks and associated sediments. These mountains, particularly the Mount Elgon, form a typical shape of strato-volcano with circular foots and slopes of more than 10 degrees. On the other hand, the mountainous area located in the northern part runs from north to south and is mainly composed of Precambrian banded gneisses. These mountains have relatively gentle slope (3 to 10 degrees) and form the northern watershed of Lake Kyoga Basin.

2.1.3 Vegetation and Soil of Lake Kyoga Basin

Vegetation – soil – water index (hereafter VSW index) is an advanced technique to calculate the ratio between vegetation, soil, and water. The VSW index image processed from satellite image, acquired in January of 2003, is shown in Figure 2-6.

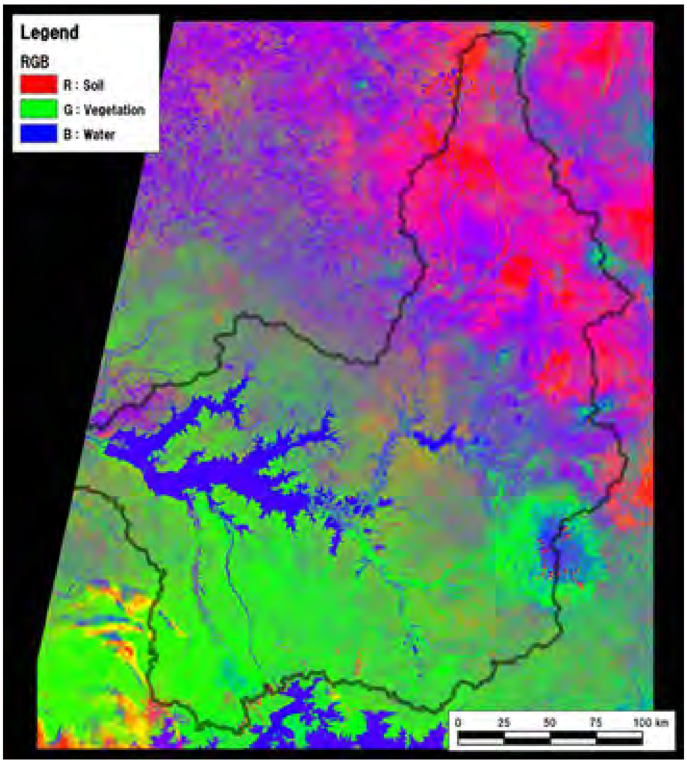


Figure 2-6 VSW Index Image of January of 2003

The condition of ground surface varies considerably depending on its location in the study area, especially in the area between the northern and southern part due to the differences of meteorological condition. In the VSW Index map which is produced from the LANDSAT data acquired in January of 2003 (in dry season), the northern part with low precipitation is shown in reddish to pinkish colored pixels suggesting high soil content. On the other hand, the southern part with relatively high precipitation is shown in greenish or bluish colored pixels suggesting high vegetation and water content.

Concerning the northern part, although the field survey could not be carried out due to the security reason, the result of VSW Index suggests that the ground surface of this part is dry conditions; dried soils, exposed basement rocks, sparse trees and low vegetation, and distribution of vegetated area is limited to the area near the foot of isolated high mountain and along the rives. According to the 1996 version of land use map prepared by the National Biomass Project of Forest Department, the ground surface of the northern part is mainly classified as grassland and bushland, and consequently it can be said that most of the northern part is utilized as a grazing land and a small-scale farmland.

Most of the southern part is already developed and cultivated by the residents except the wetlands and protected area (forest reserves, wildlife reserves, enclaves and national parks). As the result of VSW

Index, the ground surface of this area is widely covered by vegetation even though the LANDSAT data was acquired during the season of low precipitation. According to the existing land use map and the result of field survey, the ground surface of this part is mainly utilized as small-scale farmland, and some uniform (large-scale) farmlands, e.g. sugar cane and paddy plantations, are scattered throughout this part of the area.

2.2 Geology

2.2.1 General Geology of Uganda

One of the oldest geological units in the world is distributed in Uganda. Eighty percent of the country comprises Precambrian formations, which were formulated 3 billion to 600 million years ago. These rocks are metamorphosed by orogenic movement, which was activated during Precambrian. Although the geology is classified by the period, types, magnitudes of metamorphism and so on in each area, most of the rocks are Gneisses and Granites. After the time to now, Uganda has been on the continental crust and never sunk into the ocean except only once when the transgression of Karoo was happened. The volcanic activities had begun from the middle of Tertiary: 23 million years ago concurrently with the formulation of the Great Rift Valley. It produced some volcanoes in the eastern part of Uganda, for example: Mt. Elgon. Furthermore, activity of the West Great Rift Valley had started about a million years ago and has been continuing until now.

In addition, in the period of forming eastern volcanoes, Mt. Elgon was higher than current Mt. Kilimanjaro (5,895m), and rivers in the area of Uganda were flowing from east to west. However, after forming the Western Rift Valley, a long and thin lake (Lake Obweruka) was formed as combined as current Lake Edward and Lake Albert, and then Ruwenzori Mountains were uplifted, rivers which couldn’t flow to west formed Lake Victoria and Lake Kyoga. River Nile was formed about 30,000 years ago.

Figure 2-7 shows the geological map in Lake Kyoga Basin. The Stratigraphy of Lake Kyoga Basin is shown in Table 2-1.

Table 2-1 Stratigraphy of Lake Kyoga Basin

Era		Period	Epoch	Name	Age (Ma)	Symbol	Lithology
Cenozoic		Quaternary	Pleistocene to Recent	Quaternary Sediments	0 - 1.6	P1	Sediments, alluvium, black soils and moraines
		Tertiary	Miocene	Volcanic	12.5 - 25	T	Volcanic Rocks and Associated sediments; Nephelinite, Phonorite,.....
			Miocene - Oligocene	Carbonatite Centre	20 -35	TC	Carbonatite and Syenite
Paleozoic		Lower Permian		Karoo System	256 - 290	KR	Shales
Precambrian	Proterozoic			Aswa Shear Zone	600 - 700	CM	Cataclasite, mylonite
				Karasuk Series	700 - 800	KS	Mozambique Belt: acid gneiss, amphibolites, quartzites, marbles, and granulite facies rocks
				Kioga Series	800 - 1,000	K	Shales, arkoses, quartzites, and tillite
				Granite	1,000 - 1,350	G	Mobilized and intrusive granites
				Buganda-Toro System	1,800 - 2,500	B-T	shales, argillites, phylites, mica-schists, basal quartzites, and amphibolite
	Archean			Nyanzian System	2,400 - 2,700	NZ	Metavolcanics, banded ironstones, cherty quartzites and greywackes
				Aruan Techtonic	2,600	A	Banded gneiss
				Watian Series	2,900	W	Granulite facies rock: charnokites, enderbites and retrograded derivatives
				Gneissic -Granulitic Complex	-3,400	GC	Undifferenciated gneiss and granulite facies rock in the north: gneiss, granite, amphibolite, charnockite, enderbite, quartzite
						GZ	Granitoid and highly granitized rocks

1) The Atlas of Uganda (1962); Department of Geological Survey and Mines, Ministry of Energy and Mineral.
2) Uganda Geology (2004); Department of Geological Survey and Mines, Ministry of Energy and Mineral.
3) Geology of East Africa (1997); Thomas Schluter, Gebruder Borntraeger.

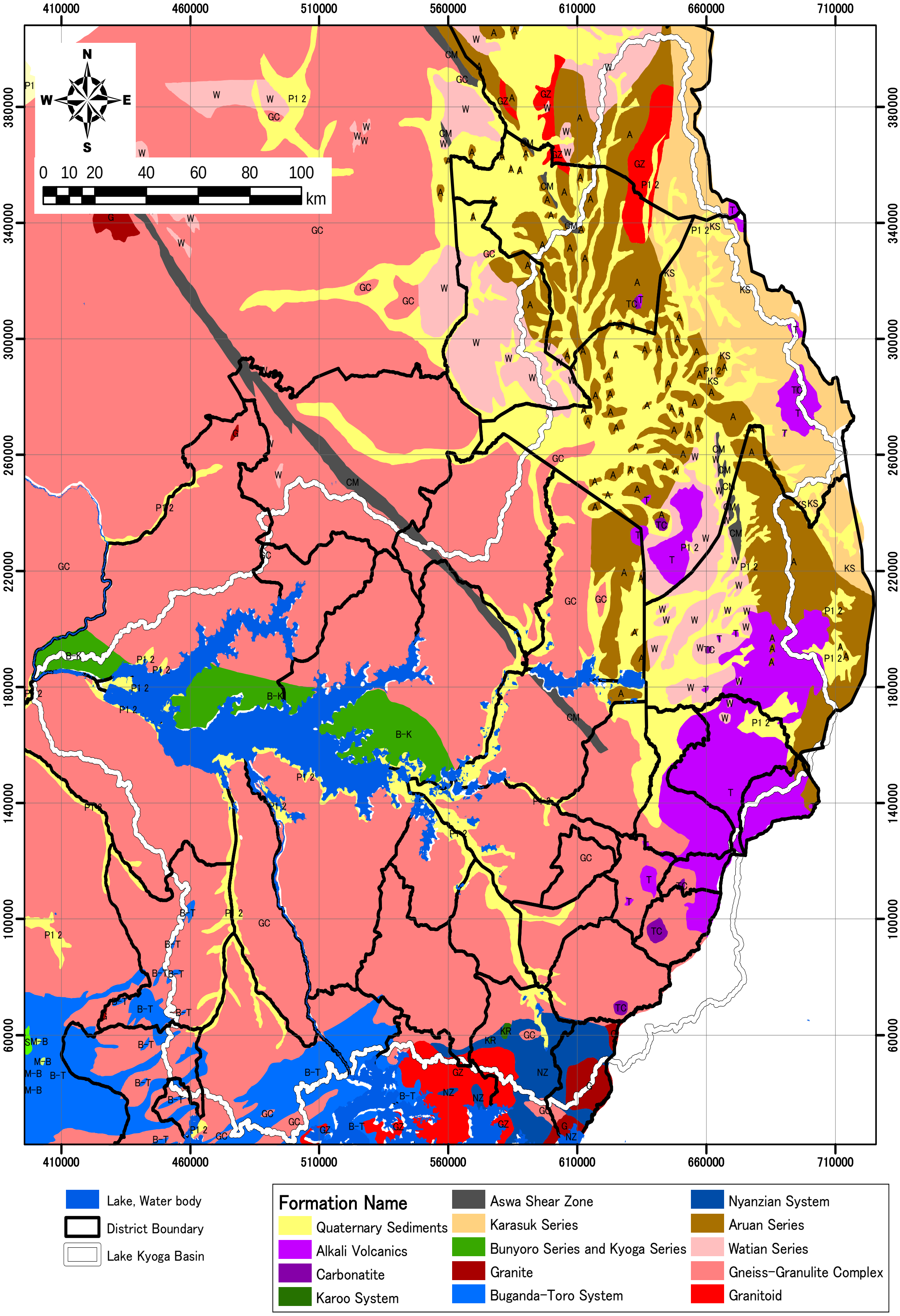


Figure 2-7 Geological Map in Lake Kyoga Basin

After "Uganda Geology (2004)

2.2.2 Geological Description in Lake Kyoga Basin

The features of each geological unit are described below in chronological order.

(1) Pre-Cambrian

Geology of Uganda and even Lake Kyoga Basin comprise almost Precambrian rocks. Precambrian formations are occupying almost whole area of the Basin except volcanic area in the eastern part of it.

i) Gneissic-Granulitic Complex (GC, GZ)

The most part of the eastern Uganda is covered by this geology, which forms peneplain in Uganda. This formation is called as “Basement Complex” as well. This geological unit is bracketed as “Complex” because it has not been classified yet lithologically and geologically. Its rock type is metamorphic rock varying amphibolite facies to granulite facies more or less and its composition ranges from acid to intermediate, and occasionally to basic. This complex includes charnockites, enderbites, quartzites and acidic gneisses or granite are also common.

Fold axis are mainly east - west direction, and it can be seen in the northwestern part of Uganda. However, explicit lineament in the Basin is very scarce. This complex can be classified into four series now in terms of structural movement. As for the Basin, two series can be observed in Karamoja area as follows.

a) Watian Tectonic Series (W)

Rock types are same as the complex mentioned above. Directions of folding axes are mainly east to west. Main metamorphic rocks have retrogressive metamorphism, which is the oldest structural movement in Uganda.

b) Aruan Techtonic Series (A)

Amphibolitic facies metamorphism and north – north east folding axis are featured for this series.

ii) Nyanzian System （NZ）

This system comprises metamorphic rocks, which originate volcanic rocks and sedimentary rocks. Their original rocks are rhyolite, andesite, porphyry, tuff and basalt, covered by cherty quartzite, shale and banded ironstone. The geological age of this is 2,400 to 2,700 million years .

iii) Intrusive Granite (G)

There are several intrusion stages of granite in and after orogenic movement period. This granite appears only at southern part of Busia district.

iv) Buganda-Toro System (B-T)

This system has been called "Cover Formation", which is distributed widely in the southwestern part of Uganda, because it is laid over the "Basement Complex". This formation is distributed formulating hilly area ranging from Kampala to Jinja. Component of rocks are argillite, arenite, phyllite, mica-schist, quartzite, amphibolite and so on. Folding axes are direction from north-east to south-west, and the folding plane has high angle.

v) Kioga Series (K)

This series appears around the northern shore of Lake Kyoga in the southern part of Soroti district and Amolatar district. Rocks are sedimentary rocks, mainly, shales and sandstones.

vi) Karasuk Series (KS)

This series is considered as a part of Mozambique Mobile Belt. This series is distributing in Karamoja area along the border between Uganda and Kenya. Rocks are mainly gneisses, amphibolites, marbles, quartzites, ultra-basic rocks, and so on.

vii) Aswa Shear Zone (CM)

Aswa shear zone is lined the direction from north-west to southeast, on straight line from central part of northern Uganda to Kumi district through Amuria and Katakwi district. Cataclasite and mylonite are observed in the zone. The same kinds of shear zone are observed in Karamoja area. This is considered the stressed zone at the time of formulating the Mozambique Mobile Belt.

(2) Palaeozoic to Mesozoic (KR)

The Karoo system is distributed in the wide area of the southern part of Africa and it is found in the limited area of Entebbe, Dagusi Island, and Bugiri in Uganda. Only Bugiri belongs to Lake Kyoga Basin. Since the Karoo system is continental sediments, it comprises sandstones or shales, igneous rocks.

(3) Cenozoic

Volcanic activity was activated concurrently with the activity of the Great Rift Valley in Cenozoic. Eastern mountainous area of the Basin was formulated by this activity.

i) Intrusion of Carbonatite (TC)

Carbonatites and Syenites intruded to the Basement Complex before the volcanic activity. This intrusive body was formulated anomalous circular topography around the volcanoes as mentioned below. Caobonatite is used for the raw material of cement.

ii) Alkali volcanic rocks (T)

Mt. Elgon (4321m), Mt. Kadam (3068m), Mt. Napak (2539m), Mt. Moroto (3083m), and Mt. Toror (1948m) are lined sequence from south to north along the border of Kenya. These rocks are alkali volcanic rocks, mainly, nephelinite, phonolite. These mountains are covered by the alkali lavas. Conglomerates and sandstones are underlain the volcanic rocks.

iii) Allvium (P1 2)

Alluvial sediments: sands, gravels and black soils, are deposited in the lowlands along the rivers. In the peneplain area, many swamps are formulated because of very gentle slopes.

2.2.3 Geological Structure in Lake Kyoga Basin

The satellite image interpretation was carried out to understand the geological structures of the study area. In this study, lineaments, beddings and circular structures were extracted as a geological structure from the shaded relief image of SRTM-3 data and the color composite image of LANDSAT data. The result of image interpretation is shown in Figure 2-8.

A lineament is defined by “straight and/or semi-curve linear features on the surface, which seems to reflect subsurface geological structures such as fracture”. The clearest lineaments, which can be traced from the northwestern to the central part of the Basin as shown in Figure 4-2, correspond to the Asawa Fault, a zone of mylonites in the Precambrian Basement Complex. Some lineament zones are observed near the northern border of the Lake Kyoga Basin and Mount Elgon, but its continuous distribution is not clear.

The beddings are mainly observed in the northern and southwestern part of the study area; the Precambrian banded gneisses are distributed in the northern part, and the Precambrian Toro System composed largely of argillaceous sediments (mainly phyllite and schist) and folded tightly is predominant in the Southwestern part. The circular structures extracted as a cone near Mount Elgon and Napak correspond the carbonatite ring complex, which related to the Cretaceous to Miocene soda-rich volcanism.

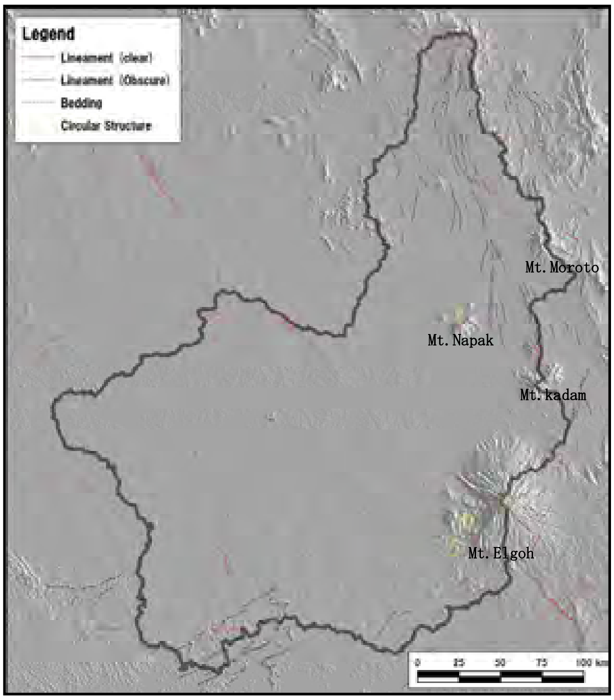


Figure2-8
Faults and Lineaments in Lake Kyoga Basin

CHAPTER 3 WATER QUALITY

3.1 Water Quality Standard

In Uganda, there are drinking water standards for urban and rural water supplies, industry wastewater standards, and sewage discharge standards. The drinking water standards are shown in Tables 3-1 and 3-2. The urban drinking water standard is close to WHO and the Japanese tap water quality standard. On the other hand, the rural drinking water standard is not so strict as compared to the urban standard in terms of the number of items and its values. In addition, the rural standard has Maximum Allowable Concentration (MAC). (Water Quality Standards, March 2007)

Table 3-1 Urban Drinking Water Standard

Items	Urban Drinking water Standard(Uganda)	WHO Guideline	Tap Water Quality Standard(Japan)
Color	10 (Platinum scale)	15 TCU	< 5
Odor	Unobjectionable	－	Normal
Taste	Acceptable	－	Normal
Turbidity	10 NTU	5 NTU	2 NTU
Dissolved solids	500 mg/l	1000 mg/l	500 mg/l
PH	6.5 － 8.5	－	5.8 － 8.6
Total Hardness (CaCO3)	500 mg/l	－	300 mg/l
Calcium (Ca)	75 mg/l	－	300 mg/l(Ca,Mg)
Sodium (Na)	200 mg/l	200 mg/l	200 mg/l
Magnesium (Mg)	50 mg/l	－	300 mg/l(Ca,Mg)
Barium (Ba)	1.0 mg/l	－	－
Iron (Fe)	0.3 mg/l	0.3 mg/l	0.3 mg/l
Copper (Cu)	1.0 mg/l	1.0 mg/l	1.0 mg/l
Aluminum (Al)	0.1 mg/l	0.2 mg/l	0.2 mg/l
Manganese (Mn)	0.1 mg/l	0.1 mg/l	0.05 mg/l
Zinc (Zn)	5.0 mg/l	3.0 mg/l	1.0 mg/l
Arsenic (As)	0.05 mg/l	0.01 mg/l	0.01 mg/l
Lead (Pb)	0.05 mg/l	0.01 mg/l	0.05 mg/l
Selenium (Se)	0.01 mg/l	0.01 mg/l	0.01 mg/l
Chromium (Cr 6+)	0.05 mg/l	0.05 mg/l	0.05 mg/l
Cadmium (Cd)	0.01 mg/l	0.003 mg/l	0.01 mg/l
Mercury (Hg)	0.001 mg/l	0.001 mg/l	0.0005 mg/l
Nitrates (NO3)	10 mg/l	50 mg/l	10 mg/l
Chloride (Cl)	250 mg/l	250 mg/l	200 mg/l
Fluoride (F)	1.0 mg/l	1.5 mg/l	0.8 mg/l
Phenol substances	0.001 mg/l	0.0001－0.2 mg/l	0.005 mg/l
Cyanide	0.01 mg/l	0.07 mg/l	0.01 mg/l
Poly Nuclear Aromatic Carbons	Nil	(each substance)	(each substance)
Residual, free chlorine	0.2 mg/l	5 mg/l	1.0 mg/l
Mineral oil	0.01 mg/l	0.01 mg/l	0.01 mg/l
Anionic detergents	0.2 mg/l	－	0.2 mg/l
Sulfate	200 mg/l	－	－
Pesticides	Trace	(each substance)	(each substance)
Carbon chloroform	0.2 mg/l	0.2 mg/l	0.06 mg/l
Microscopic organisms	Nil	－	100/ml
Escherichia Coliforms	0/100ml	0/100ml	Nil

Table 3-2 Rural Drinking Water Standard

Items	Rural Drinking water (Uganda)		WHO Guideline
	Standard	Maximum Allowable Concentration(MAC)	
Turbidity	10 NTU	30 NTU	5 NTU
Total Dissolved Solids	1000 mg/l	1500 mg/l	1000 mg/l
PH	5.5 － 8.5	5.0 －9.5	－
Total Hardness (CaCO3)	600 mg/l	800 mg/l	－
Iron (Fe)	1 mg/l	2 mg/l	0.3 mg/l
Manganese (Mn)	1 mg/l	2 mg/l	0.1 mg/l
Nitrate (NO3)	20 mg/l	50 mg/l	50 mg/l
Nitrite (NO2)	0 mg/l	3 mg/l	－
Chloride (Cl)	250 mg/l	500 mg/l	250 mg/l
Fluoride (F)	2 mg/l	4 mg/l	1.5 mg/l
Sulfate	250 mg/l	500 mg/l	－
Escherichia Coliforms	0/100ml	50/100ml	0/100ml

3.2 Existing Data

3.2.1 Existing Survey Documents

The water quality data from existing monitoring network and borehole drilling applications submitted by contractors (mandatory since 1995, Water Statute) are obtained through DWRM (Directorate of Water Resource Management).

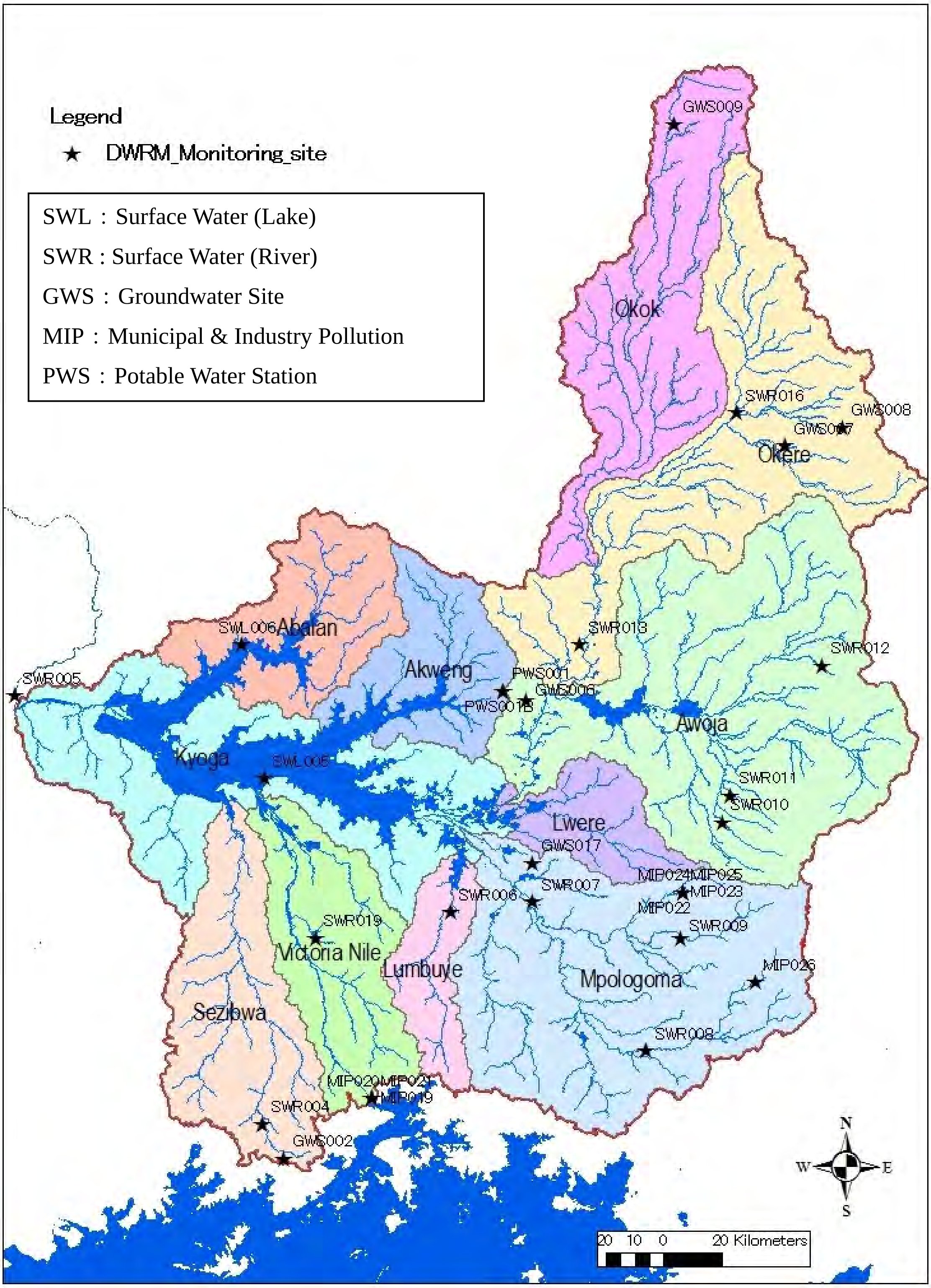
(1) Water Quality Monitoring Data

Figure 3-1 shows location of monitoring points in the water quality-monitoring network. There are 30 monitoring points in the Basin for water quality measurement of lake water, river water, well water, urban drain, and drinking water. Data for 11 years from 1998 to 2008 is available. Frequency and types of measurement performed are shown in Table 3-3. Since 2003, the frequency of measurements has decreased significantly; no measurement has been done for groundwater since 2005 and measurement of urban wastewater and drinking water has decreased to one to two per year. Furthermore, within the 29 measurement items, only about 18 items such as rural water standard items and water pollution index (TDS, EC, BOD and COD) have been performed in all of the points.

(2) Borehole Data

In the borehole data obtained, water quality data of 2,003 boreholes is available, of which parameters such as the location and drill depth are available for 1,524 boreholes. The distribution of boreholes with water quality data for analysis are shown in Figure 3-2. The boreholles spread over the target districts, except for Kapchorwa where has only one borehole data . As shown in Figure 3-3, many of the boreholes are more than 30m in depth, and 50-60m is the majorities.

Analysis items include rural drinking water standard items and other items such as Conductivity, Alkalinity, Calcium, and Magnesium.



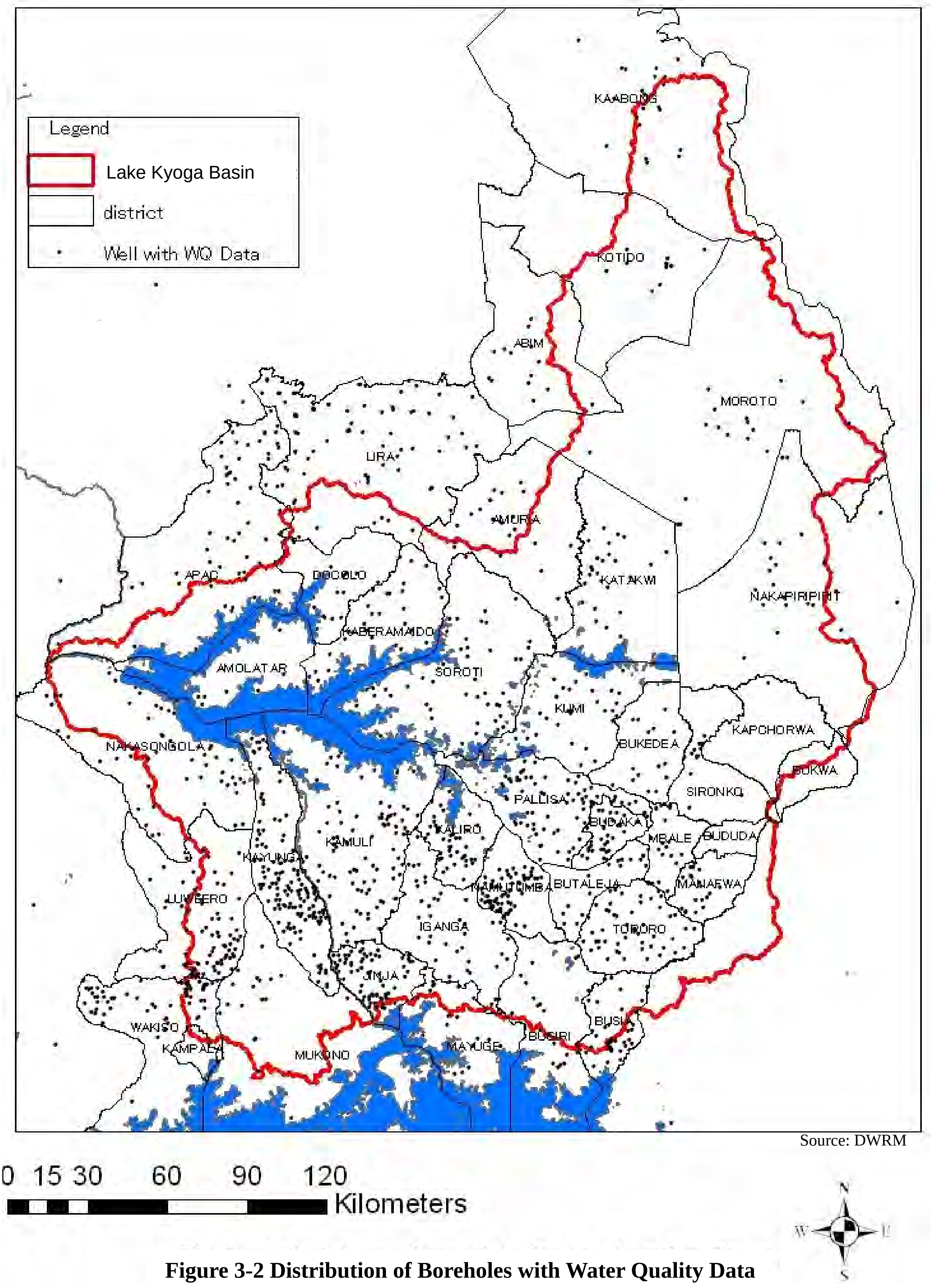
Source: DWRM

Figure 3-1 Monitoring Network for Water Quality

Table 3-3 Frequency of Water Quality Monitoring

Survey Site				Survey Frequency in Each Year										
No.	SiteName	SiteID	Sub basin No. & name	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Lake														
1	L . Kyoga at Bukungu	SWL005	7 Kyoga Lakeside	0	2	3	3	2	1	1	1	1	0	0
2	L . Kwania at Nabyeso	SWL006	6 Abalan	0	2	1	3	2	0	0	0	1	1	0
River														
3	R. Sezibwa at Sezibwa Falls	SWR004	11 Sezibwa	2	4	5	4	3	2	2	1	0	0	2
4	R. Nile at Masindi Port	SWR005	Lakeside Zone	0	2	2	3	2	0	0	0	1	1	0
5	R. Lumbuye at Kaliro - Nawaikoke road	SWR006	9 Lumbuye	0	2	2	1	2	0	0	1	0	0	0
6	R. Mpologoma at Budumba	SWR007	Mpologoma	1	2	2	1	1	4	1	1	0	0	2
7	R. Malaba at Busitema	SWR008	Mpologoma	1	2	2	3	2	4	0	0	1	1	1
8	R. Manafwa at NWSC Treatment Works	SWR009	Mpologoma	1	1	1	1	1	2	0	0	1	1	1
9	R. Simu at Mbale - Moroto road	SWR010	3 Awoja	1	0	1	1	1	1	0	0	1	1	1
10	R. Sipi at Mbale - Moroto road	SWR011	3 Awoja	1	1	1	1	1	1	0	0	1	1	1
11	R. Namalu at Mbale - Moroto road	SWR012	3 Awoja	0	1	0	1	1	1	0	0	1	1	0
12	R. Olumot at Soroti - Moroto road	SWR013	2 Okere	0	2	1	0	3	0	1	0	0	0	0
13	R. Alamacha at Lopei	SWR016	2 Okere	0	1	0	0	0	0	0	0	0	0	0
14	R. Nile at Mbulamuti Cable Way	SWR019	Nile	0	2	2	3	2	1	1	1	0	0	0
Borehole														
15	Nkokonjeru Ground water site	GWS002	11 Sezibwa	1	2	4	1	1	1	0	0	0	0	0
16	Soroti Ground Water Site at DWD Camp,Otuchopi - Soroti	GWS006	3 Awoja	0	2	5	5	2	1	1	1	0	0	0
17	Morulinga Ground Water Site at Kangole - Moroto	GWS007	2 Okere	0	2	1	0	1	0	0	0	0	0	0
18	Moroto Ground Water Site at Prison Barracks - Moroto	GWS008	2 Okere	0	2	1	0	2	0	0	0	0	0	0
19	Kabong Ground Water Site at Kabong Hospital - Kotido	GWS009	1 Okok	1	0	1	0	1	0	0	0	0	0	0
20	Osera Ground Water Site - Pallisa	GWS017	Mpologoma	1	3	3	4	2	0	3	0	0	0	0
Municipul														
21	L . Victoria at Kirinya Bay opposite NWSC Lagoons	MIP019	10 Victria Nile	1	5	4	4	2	2	1	1	1	0	0
22	L . Victoria at Masese	MIP020	Nile	1	5	4	4	2	2	1	1	1	0	0
23	R. Nile at Owen Falls Bridge	MIP021	Nile	1	4	4	4	2	2	3	1	1	0	2
24	Mbale NWSC Old Lagoons(Effluent Discharge)	MIP022	8 Mpologoma	1	4	4	4	1	2	3	2	1	2	0
25	Mbale NWSC New Lagoons (Point of Confluence)	MIP023	8 Mpologoma	1	5	3	1	2	2	4	2	1	2	0
26	Mbale Soap Works (Railway Bridge)	MIP024	Mpologoma	1	5	4	4	2	2	3	2	0	2	0
27	Mbale Soap Works (Up Stream)	MIP025	Mpologoma	1	5	4	4	2	2	2	1	1	2	0
28	River Lwakhaka (Road Bridge Kenya - Uganda Border)	MIP026	8 Mpologoma	1	5	4	3	2	1	3	1	1	3	0
Portabl water														
29	Soroti Water Works(intake)	PWS001	5 Akweng	1	5	5	5	2	2	1	2	0	0	0
30	Soroti Water Works(Distribution)	PWS001B	5 Akweng	0	2	2	2	1	3	1	2	0	0	0

Source: DWRM



Source: DWRM

Figure 3-2 Distribution of Boreholes with Water Quality Data

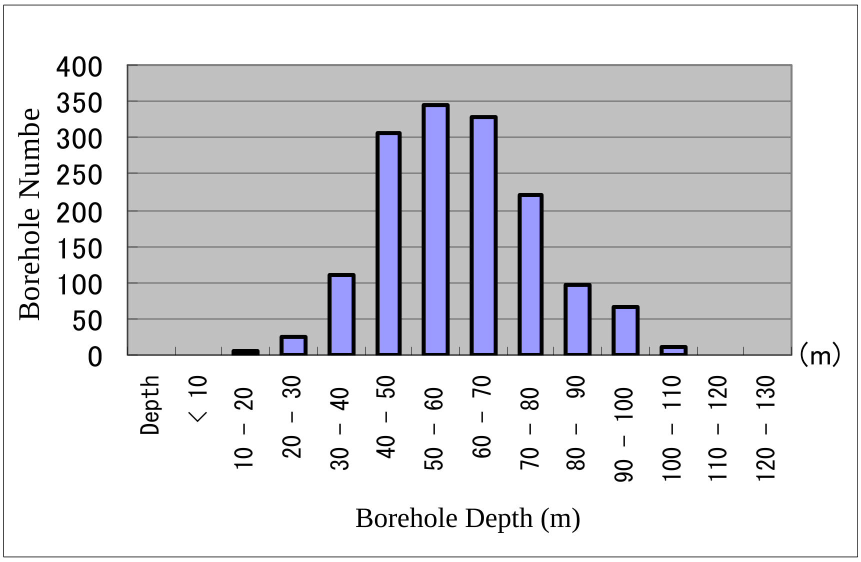


Figure 3-3 Distribution of Borehole Depth which were used as Existing Water Quality Data

3.2.2 Result of Existing Water Quality Surveys

(1) Results of Water Quality Monitoring

Results of water quality monitoring are shown in Table 3-4 according to the water sources. In the table the average, maximum and minimum values of the monitoring results were shown. The results have large differences of the sample number and the measured values for each survey item so that it is difficult to do detailed consideration. Therefore, the average values are studied to understand the trends of water quality of each source. In the table, yellow cells indicate the values dissatisfy the standard of urban drinking water quality, and red cells indicate the values dissatisfy the Maximum Allowable Concentration (MAC) of rural drinking water.

Turbidity, Total Iron and Total Coliform Population exceeded the MAC at many of water sources. And Color Degree exceeded the standard of urban drinking water. Additionally, Fluoride of river waters slightly exceeded the standard.

The Value of EC in rivers is usually around 110 μs/cm in Japan, Rivers and Lakes in the study area have similar values to it except for Swamps and MIP

As for the indicators of eutrophication, Total-Phosphorus and Total-Nitrogen exceeded the Japanese standards (each 0.1mg/l, 1.0mg/l) in the lakes and rivers.

Seeing about each water source, lake water shows on average high pollution level of COD which indicate organic pollution from human activity. Moreover, Total Phosphorus and Total Nitrogen (index of eutrophication) are 0.3 mg/l and 4.6 mg/l respectively, which were four to five times more than Japanese ambient standards. As for river water, BOD and COD are 16.3 mg/l, 72.7 mg/l respectively; it is also suggestive of high pollution level. As for groundwater, EC, TDS and Chloride are comparatively at high level, but items which indicate pollution level such as COD, Total Nitrogen, Total Phosphorus, are not measured for groundwater. Comparing municipal effluent with other water sources, most of items like pH, Turbidity, TDS, COD and so on, showed highest level of pollution.

Table 3-4 Water Quality for Each Water Source based on Monitoring by DWRM

		Items	Colour	DO	EC	pH	Turbidity	TDS	TSS5	Ca-Hardness	T-irons	F	Na	PO4	T-Phosphorus	Cl	NO2	NH4	BOD	COD	T-nitrogen	T- Con Coliform	Faecal Con Coliform
Lake	Local	Minimum	-	0.1	94.0	7.0	2.6	66.0	0.0	11.0	0.0	0.1	8.6	0.0	0.2	5.0	0.0	0.0	-	0.0	0.0	-	-
		Maxmum	-	18.0	373.0	9.2	34.0	260.0	8.0	38.0	3.8	0.5	48.4	0.4	0.6	11.0	0.0	0.8	-	64.0	9.2	-	-
		Average	-	9.0	161.2	8.1	12.3	141.5	2.1	24.5	0.4	0.3	18.3	0.1	0.4	6.7	0.0	0.3	-	27.9	4.0	-	-
		Number	-	14	24	22	17	12	20	21	19	8	22	17	4	15	18	4	-	10	8	-	-
	L.Victoria	Minimum	5.5	0.5	75.0	6.8	1.7	0.0	0.0	-	0.0	0.2	8.6	0.0	0.1	0.0	0.0	0.5	0.0	0.0	0.7	3.0	0.0
		Maxmum	50.0	145.8	105.0	9.9	48.0	71.0	7.0	-	0.6	0.8	134.0	0.4	0.3	13.0	0.0	0.6	5.1	61.0	63.0	1715.0	20.0
		Average	20.5	19.8	89.5	8.4	10.3	37.2	1.8	-	0.1	0.3	14.5	0.1	0.2	6.1	0.0	0.5	1.7	21.6	8.0	1080.1	6.1
		Number	6	28	43	40	36	5	40	-	32	15	42	36	11	36	37	2	3	16	18	8	8
	Lagoon	Minimum	42.0	0.1	100.0	6.3	11.0	140.0	8.7	68.0	0.4	0.2	8.0	0.1	0.2	4.0	0.0	0.3	2.7	47.0	2.5	999.0	400.0
		Maxmum	245.0	104.0	1180.0	10.7	750.0	988.0	185.0	68.0	8.1	0.8	219.0	43.9	8.1	549.0	2.2	11.7	531.3	435.0	180.0	1013000.0	42000.0
		Average	140.3	8.9	623.1	8.4	138.8	408.1	37.2	68.0	2.5	0.4	96.4	4.4	3.3	80.5	0.2	4.2	159.9	134.1	24.2	183321.2	14077.1
		Number	4	22	47	41	32	33	35	1	32	12	41	41	23	43	38	8	16	11	22	6	7
River	Local	Minimum	51.0	0.0	25.0	3.6	1.0	0.0	0.0	0.0	0.0	0.1	1.4	0.0	0.0	0.0	0.0	0.0	4.6	0.0	0.0	999.0	0.0
		Maxmum	580.0	398.0	968.0	9.9	1000.0	700.0	960.0	180.0	18.1	28.0	222.0	20.2	0.6	151.0	0.1	2.3	28.0	1010.0	22.0	16500.0	1200.0
		Average	250.8	17.2	147.0	7.0	90.2	159.0	39.5	30.2	4.1	1.4	14.1	0.4	0.2	8.6	0.0	0.2	16.3	66.8	4.5	5116.7	343.8
		Number	12	41	92	83	75	44	82	93	82	27	96	82	20	79	86	19	2	32	41	6	6
	R.Nile	Minimum	20.0	0.0	86.0	6.8	1.2	26.0	0.0	10.0	0.0	0.1	7.5	0.0	0.2	0.0	0.0	0.0	-	0.0	0.9	8850.0	0.0
		Maxmum	20.0	13.9	182.0	8.8	14.0	364.0	16.0	200.0	1.5	0.5	33.5	0.4	0.4	13.0	0.0	0.9	-	170.0	6.4	8850.0	0.0
		Average	20.0	5.2	100.9	7.5	5.9	147.6	2.4	24.8	0.3	0.3	12.8	0.2	0.3	5.8	0.0	0.3	-	31.1	3.6	8850.0	0.0
		Number	1	14	22	20	15	5	19	20	18	8	22	15	4	14	18	5	-	11	7	1	1
	(Municipal industory)	Minimum	2.2	1.2	61.0	5.3	1.4	0.0	0.0	-	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.1	10.0	0.0
		Maxmum	275.0	99.8	4690.0	11.8	1116.0	2400.0	1060.0	-	53.6	4.2	909.4	11.9	17.7	402.0	1.6	1.1	890.0	800.0	158.0	1445000.0	109100.0
		Average	82.5	8.4	530.0	8.1	99.3	466.4	60.7	-	3.9	0.5	90.0	1.0	1.6	40.2	0.1	0.3	134.8	97.2	12.1	115986.1	11804.9
		Number	6	40	89	80	73	51	68	-	70	34	86	84	32	84	86	14	21	31	40	13	15
Borehole	Total	Minimum	0.0	-	80.0	5.5	0.0	69.0	-	12.0	0.0	0.1	8.2	0.0	-	0.0	0.0	-	-	-	-	0.0	0.0
		Maxmum	11.0	-	11900.0	8.2	65.0	1500.0	-	225.0	7.5	1.1	420.0	0.5	-	148.0	0.3	-	-	-	-	200.0	0.0
		Average	3.3	-	657.8	6.6	4.5	345.4	-	80.9	0.7	0.4	55.8	0.1	-	38.2	0.0	-	-	-	-	40.3	0.0
		Number	6	-	55	54	47	35	-	54	45	28	57	50	-	50	53	-	-	-	-	10	10
Standerds for urban treated			10 TCU			6.5- 8.5	10 NTU			500mg/l	0.3 mg/l	1.0 mg/l	200 mg/l			250 mg/l						0 /100ml	
Rural drinking water standerds						5.0 - 9.5	10 (30)			600 (800)	1 (2)	2 (4)					0 (3)					(50/100 ml)	
WHO criteria (drinking water)			15 TCU				5 NTU		<1000mg/l		0.3 mg/l	1.5 mg/l				250 mg/l	3mg/l	1.5mg/l				0/100 ml	
Drinking water criteria (Japan)			< 5 TCU			5.8-8.6	< 2 NTU	< 500mg/l		< 300mg/l	0.3 mg/l	0.8 mg/l	200 mg/l			200 mg/l					< 10 mg/l	0/100 ml	0 /100ml
Ambient standards (Lake, Type C				>2.0mg/l		6.0- 8.5						(0.8 mg/l)			0.1 mg/l					(8mg/l)*1	1.0 mg/l		
Ambient standards (River, Type C				>5.0mg/l		6.5- 8.5						(0.8 mg/l)			0.1 mg/l				5mg/l				

MAC : Maximum Allowable Concentration

*1 : COD(Mn)

*Evaluate Average Value : 🟨 : Over Criteria value (Urban drinking water)、 🟥 : Over Criteria value (Rural drinking water MAC)

(2) Water Quality Data of Existing Boreholes

Table 3-5 shows average values of each analysis item for each district obtained from the water quality data upon borehole drilling. Yellow and red cells indicate those exceeding the water quality standards of urban and rural drinking waters, respectively. In many districts, the measured values of Turbidity, Color, Calcium, Manganese, and Iron exceed the standard. Especially in Bukedea, Kaberamaido, Kumi, Namtumba, and Sironko, the average values of Turbidity, Fluoride, and Iron exceed the rural drinking water tolerance.

For assessment of the water quality values, the number of boreholes whose values dissatisfied the standard by districts was counted as shown in Table 3-6 since water quality values vary a lot borehole to borehole. The table also shows the percentage of the boreholes that do not meet the standard for each item to compare fairly among districts with different number of boreholes. Bugiri, Dokolo and Kaliro ranked at top three districts in the percentage for many different items such as pH, Hardness and Fluoride.

Table 3-5 Average Value of Water Quality of Boreholes by District

District	Items	pH	Turbidity	Colour	Total Hardness	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Chloride (Cl)	Nitrate (NO3)	Fluoride (F)	Manganese (Mn)	Total Iron (Fe)
ABIM	Average	6.80	14.3	9	186	30.3	26.5		1.4	0.03	0.45		1.17
	Number of Data	19	13	10	19	19	19		19	13	19		19
AMOLATAR	Average	6.69	2	15	293	52.9	32.5		29.0	0.65	0.25		0.07
	Number of Data	9	9	8	7	7	6		8	8	8		9
AMURIA	Average	6.78	9	22	213	76.9	37.7	20.2	2.6	1.30	0.39	0.02	0.41
	Number of Data	22	20	13	22	22	22	6	19	6	20	2	21
APAC	Average	6.67	3	18	212	53.2	33.6	26.4	10.0	0.40	0.41	0.12	0.22
	Number of Data	70	58	44	69	68	68	9	68	54	56	5	70
BUDAKA	Average	6.68	6	26	157	68.5	32.3	56.2	20.9	1.72	0.37	0.22	0.19
	Number of Data	41	38	19	38	39	39	12	36	34	33	8	39
BUGIRI	Average	6.60	2	12	269	73.8	21.6	29.2	41.1	0.50	0.26		0.20
	Number of Data	33	29	9	33	33	33	17	33	27	25		32
BUKEDEA	Average	6.81	33	6	203	84.8	13.9	40.0	20.5	7.54	0.44		0.50
	Number of Data	19	17	7	19	19	19	13	19	12	16		18
BUSIA	Average	6.58	6	7	193	102.6	65.4	33.5	22.8	3.47	0.93	0.58	0.14
	Number of Data	46	29	12	45	46	46	12	44	24	44	14	43
BUTALEJA	Average	6.98	3	46	214	79.2	23.0	53.7	17.0	1.60	0.53	0.26	0.51
	Number of Data	21	17	12	21	21	21	6	21	16	19	6	21
DOKOLO	Average	6.44	4	18	238	59.9	21.1	531.5	157.4	0.27	0.27		0.14
	Number of Data	20	19	12	20	20	20	5	16	10	18		20
IGANGA	Average	6.84	11	12	174	52.6	18.4	30.0	17.2	2.74	1.21	0.08	0.23
	Number of Data	64	46	20	64	65	64	30	56	53	50	9	63
JINJA	Average	6.63	6		210	128.1	23.0	27.5	43.4	18.71	0.53	0.37	0.11
	Number of Data	83	16		84	82	84	84	83	77	70	59	68
KAABONG	Average	7.23	3	9	392	62.4	59.0		36.1	0.31	0.26		0.19
	Number of Data	29	28	23	29	29	29		29	25	17		29
KABERAMAIDO	Average	6.57	57	8	195	88.8	32.8	173.5	62.9	2.94	0.55	0.09	0.05
	Number of Data	34	31	25	34	33	33	11	30	27	28	7	33
KALIRO	Average	6.53	11	17	333	188.3	33.9	59.1	78.4	5.45	0.91	0.20	1.77
	Number of Data	105	31	2	98	100	73	64	80	73	41	36	67
KAMULI	Average	6.62	14	7	241	110.5	26.1	55.5	57.8	5.41	1.21	0.10	0.29
	Number of Data	228	98	24	231	227	227	170	201	188	135	81	183
KAPCHORWA	Average	8.20	7		20	8.0	2.9	200.0	2.0	0.44	1.63	0.05	0.09
	Number of Data	1	1		1	1	1	1	1	1	1	1	1
KATAKWI	Average	6.98	6.9	32.9	196	82.0	46.9	29.9	11.4	1.93	0.54	0.14	0.23
	Number of Data	43	40	18	43	40	40	8	41	24	24	11	43
KAYUNGA	Average	6.77	5.6	22.0	251	134.0	36.3	42.8	72.4	14.19	0.72	0.09	0.18
	Number of Data	119	46	11	122	115	115	88	100	89	74	65	105
KOTIDO	Average	6.88	3.1	10.5	275	49.7	29.3		11.3	0.02	0.38		0.64
	Number of Data	16	13	13	16	16	16		14	6	15		14
KUMI	Average	6.83	83.0	17.6	170	74.7	15.6	37.2	9.3	3.22	0.51	1.99	3.82
	Number of Data	31	30	19	31	31	30	26	30	21	25	5	29
LIRA	Average	6.73	3.2	17.6	114	28.6	11.7	22.7	4.8	0.29	0.21	0.21	0.53
	Number of Data	93	80	45	94	94	94	38	88	61	86	1	94
LUWERO	Average	6.50	21.3	6.8	131	111.7	31.0	33.7	20.9	8.74	0.69	0.62	0.13
	Number of Data	74	58	12	73	74	73	49	61	61	53	48	66
MANAFWA	Average	7.14	6.4	39.2	154	57.9	16.8	35.4	4.8	1.66	0.34	0.14	0.15
	Number of Data	23	21	12	24	24	24	8	21	17	22	6	24
MAYUGE	Average	6.60	12.7	5.8	422	84.4	45.3	14.0	27.9	0.38	0.48		0.22
	Number of Data	20	19	4	20	19	20	3	18	16	16		19
MBALE	Average	6.99	16.7	5.0	162	102.5	27.3	60.6	6.9	1.77	0.63	0.07	0.10
	Number of Data	19	13	3	19	19	18	10	13	11	18	6	14
MOROTO	Average	6.95	2.1	6.7	301	86.3	81.6		2.5	0.10	0.50		0.16
	Number of Data	23	14	16	22	22	22		21	11	22		21
MUKONO	Average	6.73	6.2	35.6	199	133.2	22.8	38.8	59.4	18.75	0.69	0.34	0.93
	Number of Data	208	42	17	211	208	206	176	196	180	168	127	155
NAKAPIRIPIRITI	Average	7.03	3.3	22.5	374	126.0	111.9	96.0	10.8	0.41	0.53		0.13
	Number of Data	29	25	24	29	29	29	1	24	23	19		29
NAKASONGOLA	Average	7.26	15.3	9.2	213	72.0	55.0	82.7	30.0	1.24	0.42	0.01	0.45
	Number of Data	56	45	15	58	58	58	33	55	40	32	1	57
NAMUTUMBA	Average	6.48	22.4	13.9	119	47.9	16.2	27.8	20.1	3.46	0.49	0.17	2.33
	Number of Data	85	51	15	89	86	89	62	59	70	51	35	63
PALLISA	Average	6.63	5.4	28.2	230	106.7	42.6	107.4	57.3	2.82	0.76	0.07	0.20
	Number of Data	79	73	34	79	79	78	20	70	60	71	15	79
SIRONKO	Average	7.07	7.7		215	121.3	32.8	78.7	9.5	4.35	0.91	13.16	0.19
	Number of Data	16	16		16	16	16	12	16	10	14	12	16
SOROTI	Average	6.55	3.4	14.4	167	54.7	37.8	25.0	6.9	0.88	0.36	0.09	0.12
	Number of Data	59	44	41	60	60	59	10	57	25	58	7	60
TORORO	Average	6.81	4.3	12.8	205	83.1	33.9	24.1	15.4	3.09	0.55	1.10	0.11
	Number of Data	58	50	30	60	59	58	18	59	47	53	15	58
WAKISO	Average	7.10	5.9	5.2	140	15.4	6.6	8.7	29.0	6.17	0.76	0.59	0.58
	Number of Data	67	45	33	52	7	9	2	65	64	51	29	53

standards for urban treated drinking water	6.5- 8.5	< 10 NTU	< 10 TCU	< 500mg/l	< 75 mg/l	< 50 mg/l	< 200 mg/l	< 250 mg/l	< 10 mg/l	< 1.0 mg/l	< 0.1 mg/l	< 0.3 mg/l
Rural drinking water standards (MAC)	5.5 - 8.5 (5.0 - 9.5)	< 10 NTU (30 NTU)		< 600 mg/l (800 mg/l)				< 250 mg/l (500 mg/l)	< 20 mg/l (50 mg/l)	< 2 mg/l (4mg/l)	< 1 mg/l (2 mg/l)	< 1 mg/l (2 mg/l)
WHO criteria (drinking water)		< 5 NTU	< 15 TCU				< 200mg/l	< 250 mg/l	< 50 mg/l	< 1.5 mg/l	< 0.1 mg/l	< 0.3 mg/l
Drinking water criteria (Japan)	5.8 - 8.6	< 2 NTU	< 5 TCU	< 300 mg/l				< 200 mg/l	T-N < 10 mg/l	< 0.8 mg/l	< 0.05 mg/l	< 0.3 mg/l
Ambient standards (Lake, Type C :Japan)	6.0 - 8.5									< 0.8 mg/l		
Ambient standards (River, Type C :Japan)	6.5 - 8.5									< 0.8 mg/l		

MAC : Maximum Allowable Concentration

🟨 : Over Criteria value (Urban drinking water)、🟪 : Over Criteria value (Rural drinking water MAC)

Table 3-6 Ratio of Number of Boreholes Dissatisfy Standards (MAC)

District	Number of well data	Number of over standard(MAC) well									
		pH		Total Hardness		Chloride (CL)		Fluoride (F)		Total iron (Fe)	
		Number	(%)	Number	(%)	Number	(%)	Number	(%)	Number	(%)
1 ABIM	13										
2 AMOLATAR	5										
3 AMURIA	26									1	4.2
4 APAC	67			5	7.5			1	1.9	1	1.5
5 BUDAKA	35			1	2.9						
6 BUGIRI	30	1	**3.3**	5	**16.7**	1	3.3			1	3.4
7 BUKEDEA	17									2	**12.5**
8 BUSIA	35			3	8.6	1	3.0	1	**2.9**		
9 BUTALEJA	6										
10 DOKOLO	15	1	**6.7**	3	**20.0**	3	**23.1**				
11 IGANGA	52							1	**2.4**	1	1.9
12 JINJA	69	2	2.9	4	5.8						
13 KAABONG	26			1	3.8						
14 KABERAMAIDO	32			1	3.1	3	**10.7**				
15 KALIRO	52	2	**3.8**	10	**19.2**	4	**9.8**	1	**3.4**	6	**22.2**
16 KAMULI	91			2	2.2	1	1.2	1	2.1	2	2.5
17 KAPCHORWA	1										
18 KATAKWI	39										
19 KAYUNGA	119	1	0.9	7	5.9	9	9.4			1	1.0
20 KOTIDO	16									4	**26.7**
21 KUMI	26									1	4.3
22 LIRA	83	1	1.2							3	3.6
23 LUWERO	72			1	1.4			1	1.9		
24 MANAFWA	24										
25 MAYUGE	18			3	**16.7**						
26 MBALE	16										
27 MOROTO	16										
28 MUKONO	87			4	4.6	4	5.2			2	2.7
29 NAKAPIRIPIRITI	28			4	14.3						
30 NAKASONGOLA	48			3	6.3					3	6.3
31 NAMUTUMBA	97			2	2.1					2	3.0
32 PALLISA	74			4	5.4	3	4.6	1	1.5	1	1.4
33 SIRONKO	14										
34 SOROTI	53			2	3.8						
35 TORORO	56			1	1.8						
36 WAKISO	66			2	3.9					1	1.9
37 BUKWA	0										
38 BUDUDA	0										
Total	1524	8		68		29		7		32	

MAC: Maximum Allowable Concentration for Rural Drinking Water

3.3 Field Survey for Water Quality

3.3.1 Overview of the Survey

JICA Study Team investigated the entire basin except the restricted area to enter for safety, to examine the water quality condition of the water sources targeted for water resource development. One borehole, one shallow well and one spring were selected as sampling points in each county. As for surface-water, sampling points were placed in the upper, medium, and lower parts of each sub-basin and major lakes. When sampling teams could not find planed points for some reason, the team selected alternative points around the planed points, and took samples.

Analysis of Alkalinity and Suspended Solids (SS) were added to the list of analysis items as per a request from Ugandan side.

(1) Analysis items

The analysis items are shown in Table 3-7. There are 25 items for understanding the basic aspect and pollution aspect as well as hydrogeological aspect. Temperature, pH, EC and Coliform groups are measured by portable device at on site; other items are analyzed in laboratory.

As for Arsenic, it can’t analyze in Uganda, so it was analyzed in Tanzania for the samples taken at rainy season, and analyzed in Japan for the samples taken at dry season.

Table 3-7 Items of Water Quality Analysis in this Study

Analysis Item			Uganda Water Quality Standard		WHO guidelines	Remarks
			Urban Water Supply	Rural Water Supply		
On site Analysis	1	Water Temperature	-	-	-	Basic aspect
	2	pH	+	+	-	ditto, corrosiveness
	3	Electrical conductivity (EC)	-	-	-	Indicator of inorganic pollution
	4	Coliform Bacteria	+	+	+	Indicator of excrement pollution
Laboratory Analysis	5	Alkalinity	-	-	-	Basic aspect
	6	Suspended Solids (SS)	-	-	-	ditto
	7	Turbidity (NTU)	+	+	+	ditto
	8	Hardness ($CaCO_3$)	+	+	-	ditto
	9	Total Dissolved Solid (TDS)	+	+	+	ditto
	10	Ammonium (NH_4)	-	-	+	Indicator of excrement pollution
	11	Fluoride (F)	+	+	+	Inorganic (hazardous)
	12	Arsenic (As)	+	-	+	ditto
	13	Nitrite nitrogen (NO_2)	-	+	+	ditto
	14	Total iron (Fe)	+	+	+	ditto
	15	Manganese ion (Mn)	+	+	+	ditto
	16	Nitrate nitrogen (NO_3)	+	+	+	ditto, for hydrogeological analysis
	17	Chloride ion (Cl)	+	+	+	for hydrogeological analysis
	18	Sulfuric ion (SO_4)	+	+	+	ditto

	19	Sodium (Na)	+	-	+	ditto
	20	Potassium (K)	-	-	-	ditto
	21	Magnesium (Mg)	+	-	-	ditto
	22	Calcium (Ca)	+	-	-	ditto
	23	Hydrogen carbonate (HCO_3)	-	-	-	ditto
	24	BOD	-	-	-	Indicator of organic pollution. Only for river, lake
	25	COD	-	-	-	ditto

(2) Sampling points and its classification by water sources

Originally a total of 200 sampling points were planned including 10 lakes, 46 rivers, 89 deep wells (boreholes), 26 shallow wells and 29 springs. However, some points were not accessible or not found in the sites. In such a case, other points were selected as alternative points located near the planed points. As a result, measured 203 points are shown in Table 3-8, 3-9 and their locations are shown in Figure 3-4 and 3-5.

Under ordinary circumstance sampling points are same during rainy season and dry season. However, 17 points couldn’t get samples at dry season because of dried up of water or some other reasons. The replaced points and the reasons of replacement are shown in the Table 3-10.

(3) Survey schedule

Rainy season; Survey was curried out from May 20 to June 10 in 2009.

Dry season; Survey was curried out from January 19 to February 7 in 2010

Table 3-8 Sampling Points of Water Quality Survey (by District)

District	County	Number of Sampling points (Site Number)				
		River	Lake	Deep well (Borehole)	Shallow well	Protected Spring
AMURIA	amuria	R04		BH03	SW01	PS01
	kapelebyong	R03		BH01,02		
	wera			BH04		
KABERAMAIDO	kaberamaido			BH35,36,95	SW04	PS14
	kalaki	R01,R02		BH34		
SOROTI	kasilo		L02,03	BH84,85,86	SW18,19	PS35
	serere			BH87,88		
	soroti					
KATAKWI	usuk	R06,R07	L07,08	BH42,43,44,45,46	SW08	
NAKASONGOLA	buruli		L01,06	BH71,72,96		
KAYUNGA	baale	R34,38,39		BH48	SW09	
	ntenjen	R33		BH47		
KAMULI	budiope	R30	L04,05	BH40	SW06,07	
	bugabula	R29		BH41		
	buzaaya	R31		BH39		
KALIRO	bulamogi	R28		BH37,38	SW05	PS15
PALLISA	butebo			BH79	SW15	PS33
	pallisa	R21,25	L09	BH77,78		
BUDAKA	budaka	R15		BH05	SW16	PS02
	kibuku			BH76		
KUMI	kumi	R12,14		BH49		PS25,26
	Ngora	R05		BH50,51		
BUKEDEA	bukedea	R11,13		BH10,11		PS05
KAPCHORWA	tingey					PS16,17,18,19,20,21,22,23,24
	kween					
BUKWA	kongasis			BH12		PS06,07,08,09
SIORONKO	budadiri			BH81,82	SW17	PS34
	bulambuli	R08,09,10		BH80,83		
MANAFWA	bubulo	R16		BH56,57,58,59		PS27
MBALE	bungokho			BH63,64,65	SW13	PS29
BUTALEJA	bunyole	R17		BH18,19,20,21	SW02	PS10
NAMUTUMBA	busiki	R24		BH73,74,75	SW14	PS32
TORORO	budama			BH91,92,93	SW20	PS36
	tororo	R18,19		BH89,90		
IGANGA	bugweri	R22,23		BH23,24,25,26		PS11,12
	kigulu	R26		BH27,28,29		
	luuka	R27		BH22		
JINJA	kagoma			BH30,33	SW03	PS13
	butembe			BH31,32		
MUKONO	buyikwe	R32,35		BH69		PS30,31
	mukono	R37		BH66		
	nakifuma	R36		BH67,68,70		
LUWEERO	katikamu			BH54,54	SW10,11	
	wabusana			BH53,55		
WAKISO	kyaddondo			BH94		PS37,38
MAYUGE	bunya			BH60,61,62	SW12	PS28
BUGIRI	bukooli	R20	L10	BH06,07,08,09		PS03,04
BUSIA	samia-bugwe			BH13,14,15,16,17		
Total		39	10	96	20	38

Total 203 sampling points、but following site datas are not available. PS31(raniy season), BH09(dry season)

Table 3-9 Sampling Points of Water Quality Survey by Sub-Basin

Sub-Basin		WQ_survey points				
No	Name	Surface Water		Ground Water		
		River	Lake	Deep well	Shallow well	Protected Spring
1	Okok	-	-	(BH01,02)	-	-
2	Okere	R 03,04	-	BH04,44	SW01,18	PS01
3	Awoja	R05,06,07,08,09,10, 11,12	L07,08	BH10,11,42,43,45,46,50,51,80,81,82,83,88,(12)	SW 08,17	PS05,06,08,16,17,18,19,20,21,22,23,24, 26, (07,09)
4	Lwere	R13,14	-	BH49,77,79	SW15	PS-25,33
5	Akweng	R01,02	L02	BH03,34,36,95	SW04,19	PS-14,35
6	Abalan	-	-	BH35	-	-
7	Kyoga Lakeside Zone	-	L01,03,04,05,06	BH71,72,84,85,86,87,96	-	-
8	Mpologoma	R15,16,17,18,19,20, 21,22,23,24,25	L09,10	BH05,06,07,08,13,14,15,16,17,18,19,20,21,23,24,25,26,38,56,57,58,59,63,64,65,73,74,75,76,78,89,90,91,92,93	SW02,13,14,16,20	PS02,03,04,10,11,27,29,32,34,36
9	Lumbuye	R26,27,28	-	BH22,27,28,29,37,60,61,62	SW05,12	PS12,15,28
10	Victoria Nile	R29,30,31,32,33,34	-	BH30,31,32,33,39,40,41	SW03,06,07	PS13,30,31
11	Sezibwa	R35,36,37,38,39	-	BH47,48,52,53,54,55,66,67,68,69,70,94	SW09,10,11	PS37,38

Note: Parenthetic points are located at outside of Lake Kyoga Basin.

Table 3-10 Replaced Sampling Points in Dry Season and the Reasons

Site No	Subbasin No	NON FUNCTIONING BOREHOLES / DRIED UP SPRINGS			REPLACEMENTS		Reason
		Site ID	Source Type	District	Site ID	Source Type	
R03	2	R. Ajeleik	River	Amuria	CD2496	Borehole	River dried up
R34	10	R34 Lumbuye lower	River	Kaliro	R34	River	Change of sampling point, other was dry.
BH03	5	DWD15226	Borehole	Amuria	Acanpi BH	Borehole	low water level,no water flows when pomp up
BH05	8	WDD 14486	Deep Well	Budaka	NUSAF....	Borehole	Not working
BH11	3	Oberei BH	Borehole	Bukedea	Oberei Dug well	shallow well	No yield, dries up in dry season
BH29	9	WDD5934	Borehole	Iganga	Budhege SW	shallow well	Not working
BH43	3	CD3303	Borehole	Katakwi	Akwareka DWD18481	Borehole	No water for a month now, dried up
BH60	9	WDD12042	Borehole	Mayuge	Magada BH	Borehole	Not working
BH68	11	DWD8304	Borehole	Mukono	Wdd8399	Borehole	Not working
BH72	7	Kibengo	Borehole	Nakasongola	Wabinyonyi	Borehole	Not working
BH80	3	DWD 17168	Deep Well	Sironko	CD 36....	Borehole	Not working
BH91	8	WDD 12358	Deep Well	Tororo	WDD	Borehole	Not working
BH95	5	R Omunyal Upper	River	Kaberamaido	Olelai Ps. BH	Borehole	River was dry
BH96	7	Mukote River	River	Nakasongola	WDD35509	Borehole	River dried up
PS11	8	Sp/IG/74	Spring	Iganga	Namiganda SW	shallow well	Dried up
PS17	3	DWSCG/KAP/02166	Spring	Kapchorwa	KAP/02/027	spring	Dried up
PS19	3	KAP/02/142	Spring	Kapchorwa	Chemotow	spring	Dried up

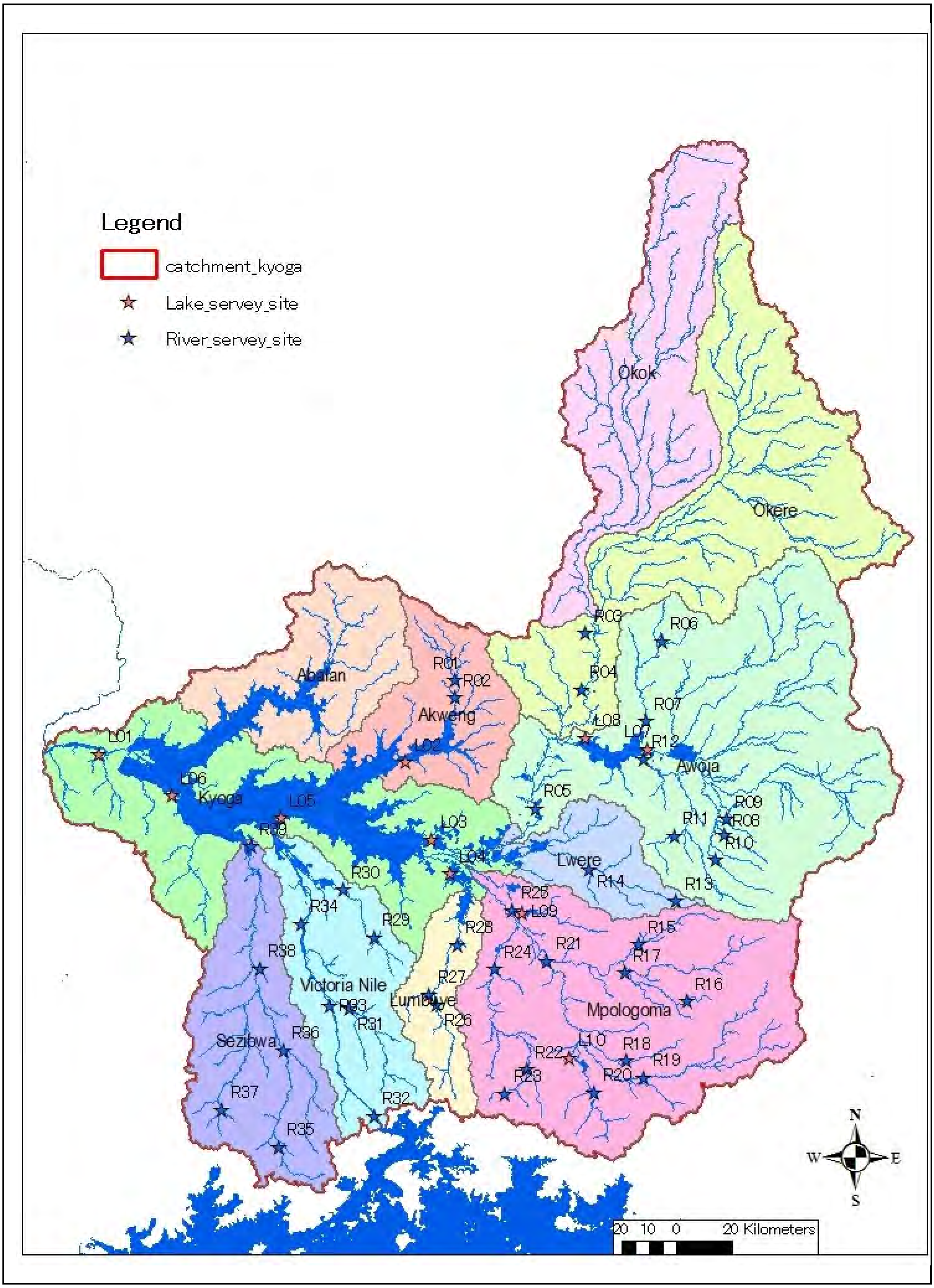


Figure 3-4 Water Quality Survey Sampling Points (Rivers, Lakes)

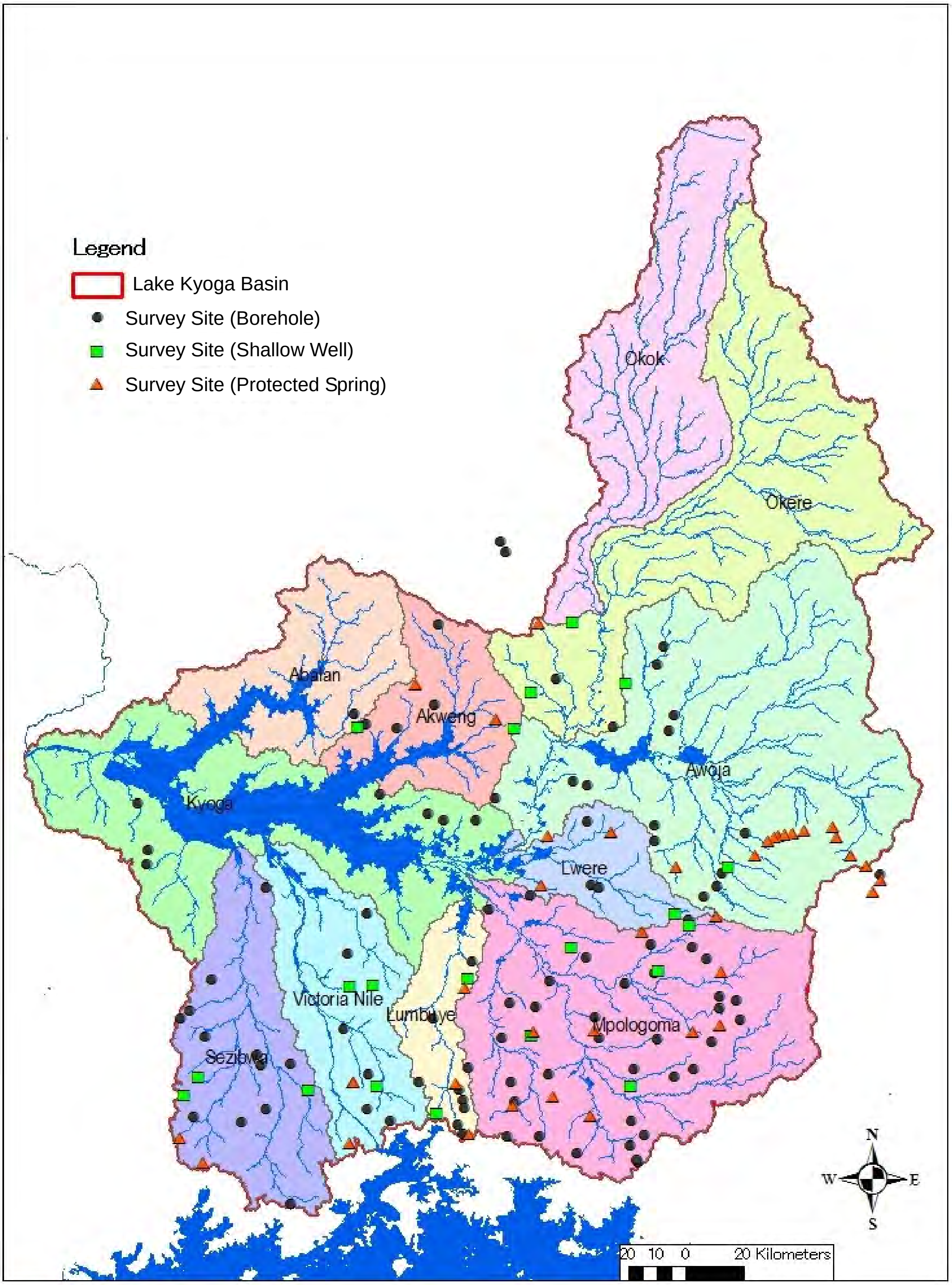


Figure 3-5 Water Quality Survey Sampling Points (Deep wells, Shallow wells and Springs)

3.3.2 Survey Result

The survey results (rainy season and dry season) are shown in Table 3-11 to 3-15 by sources. Hue of cells for survey items indicates characteristic features; Blue indicates basic items, yellow indicates pollution items and red indicates harmful items. Yellow and red cells in the survey result indicate those results exceed the water quality standards of urban and rural water supplies, respectively.

Overview of the basic items, pollution items and harmful items are described bellow.

The survey results are explained below by source (rivers, lakes, deep wells, shallow wells and springs).

Piper (Tri-linear) diagram applied for consideration on origin of each water source using hydrogeological items.

(1) Water Quality of Rivers

▪ **Basic items**

pH; Most of pH values satisfied the urban drinking water standards, but the values are slightly at low level. Sub-basin 8 (Mpologoma) and Sub-basin 11 (Sezibwa) shows high pH level (nearly 10) in maximum value.

Turbidity; the results of Sub-basin7 (Kyoga Lakeside) and Sub-basin 9 (Lumbuye) are under the standard, but the results of other sub-basins exceed the standard. Higher value (over 2000mg/l) are found in Sub-basin 3 (Awoja) and Sub-basin 8 (Mpologoma). The reason seems to be heavy rain precipitated prior to the samplings. These points also show higher SS values like 8000mg/l, 1600mg/l respectively.

Alkalinity; it is measured for indicator of corrosiveness. In generally, corrosive water has alkalinity under 20 mg/l. Almost all sub-basins have alkalinity more than 50 mg/l in average. But Sub-basin 10 (Victoria Nile) and Sub-basin 11 (Sezibwa) show lower value than 20 mg/l in minimum value.

Hardness; the result of all of survey points meets the standard (500mg/l).

▪ **Pollution items**

Coliform groups; the results of all sub-basins exceeded the standard.

BOD; mean values of the results are slightly at low level (2 to 8 mg/l).

PO_4-P; Being compared to Japanese ambient standard for lakes, the result of PO_4-P shows higher level than Japanese standard.

▪ **Harmful items**

T-Iron; all of sub-basins have higher values than the urban drinking water standard.

Manganese; the results of Sub-basin 4 (Lwere) and Sub-basin 9 (Lumbuye) exceeded the standard.

Overviewing the results, Sub-basin 2 (Okere), Sub-basin 5 (Akweng) and Sub-basin 10 (Victoria Nile) have relatively good condition of water quality except the period under influence of heavy rain.

When taking detailed look at Sub-basin 8 (Mpologoma), Sub-basin 10 (Victoria Nile) and Sub-basin 11 (Sezibwa) which has large city in upper area in the basin, those water quality of upstream are serious but it is sometimes improved in the downstream.

(2) Water Quality of Lakes

Lakes water are sampled at Lake Bisina in Sub-basin 3 (Awoja), Lake Opeta in sub-basin 8 (Mpologoma), and Lake Kyoga for Sub-basin 5 (Akweng) and Sub-basin 7 (Kyoga Lakeside zone).

- **Basic items**
  - pH: the values show about 7 level, which are slightly higher than that in rivers.
  - Turbidity; most of sub-basins have values less than 10 NTU in average except for Sub-basin 8 (Mpologoma). The maximum turbidity is 30 NTU.
  - SS; most of sub-basin have values under 20 mg/l, especially Sub-basin 3 (Awoja) shows 1.0 mg/l, it means that water is clear. The alkalinity is more than 100mg/l, and hardness are under 300mg/l.
- **Pollution items**
  - Coliform groups: it indicates fecal pollution; all of sub-basins values exceeded the drinking water standard.
  - BOD; the results of BOD average values of each sub-basin are under 5mg/l, it means that organic pollution level is slightly low. Especially Sub-basin 3 (Awoja) and Sub-basin 5 (Akweng) shows lower value than the others, maximum values is 3mg/l.
- **Harmful item**
  - T-iron; the values of Sub-basin 8 (Mpologoma) exceeded the standard for urban drinking water at the lake near wetlands located downstream of the sub-basin.
  - Manganese; the values of Sub-basin 3(Awoja) exceeded the standard.

(3) Water Quality of Deep wells (Boreholes)

- **Basic items**
  - pH; average values in all of sub-basins are 6 level. Especially in Sub-basin 4 (Lwere) and Sub-basin 8 (Mpologoma), the average values are slightly lower than allowable range of the urban drinking water standards. (pH>6.5).
  - Turbidity; the results of some wells are over the standard (MAC: 30 NTU), but the values of most of wells are under 10 NTU in each sub-basin.
  - SS; similarly, most of values are less than 20mg/l, however, the maximum values of SS in Sub-basin 11 (Sezibwa) shows 490 NTU. In addition, the average value even shows 35 NTU. It is higher than the other sub-basins.
  - Alkalinity; most of wells show more than 100 mg/l in average.. However, there are some wells which indicate less than 20 mg/l in Sub-basin 3 (Awoja) and Sub-basin 11 (Sezibwa),
  - Hardness; wells in almost all of sub-basins are under the standard (500mg/l), but one well in Sub-basin 8 (Mpologoma) indicates over 1,000 mg/l.

- **Pollution items**

Coliform groups; there are many wells of which results exceeded the standard. It is supposed to be under influence of the surface water intrusion into wells, inadequate maintenance or low quality of the construction control.

- **Harmful item**

T-iron; the average values in Sub-basin 11 (Sezibwa) are higher than the standard for rural drinking water (MAC). The highest value is 63 mg/l. but the average values in the other sub-basins are under the standard.

Manganese; the results of some wells in six sub-basins exceeded the urban standard, but there are no well which results exceed the MAC in all sub-basins.

Fluoride; there are some wells of which water contains Fluoride and the values exceeded the urban standard, but all results are lower than the MAC.

Arsenic; there are few wells of which water contains arsenic, however, the concentrations are very low (0.009 mg/l)..

(4) Water Quality of Shallow Wells

- **Basic items**

pH; Average values of pH in all of sub-basins are 5.9 to 6.7. They are slightly low. Average values of 5 sub-basins among 8 sub-basins are less than urban drinking water standard (pH>6.5).

Turbidity; average values of 4 sub-basins among 8 sub-basins exceeded the MAC (30 NTU). Meanwhile in sub-basin 10 (Victoria Nile), the turbidity is 1.2 NTU in maximum and less than 1.0 NTU in average.

Alkalinity; in sub-basin 3 (Awoja) and sub-basin 11 (Sezibwa), there are some wells of which results are less than 20 mg/l. The averages of 8 sub-basins indicate about 40 to 170mg/l.

Hardness; although one well in sub-basin 8 (Mpologoma) shows the value of 460 mg/l, all wells in all of sub-basins have the values under the standard (500mg/l) level.

- **Pollution items**

Coliform groups; there are many wells of which results exceeded the urban standard and the MAC in similarity with the result of deep wells. It is supposed to be under influence of the surface water intrusion into wells, inadequate maintenance or low quality of the construction control.

- **Harmful item**

T-iron; there are some wells of which results are over the MAC (2.0 mg/l) in the Sub-basin 2 (Okere) and Sub-basin 11 (Sezibwa). Average value also exceeded the MAC in sub-basin11. In the other sub-basins, the results of many wells are over the standard of urban drinking water but under the MAC.

Manganese; there are some wells of which results are over the urban standard in the Sub-basin 9 (Lumbuye) and Sub-basin 11 (Sezibwa). The other shallow wells have lower values than the urban standard.

Fluoride; there are no wells which exceeded the urban standard (1.0 mg/l).

(5) Water Quality of Protected Spring

▪ Basic items

pH; average values in all of sub-basins are 5.6 to 6.4. They are lower than those of deep wells. In the Sub-basin 4 (Lwere), there is a spring which pH is lower than the MAC (pH 5.0). On the other hand there is another spring which pH is over the standard of urban drinking water (pH<9.0) in Sub-basin 8 (Mpologoma). .

Turbidity; average values of Sub-basin 2 (Okere) and Sub-basin 4 (Lwere) exceed the MAC (30 NTU). Meanwhile Sub-basin 9 (Lumbuye) and Sub-basin 10 (Victoria Nile) shows the values under 2.0 NTU in average. In these sub-basins SS is less than ten at a maximum.

Alkalinity; in the Sub-basin 3 (Awoja), 5 (Akweng) and 11 (Sezibwa), there are some springs of which results are less than 20 mg/l. Most of wells in averages have the values with 30 to 100mg/l.

Hardness; all of springs have the values under the standard (500mg/l) level. The maximum is 270 mg/l of a well in the Sub-basin 8 (Mpologoma).

▪ Pollution item

Coliform groups; there are many springs of which results are over the standard in similarity with the result of deep wells

▪ Harmful item

T-iron; there are some springs of which results are little bit over the MAC (Fe:2.0mg/l) in the Sub-basin 2 (Okere) and Sub-basin 3 (Awoja). Although the results of many sub-basins exceed the standard of urban drinking water (0.3 mg/l) in average, no sub-basin of which results exceeded the MAC in average.

Manganese; there are some springs of which results exceeded the standard of urban drinking water (0.1mg/l) in Sub-basin 2 (Okere) and 4 (Lwere). The average value of each sub-basin is under the standard.

Fluoride; there are no wells of which results exceeded the urban standard (1.0mg/l).

Table 3-11 Result of Water Quality Survey (River)

SOURCE TYPE	Subbasin	ITEMS	pH	Temp. (℃)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)	Alkalinity (total) (mg/l)	Hardness (CaCO3) (mg/l)	E.C. (μS/cm)	Coliform Group (group/100ml)	BOD5 (mg/l)	COD(Cr) (mg/l)	PO4-P (mg/l)	NH4 (mg/l)	Mn (mg/l)	As (*1) (mg/l)	F (mg/l)	Fe (mg/l)
River	2 Okere	Maximum	7.3	28.4	19.5	27	205	171	122	306	TNTC	3.8	55.0	0.23	0.20	0.18	< 0.001	0.41	3.590
		Minimum	6.1	19.9	4.9	2	137	112	96	282	10	0.4	5.0	0.15	0.02	0.00	< 0.001	0.13	0.200
		Average	6.7	24.9	10.8	10	172	136	113	296	—	2.5	26.3	0.19	0.13	0.06	< 0.001	0.28	1.398
	3 Awoja	Maximum	7.7	30.6	146.0	185	320	240	180	460	TNTC	9.1	342.0	1.38	0.49	0.18	< 0.001	0.65	13.990
		Minimum	5.8	19.8	0.5	0	47	18	18	115	6	0.3	3.0	0.08	0.07	0.00	< 0.001	0.00	0.000
		Average	7.1	25.7	32.0	37	137	85	68	227	—	4.0	75.8	0.54	0.22	0.02	< 0.001	0.25	3.064
	4 Lwere	Maximum	7.0	28.7	35.9	28	205	202	155	392	TNTC	9.1	140.0	0.83	0.09	0.27	< 0.001	0.50	20.010
		Minimum	6.0	24.6	3.4	3	58	34	28	69	0	1.0	10.0	0.08	0.05	0.00	< 0.001	0.02	0.210
		Average	6.7	26.8	24.3	18	123	87	72	218	—	6.0	69.3	0.46	0.08	0.10	< 0.001	0.25	5.288
	5 Akweng	Maximum	7.0	26.4	10,115.0	8,675	118	95	85	235	TNTC	2.7	150.0	0.70	0.73	0.13	< 0.001	0.22	14.980
		Minimum	6.0	23.0	6.0	7	57	54	36	82	0	2.3	9.0	0.34	0.10	0.00	< 0.001	0.00	0.190
		Average	6.5	24.6	2,063.1	1781	98	75	65	169	—	2.5	88.0	0.52	0.27	0.07	< 0.001	0.12	4.552
	7 Kyoga Lakeside Zone	Maximum	6.2	23.1	45.7	38	42	40	60	77	TNTC	8.0	28.0	—	0.50	0.02	—	0.27	1.905
		Minimum	6.2	23.1	45.7	38	42	40	60	77	TNTC	8.0	28.0	—	0.50	0.02	—	0.27	1.905
		Average	6.2	23.1	45.7	38	42	40	60	77	TNTC	8.0	28.0	—	0.50	0.02	—	0.27	1.905
	8 Mpologoma	Maximum	9.8	31.3	2,337.0	1,601	255	173	153	377	TNTC	19.0	200.0	1.70	0.31	0.39	< 0.001	1.07	27.850
		Minimum	6.1	20.9	0.6	3	50	44	50	52	0	0.1	6.0	0.08	0.03	0.00	< 0.001	0.00	0.000
		Average	7.1	25.4	182.8	136	124	92	83	218	—	5.1	45.5	0.65	0.09	0.07	< 0.001	0.37	4.710
	9 Lumbuye	Maximum	7.1	29.5	8.9	37	400	166	145	3,870	TNTC	8.0	76.0	1.20	0.10	0.89	< 0.001	0.93	8.360
		Minimum	6.3	21.2	0.7	3	142	110	97	276	4	0.3	19.0	0.13	0.02	0.00	< 0.001	0.20	0.111
		Average	6.8	24.9	3.6	13	244	146	119	982	—	3.7	52.8	0.49	0.06	0.16	< 0.001	0.62	2.372
	10 Victoria Nile	Maximum	10.0	31.0	134.0	204	600	216	222	554	TNTC	4.6	65.0	0.71	0.32	0.04	< 0.001	0.52	3.460
		Minimum	5.8	23.8	0.5	1	47	5	20	99	0	0.2	7.0	0.08	0.00	0.00	< 0.001	0.02	0.000
		Average	7.3	26.1	17.9	26	205	86	101	241	—	1.8	20.7	0.24	0.07	0.01	< 0.001	0.25	0.662
	11 Sezibwa	Maximum	9.1	31.2	36.9	23	145	90	66	1,446	TNTC	12.0	64.0	0.49	1.05	0.41	< 0.001	0.62	6.345
		Minimum	5.8	21.5	4.3	5	25	12	16	39	12	1.2	10.0	0.23	0.05	0.00	< 0.001	0.05	0.020
		Average	7.2	25.0	17.0	14	65	44	45	238	—	4.7	30.7	0.32	0.22	0.06	< 0.001	0.27	2.440
River Total		Maximum	10.02	31.3	10,115.0	8,675	600	240	222	3,870	TNTC	19.0	342.0	1.70	1.05	0.89	< 0.001	1.07	27.850
		Minimum	5.77	19.8	0.5	0	25	5	16	39	0	0.1	3.0	0.08	0.00	0.00	< 0.001	0.00	0.000
		Average	7.04	25.5	193.0	165	140	88	80	283	—	4.0	47.5	0.47	0.14	0.06	< 0.001	0.31	3.133
Standards for urban treated drinking water			6.5- 8.5		10 NTU		500mg/l		500mg/l		0 /100ml					0.1 mg/l	0.05 mg/l	1.0 mg/l	0.3 mg/l
Rural drinking water Standards			5.5 - 8.5		10 NTU		1000mg/l		600mg/l		0 /100ml					1.0 mg/l		2.0 mg/l	1.0 mg/l
Rural drinking water Maximum Allowable Concentration (MAC)			5.0 - 9.5		30 NTU		1500mg/l		800mg/l		50/100 ml					2.0 mg/l	0.5 mg/l	4.0 mg/l	2.0 mg/l
WHO criteria (drinking water)					5 NTU		1000mg/l				0/100 ml				1.5 mg/l	0.1 mg/l	0.01 mg/l	1.5 mg/l	0.3 mg/l
Drinking water criteria (Japan)			5.8-8.6		2 NTU		500mg/l		300mg/l		Nil					0.05 mg/l	0.01 mg/l	0.8 mg/l	0.3 mg/l
Ambient Standards (Lake, Type C :Japan)			6.0- 8.5			(B：15mg/l)							8mg/l (*2)						
Ambient Standards (River, Type C :Japan)			6.5- 8.5			50mg/l						5mg/l							

*1 As for arsenic, the laboratory test indicated that many sampled water contained arsenic at rainy season. Therefore verification test was implemented in Japan. The values in the Table shows the test results obtained in Japa

*2 COD (Mn) 🟨 : Over the Urban Standard 🟥 : Over the MAC

Table 3-12 Result of Water Quality Survey (Lake)

SOURCE TYPE	Subbasin	ITEMS	pH	Temp. (℃)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)	Alkalinity (total) (mg/l)	Hardness (CaCO3) (mg/l)	E.C. (μS/cm)	Coliform Group (group/100ml)	BOD5 (mg/l)	COD(Cr) (mg/l)	PO4-P (mg/l)	NH4 (mg/l)	Mn (mg/l)	As (*1) (mg/l)	F (mg/l)	Fe (mg/l)
Lake	3 Awoja	Maximum	7.6	30.7	1.6	11	330	335	276	760	TNTC	2.1	97.0	0.29	0.13	0.28	< 0.001	0.72	0.120
		Minimum	6.7	29.7	0.6	2	125	100	96	292	0	0.8	9.0	0.08	0.10	0.00	< 0.001	0.33	0.000
		Average	7.3	30.3	1.1	5	247	223	156	464	—	1.5	32.0	0.19	0.11	0.11	< 0.001	0.49	0.060
	5 Akweng	Maximum	8.4	30.3	9.1	30	125	123	82	285	TNTC	3.2	73.0	0.09	0.09	0.00	< 0.001	0.71	0.260
		Minimum	7.3	28.7	8.5	7	116	92	67	267	270	2.4	3.0	0.09	0.07	0.00	< 0.001	0.08	0.200
		Average	7.9	29.5	8.8	19	121	108	75	276	—	2.8	38.0	0.09	0.08	0.00	< 0.001	0.40	0.230
	7 Kyoga Lakeside Zone	Maximum	9.7	30.0	31.2	53	200	98	96	600	TNTC	8.3	75.0	0.22	0.41	0.09	< 0.001	0.39	1.180
		Minimum	5.1	23.7	0.6	2	51	28	26	65	0	0.9	6.0	0.08	0.01	0.00	< 0.001	0.10	0.020
		Average	7.8	27.3	8.8	14	101	58	53	196	—	4.3	25.9	0.13	0.14	0.01	< 0.001	0.27	0.352
	8 Mpologoma	Maximum	9.3	28.9	31.7	28	245	115	128	340	TNTC	4.8	85.0	2.04	0.30	0.00	< 0.001	0.75	7.610
		Minimum	6.0	23.5	5.5	8	115	96	93	180	0	1.8	4.0	0.15	0.03	0.00	< 0.001	0.09	0.240
		Average	7.4	26.8	17.6	17	186	106	110	261	—	3.3	50.7	1.10	0.17	0.00	< 0.001	0.28	2.140
Lake Total		Maximum	9.7	30.7	31.7	53	330	335	276	760	TNTC	8.3	97.0	2.04	0.41	0.28	< 0.001	0.75	7.610
		Minimum	5.1	23.5	0.6	2	51	28	26	65	0	0.8	3.0	0.08	0.01	0.00	< 0.001	0.08	0.000
		Average	7.6	28.0	9.0	13	149	106	87	271	—	3.4	32.4	0.33	0.13	0.03	< 0.001	0.33	0.639
Standards for urban treated drinking water			6.5- 8.5		10 NTU		500mg/l		500mg/l		0 /100ml					0.1 mg/l	0.05 mg/l	1.0 mg/l	0.3 mg/l
Rural drinking water Standards			5.5 - 8.5		10 NTU		1000mg/l		600mg/l		0 /100ml					1.0 mg/l		2.0 mg/l	1.0 mg/l
Rural drinking water Maximum Allowable Concentration (MAC)			5.0 - 9.5		30 NTU		1500mg/l		800mg/l		50/100 ml					2.0 mg/l	0.5 mg/l	4.0 mg/l	2.0 mg/l
WHO criteria (drinking water)					5 NTU		1000mg/l				0/100 ml				1.5 mg/l	0.1 mg/l	0.01 mg/l	1.5 mg/l	0.3 mg/l
Drinking water criteria (Japan)			5.8-8.6		2 NTU		500mg/l		300mg/l		Nil					0.05 mg/l	0.01 mg/l	0.8 mg/l	0.3 mg/l
Ambient Standards (Lake, Type C :Japan)			6.0- 8.5			(B:15mg/l)							8mg/l (*2)						
Ambient Standards (River, Type C :Japan)			6.5- 8.5			50mg/l						5mg/l							

*1 As for arsenic, the laboratory test indicated that many sampled water contained arsenic at rainy season. Therefore verification test was implemented in Japan. The values in the Table shows the test results obtained in Japa
*2 COD (Mn)

🟨 : Over the Urban Standard 🟪 : Over the MAC

Table 3-13 Result of Water Quality Survey (Deep Well : Borehole)

SOURCE TYPE	Subbasin	ITEMS	pH	Temp. (℃)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)	Alkalinity (total) (mg/l)	Hardnes s (CaCO3) (mg/l)	E.C. (µS/cm)	Coliform Group (group/100ml)	PO4-P (mg/l)	NH4 (mg/l)	Mn (mg/l)	As (*1) (mg/l)	F (mg/l)	Fe (mg/l)
Bore hole	2 Okere	Maximum	7.6	28.5	19.5	15	205	145	100	303	18	0.58	0.18	0.03	< 0.001	0.46	1.110
		Minimum	5.8	27.6	2.1	1	95	88	64	210	0	0.10	0.05	0.00	< 0.001	0.06	0.380
		Average	6.5	28.1	12.3	8	144	108	82	258	9	0.34	0.10	0.02	< 0.001	0.20	0.638
	3 Awoja	Maximum	7.5	29.1	138.0	76	660	425	375	972	240	0.50	0.19	0.14	< 0.001	1.51	4.790
		Minimum	5.7	24.9	0.4	0	32	12	14	65	0	0.08	0.00	0.00	< 0.001	0.00	0.000
		Average	6.6	27.1	13.0	12	300	229	187	538	31	0.15	0.07	0.02	< 0.001	0.48	0.660
	4 Lwere	Maximum	6.3	27.9	59.2	16	170	100	70	236	44	0.58	0.11	0.25	< 0.001	0.59	6.070
		Minimum	5.7	25.5	0.5	1	77	44	32	24	0	0.29	0.01	0.00	< 0.001	0.09	0.030
		Average	6.1	26.5	12.2	5	118	82	46	164	8	0.46	0.04	0.04	< 0.001	0.43	1.092
	5 Akweng	Maximum	7.3	28.1	101.0	84	210	160	144	434	24	0.54	0.28	0.04	< 0.001	0.82	3.030
		Minimum	5.9	26.1	3.6	1	102	74	39	182	0	0.13	0.01	0.00	< 0.001	0.00	0.530
		Average	6.6	26.6	29.1	22	145	104	70	256	7	0.28	0.15	0.01	< 0.001	0.33	1.311
	6 Abalan	Maximum	7.2	26.3	5.1	4	125	80	42	183	3	0.63	0.11	0.00	< 0.001	0.48	0.790
		Minimum	6.2	26.2	4.6	1	84	48	40	176	0	0.63	0.10	0.00	< 0.001	0.18	0.260
		Average	6.7	26.3	4.8	3	105	64	41	180	2	0.63	0.11	0.00	< 0.001	0.33	0.525
	7 Kyoga Lakeside Zone	Maximum	7.4	27.4	86.9	71	676	385	480	1,173	136	0.15	0.26	0.18	0.009	0.77	2.955
		Minimum	6.0	25.7	0.6	0	116	88	76	261	0	0.08	0.00	0.00	< 0.001	0.00	0.020
		Average	6.6	26.5	14.7	12	283	189	187	505	15	0.09	0.10	0.04	0.002	0.34	0.942
	8 Mpologoma	Maximum	7.7	29.7	45.0	85	2,800	700	1,340	3,870	TNTC	0.62	0.13	0.09	0.003	2.76	5.830
		Minimum	5.6	23.0	0.2	0	44	25	27	87	0	0.08	0.00	0.00	< 0.001	0.00	0.000
		Average	6.4	25.5	4.9	6	316	155	183	469	—	0.21	0.04	0.01	0.001	0.43	0.441
	9 Lumbuye	Maximum	7.0	27.5	59.8	44	315	176	120	515	TNTC	0.19	0.10	0.12	0.001	0.70	0.710
		Minimum	5.4	21.7	0.2	0	52	29	30	99	0	0.08	0.00	0.00	< 0.001	0.11	0.006
		Average	6.2	25.1	6.4	6	154	83	72	247	—	0.14	0.04	0.03	0.001	0.35	0.146
	10 Victoria Nile	Maximum	8.3	30.7	4.9	5	650	218	250	1,018	TNTC	0.49	0.06	0.13	< 0.001	0.56	0.810
		Minimum	5.6	23.3	0.2	0	80	42	36	94	0	0.08	0.00	0.00	< 0.001	0.31	0.000
		Average	6.6	26.2	0.8	2	264	111	136	451	—	0.23	0.02	0.01	< 0.001	0.41	0.085
	11 Sezibwa	Maximum	7.1	30.3	493.0	303	550	222	415	823	TNTC	0.49	0.18	0.14	0.001	0.79	63.250
		Minimum	6.0	23.0	0.1	0	32	12	14	41	0	0.08	0.00	0.00	< 0.001	0.00	0.000
		Average	6.5	24.8	35.2	20	194	101	119	310	-	0.24	0.03	0.03	0.001	0.46	3.817
Borehole Total		Maximum	8.3	30.7	493.0	303	2,800	700	1,340	3,870	TNTC		0.28	0.25	0.009	2.76	63.250
		Minimum	5.4	21.7	0.1	0	32	12	14	24	0		0.00	0.00	< 0.001	0.00	0.000
		Average	6.4	25.9	11.9	9	258	145	150	414	-		0.05	0.02	0.001	0.42	0.962
Standards for urban treated drinking water			6.5- 8.5		10 NTU		500mg/l		500mg/l		0 /100ml			0.1 mg/l	0.05 mg/l	1.0 mg/l	0.3 mg/l
Rural drinking water Standards			5.5 - 8.5		10 NTU		1000mg/l		600mg/l		0 /100ml			1.0 mg/l		2.0 mg/l	1.0 mg/l
Rural drinking water Maximum Allowable Concentration (MAC)			5.0 - 9.5		30 NTU		1500mg/l		800mg/l		50/100 ml			2.0 mg/l	0.5 mg/l	4.0 mg/l	2.0 mg/l
WHO criteria (drinking water)					5 NTU		1000mg/l				0/100 ml		1.5 mg/l	0.1 mg/l	0.01 mg/l	1.5 mg/l	0.3 mg/l
Drinking water criteria (Japan)			5.8-8.6		2 NTU		500mg/l		300mg/l		Nil			0.05 mg/l	0.01 mg/l	0.8 mg/l	0.3 mg/l
Ambient Standards (Lake, Type C :Japan)			6.0- 8.5			(B : 15mg/l)											
Ambient Standards (River, Type C :Japan)			6.5- 8.5			50mg/l											

*1 As for arsenic, the laboratory test indicated that many sampled water contained arsenic at rainy season. Therefore verification test was implemented in Japan. The values in the Table shows the test results obta

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Table 3-14 Result of Water Quality Survey (Shallow Well)

SOURCE TYPE	Subbasin	ITEMS	pH	Temp. (℃)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)	Alkalinity (total) (mg/l)	Hardness (CaCO3) (mg/l)	E.C. (μS/cm)	Coliform Group (group/100ml)	NH4 (mg/l)	Mn (mg/l)	As (*1) (mg/l)	F (mg/l)	Fe (mg/l)
Shallow Well	2 Okere	Maximum	6.6	27.6	83.7	52	365	156	150	518	64	0.19	0.03	< 0.001	0.16	6.660
		Minimum	5.3	27.2	6.6	4	37	14	18	68	5	0.08	0.00	< 0.001	0.00	0.280
		Average	5.9	27.4	34.0	17	175	72	79	302	36	0.11	0.01	< 0.001	0.08	1.940
	3 Awoja	Maximum	7.1	27.2	85.3	6	375	300	240	528	TNTC	0.08	0.05	< 0.001	0.54	3.310
		Minimum	5.7	25.1	0.5	0	112	46	37	160	18	0.01	0.00	< 0.001	0.18	0.020
		Average	6.6	26.0	22.5	3	212	175	148	359	—	0.05	0.01	< 0.001	0.38	0.890
	4 Lwere	Maximum	6.4	25.4	9.8	11	295	132	80	329	TNTC	0.04	0.01	< 0.001	0.50	2.465
		Minimum	6.4	25.3	2.4	1	145	123	66	313	14	0.02	0.00	< 0.001	0.33	0.440
		Average	6.4	25.4	6.1	6	220	128	73	321	—	0.03	0.01	< 0.001	0.42	1.453
	5 Akweng	Maximum	7.3	27.0	9.8	7	180	139	84	274	9	0.18	0.06	< 0.001	0.64	1.280
		Minimum	6.0	26.1	0.7	1	107	66	55	225	0	0.04	0.00	< 0.001	0.14	0.020
		Average	6.7	26.6	6.4	4	136	101	68	248	4	0.09	0.02	< 0.001	0.37	0.548
	8 Mpologoma	Maximum	7.2	27.7	225.0	193	740	305	460	1,038	TNTC	0.55	0.09	< 0.001	0.60	4.410
		Minimum	5.5	25.0	0.5	1	114	34	54	119	0	0.01	0.00	< 0.001	0.00	0.020
		Average	6.4	26.5	26.5	23	305	164	197	516	—	0.14	0.02	< 0.001	0.29	0.787
	9 Lumbuye	Maximum	6.9	28.9	9.9	9	185	75	60	519	TNTC	0.09	0.10	< 0.001	0.71	0.960
		Minimum	5.6	21.2	5.0	2	78	49	39	178	0	0.03	0.00	< 0.001	0.31	0.177
		Average	6.2	25.8	7.8	5	131	63	49	281	—	0.06	0.03	< 0.001	0.46	0.439
	10 Victoria Nile	Maximum	7.5	26.0	1.2	3	680	282	255	948	134	0.08	0.02	< 0.001	0.68	0.080
		Minimum	6.1	21.7	0.3	0	114	70	80	256	0	0.00	0.00	< 0.001	0.28	0.010
		Average	6.5	24.4	0.7	1	359	173	194	654	48	0.03	0.00	< 0.001	0.40	0.038
	11 Sezibwa	Maximum	7.0	26.9	147.0	93	160	65	105	243	TNTC	0.25	0.10	< 0.001	0.42	15.125
		Minimum	5.7	24.0	0.1	0	52	20	25	97	0	0.01	0.00	< 0.001	0.02	0.000
		Average	6.2	25.2	37.8	27	94	39	50	170	—	0.08	0.04	< 0.001	0.21	3.496
Shallow Well	Total	Maximum	7.48	28.9	225.0	193	740	305	460	1,038	TNTC	0.55	0.10	< 0.001	0.71	15.125
		Minimum	5.28	21.2	0.1	0	37	14	18	68	0	0.00	0.00	< 0.001	0.00	0.000
		Average	6.37	25.9	19.8	13	220	120	124	388	—	0.08	0.02	< 0.001	0.31	1.181
Standards for urban treated drinking water			6.5- 8.5		10 NTU		500mg/l		500mg/l		0 /100ml		0.1 mg/l	0.05 mg/l	1.0 mg/l	0.3 mg/l
Rural drinking water Standards			5.5 - 8.5		10 NTU		1000mg/l		600mg/l		0 /100ml		1.0 mg/l		2.0 mg/l	1.0 mg/l
Rural drinking water Maximum Allowable Concentration (MAC)			5.0 - 9.5		30 NTU		1500mg/l		800mg/l		50/100 ml		2.0 mg/l	0.5 mg/l	4.0 mg/l	2.0 mg/l
WHO criteria (drinking water)					5 NTU		1000mg/l				0/100 ml	1.5 mg/l	0.1 mg/l	0.01 mg/l	1.5 mg/l	0.3 mg/l
Drinking water criteria (Japan)			5.8-8.6		2 NTU		500mg/l		300mg/l		Nil		0.05 mg/l	0.01 mg/l	0.8 mg/l	0.3 mg/l
Ambient Standards (Lake, Type C :Japan)			6.0- 8.5			(B：15mg/l)										
Ambient Standards (River, Type C :Japan)			6.5- 8.5			50mg/l										

*1 As for arsenic, the laboratory test indicated that many sampled water contained arsenic at rainy season. Therefore verification test was implemented in Japan. The values in the Table sho

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🟪 : Over the MAC

Table 3-15 Result of Water Quality Survey (Protected Spring)

SOURCE TYPE	Subbasin	ITEMS	pH	Temp. (℃)	Turbidity (NTU)	SS (mg/l)	TDS (mg/l)	Alkalinity (total) (mg/l)	Hardnes s (CaCO3) (mg/l)	E.C. (μS/cm)	Coliform Group (group/100ml)	NH4 (mg/l)	Mn (mg/l)	As (*1) (mg/l)	F (mg/l)	Fe (mg/l)
Protected Spring	2 Okere	Maximum	6.1	25.9	87.4	16	64	57	30	120	1	0.21	0.22	< 0.001	0.02	2.010
		Minimum	5.1	25.7	23.9	9	55	30	26	78	0	0.20	0.01	< 0.001	0.01	0.660
		Average	5.6	25.8	55.7	13	60	44	28	99	1	0.21	0.12	< 0.001	0.02	1.335
	3 Awoja	Maximum	7.2	27.5	55.5	36	290	235	200	810	TNTC	0.12	0.04	< 0.001	0.57	3.320
		Minimum	5.1	19.6	0.4	0	36	14	14	79	0	0.00	0.00	< 0.001	0.00	0.000
		Average	6.4	21.8	6.9	3	113	75	68	224	—	0.06	0.00	< 0.001	0.27	0.362
	4 Lwere Lwere	Maximum	7.0	27.8	117.0	36	170	59	40	366	TNTC	0.11	0.17	< 0.001	0.47	0.930
		Minimum	4.7	26.3	18.0	1	56	28	20	92	0	0.08	0.01	< 0.001	0.09	0.038
		Average	5.9	26.9	60.5	16	89	39	29	186	—	0.09	0.06	< 0.001	0.22	0.562
	5 Akweng	Maximum	7.1	25.8	78.3	49	115	64	29	130	39	0.43	0.02	< 0.001	0.16	1.440
		Minimum	5.2	24.0	9.5	1	55	18	20	115	5	0.10	0.00	< 0.001	0.01	0.310
		Average	6.3	25.1	29.3	15	78	40	23	122	20	0.26	0.01	< 0.001	0.09	0.668
	8 Mpologoma	Maximum	9.1	30.0	51.3	32	375	294	275	568	TNTC	0.22	0.03	< 0.001	0.80	1.750
		Minimum	5.1	22.5	0.6	1	32	34	20	45	0	0.01	0.00	< 0.001	0.00	0.000
		Average	6.4	25.4	13.9	6	133	89	76	237	—	0.08	0.01	< 0.001	0.27	0.507
	9 Lumbuye	Maximum	6.8	26.9	6.5	8	390	270	210	610	TNTC	0.08	0.09	< 0.001	0.62	0.160
		Minimum	5.5	24.8	0.5	0	51	19	31	95	0	0.02	0.00	< 0.001	0.29	0.020
		Average	6.1	25.6	1.8	4	185	117	98	286	—	0.05	0.02	< 0.001	0.43	0.068
	10 Victoria Nile	Maximum	7.0	28.1	1.1	3	300	124	120	2,440	TNTC	0.03	0.00	< 0.001	0.47	0.150
		Minimum	5.7	19.9	0.3	0	98	30	48	176	0	0.00	0.00	< 0.001	0.24	0.010
		Average	6.5	24.1	0.6	2	172	83	88	632	—	0.02	0.00	< 0.001	0.34	0.046
	11 Sezibwa	Maximum	5.9	25.3	12.1	10	114	90	115	365	60	0.51	0.05	< 0.001	0.31	0.230
		Minimum	5.3	24.0	0.2	0	29	13	11	53	0	0.01	0.00	< 0.001	0.07	0.010
		Average	5.8	24.6	7.9	3	56	34	43	133	24	0.19	0.01	< 0.001	0.17	0.109
Protected Spring Total		Maximum	9.1	30.0	117.0	49	390	294	275	2,440	TNTC	0.51	0.22	< 0.001	0.80	3.320
		Minimum	4.7	19.6	0.2	0	29	13	11	45	0	0.00	0.00	< 0.001	0.00	0.000
		Average	6.3	24.0	13.7	5	121	76	67	250	—	0.08	0.01	< 0.001	0.26	0.397
Standards for urban treated drinking water			6.5- 8.5		10 NTU		500mg/l		500mg/l		0 /100ml		0.1 mg/l	0.05 mg/l	1.0 mg/l	0.3 mg/l
Rural drinking water Standards			5.5 - 8.5		10 NTU		1000mg/l		600mg/l		0 /100ml		1.0 mg/l		2.0 mg/l	1.0 mg/l
Rural drinking water Maximum Allowable Concentration (MAC)			5.0 - 9.5		30 NTU		1500mg/l		800mg/l		50/100 ml		2.0 mg/l	0.5 mg/l	4.0 mg/l	2.0 mg/l
WHO criteria (drinking water)					5 NTU		1000mg/l				0/100 ml	1.5 mg/l	0.1 mg/l	0.01 mg/l	1.5 mg/l	0.3 mg/l
Drinking water criteria (Japan)			5.8-8.6		2 NTU		500mg/l		300mg/l		Nil		0.05 mg/l	0.01 mg/l	0.8 mg/l	0.3 mg/l
Ambient Standards (Lake, Type C :Japan)			6.0- 8.5			(B:15mg/l)										
Ambient Standards (River, Type C :Japan)			6.5- 8.5			50mg/l										

*1 As for arsenic, the laboratory test indicated that many sampled water contained arsenic at rainy season. Therefore verification test was implemented in Japan. The values in the Table shows the test

🟨 : Over the Urban Standard 🟥 : Over the MAC

(6) Hydrogeological Items

The Piper Diagrams for each sub-basin are shown in Figure 3-6 to 3-10 based on water quality test of hydrogeological items.

Piper Diagram shows percentage of content of hydrogeological items ion. The trilinear chart on the bottom left indicates content rate of Mg, Ca, Na+K as cation, and the trilinear chart on the bottom right indicates content ratio of Cl, SO_4, HCO_3 as anion, and the diamond shaped chart on the top center, which called key diagram, indicates whole ion content percentage. It's used for study of the origin of the object water and similarity of water quality among sampled waters.

Key diagram is separated to 4 parts shown in figure 3-6, as I to IV.

Characteristic type of each part and its typical examples are,

I. Ca (HCO_3) type: river water and shallow groundwater

II. $NaHCO_3$ type: freshwater of artesian groundwater

III. $CaSO_4$, CaCl type:

IV. Na_2SO_4, NaCl type: seawater, fossil water, hot spring, mine water

On this survey most of points are distributed in I and II area, and some points are placed in III or IV area.

According to water sources, most of deep wells point are placed in area I, but about Sub-basin 4 and 5 points are placed in area II. Those are classified to surface water or artesian groundwater type. Shallow well points are placed in area I except one of Sub-basin 9. Spring points are distributed from area I to II in Sub-basin 2, 4, 5 and 11. These pints are classified to artesian groundwater type. But points of Sub-basin 3, 8, 10 are distributed only in area I, these points are classified to surface water or shallow groundwater type.

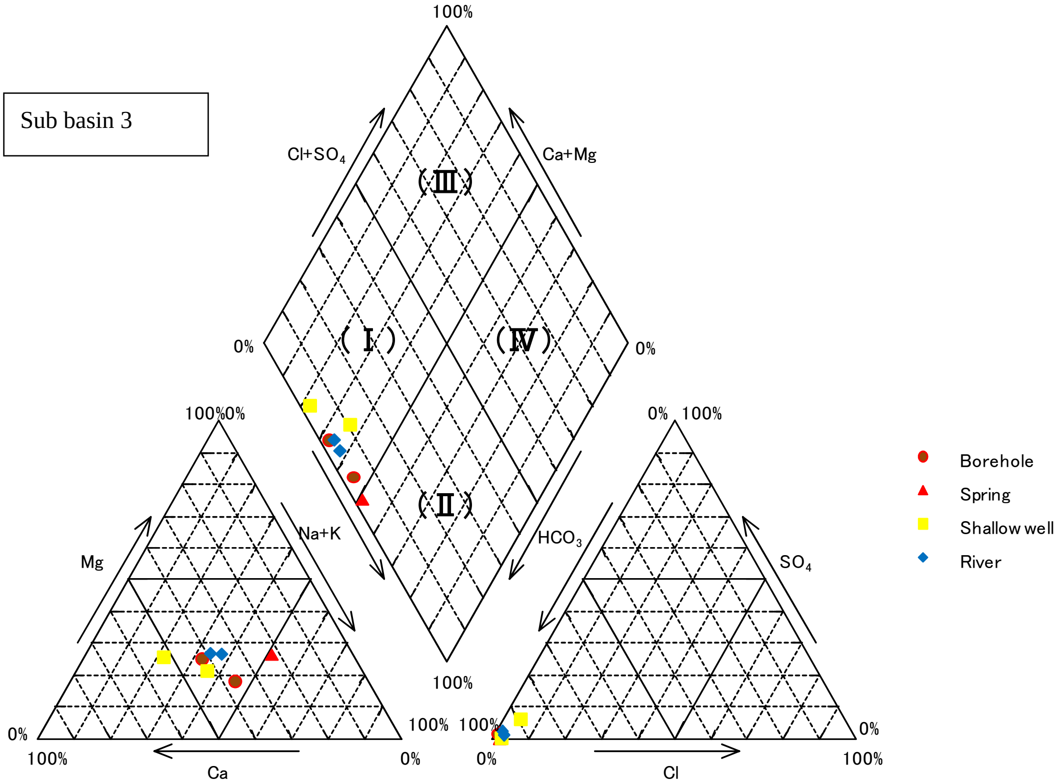


Figure 3-6 Piper Diagram (Sub-Basin 2)

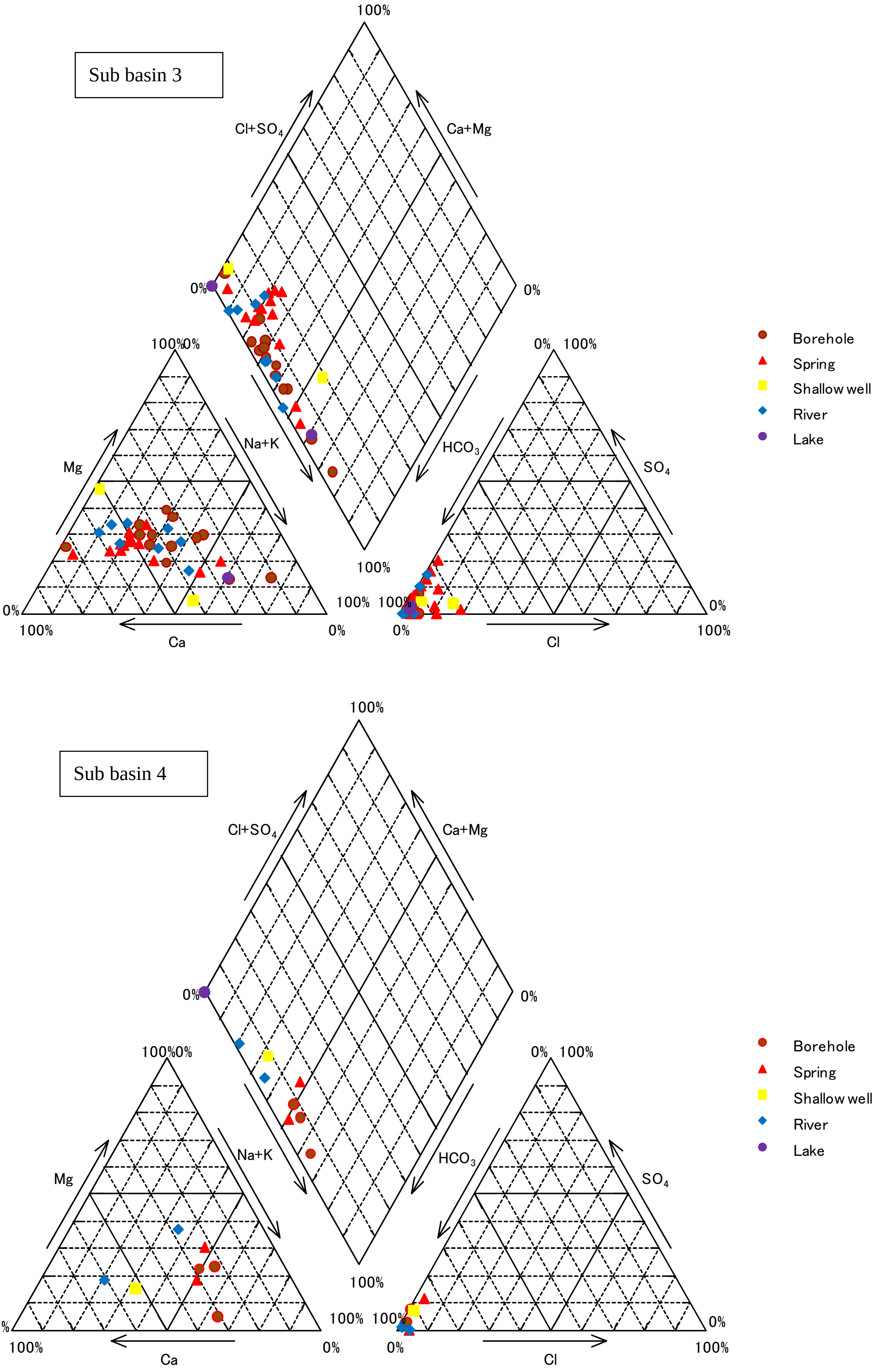


Figure 3-7 Piper Diagram (Sub-Basin 3 and 4)

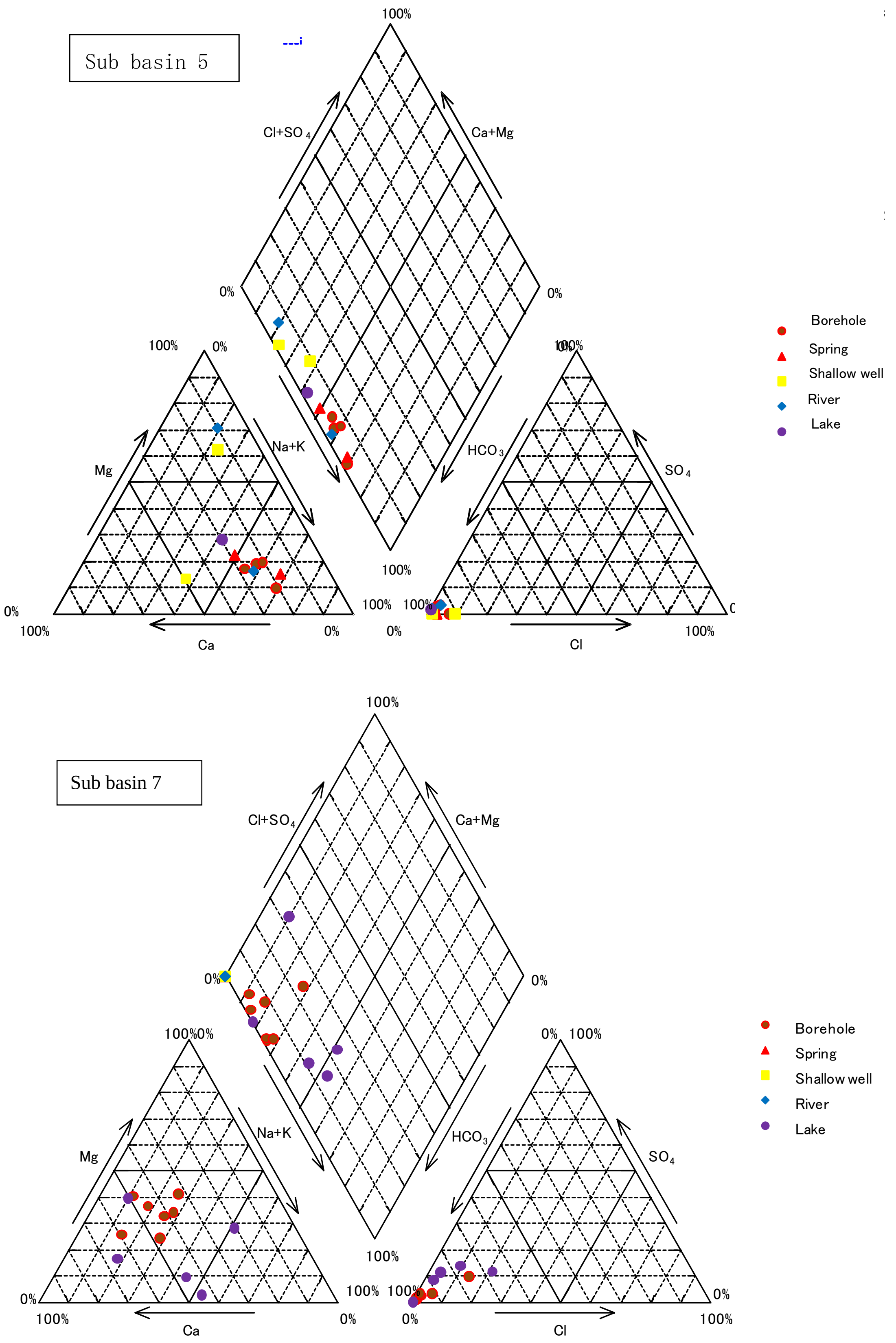


Figure 3-8 Piper Diagram (Sub-Basin 5 and 7)

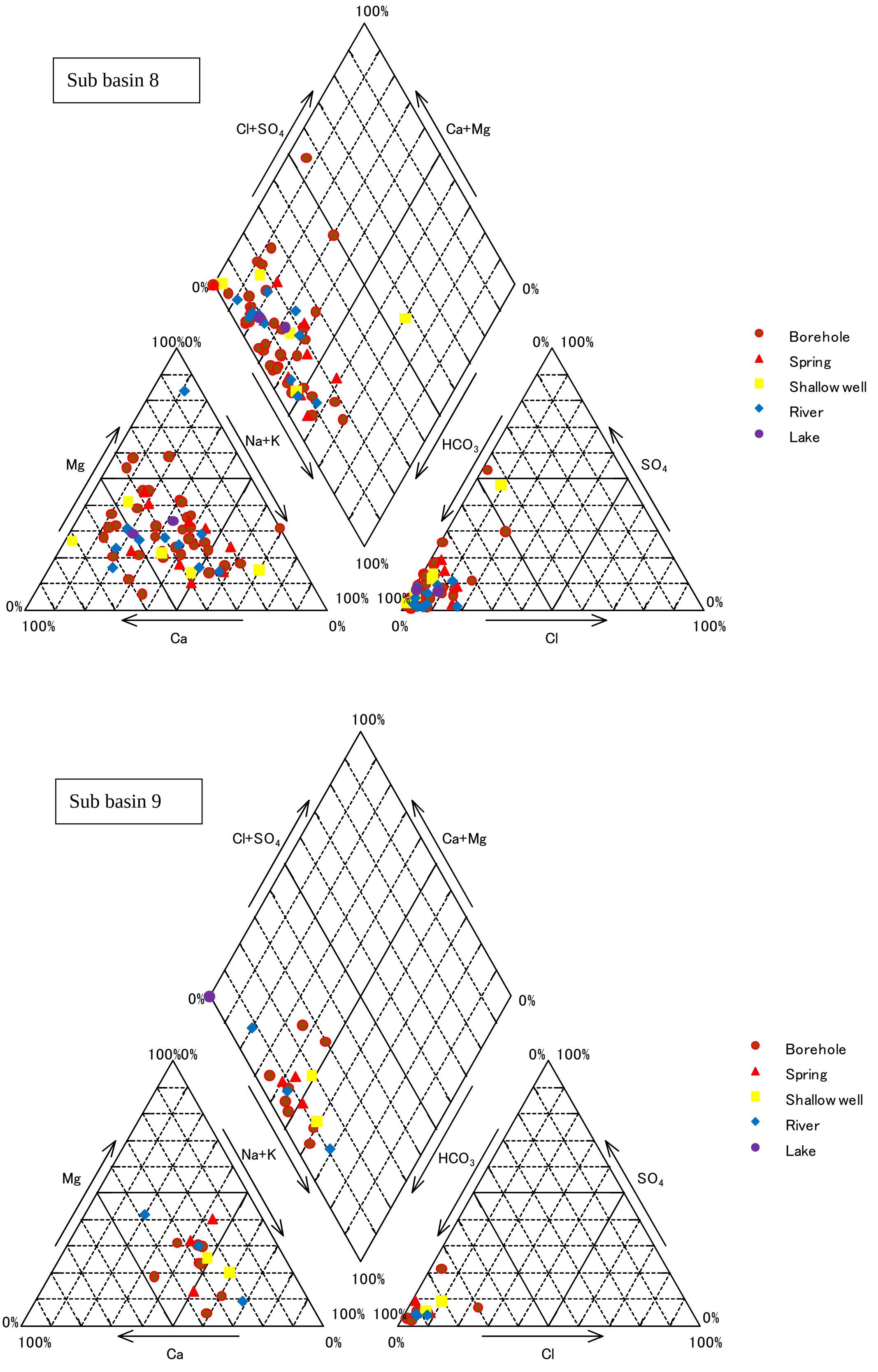


Figure 3-9 Piper Diagram (Sub-Basin 8 and 9)

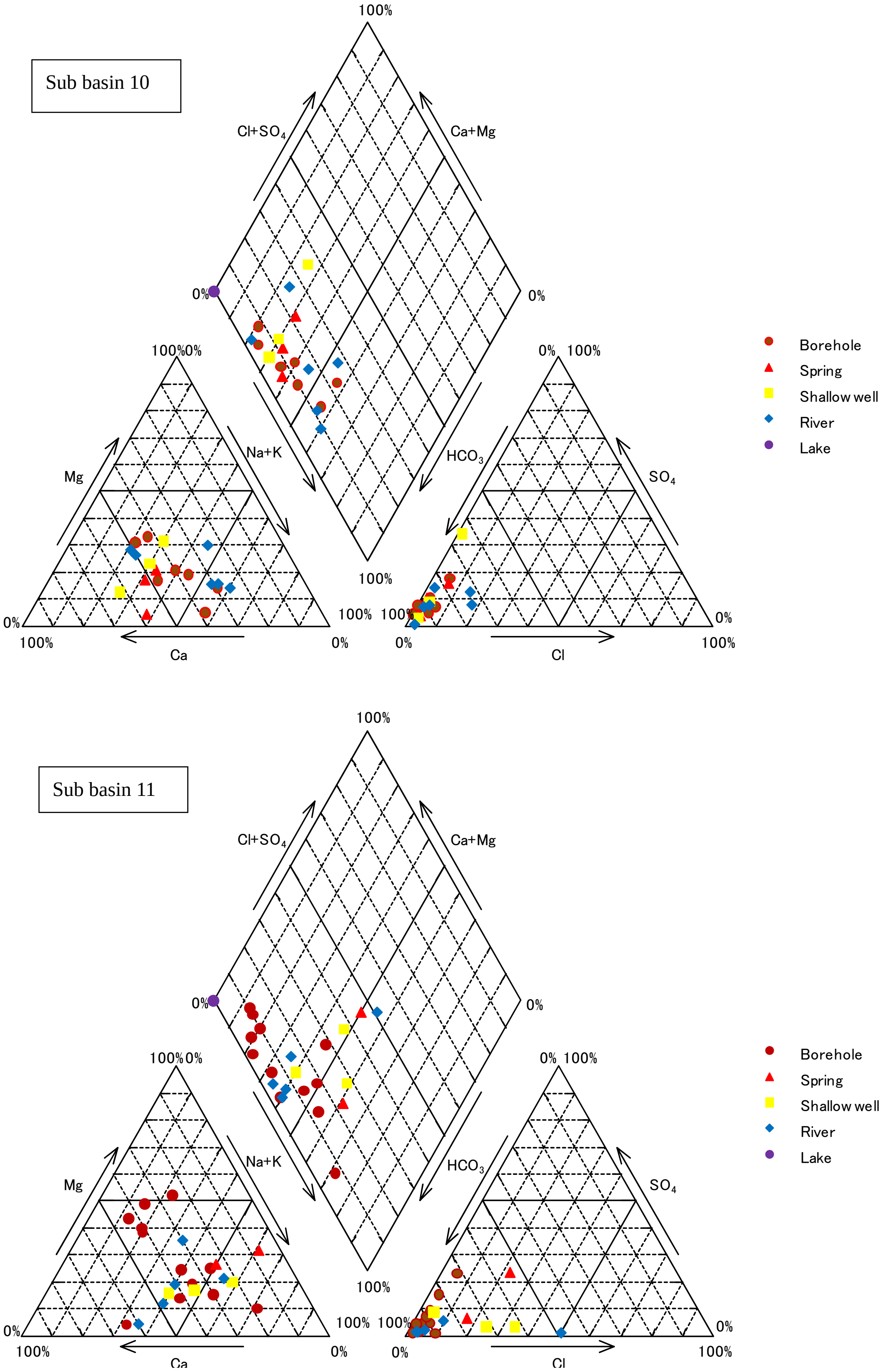


Figure 3-10 Piper Diagram (Sub-Basin 10 and 11)

3.4 Rapid Prediction of Water Quality Change in Future

Water quality of surface water will be affected directly by the population pressure, industrial development and change of life styles in future. Therefore, a rapid prediction of water quality change on surface water is conducted.

3.4.1 Procedure of Rapid Prediction and Runoff Rate of Pollution Load

To know the future water quality, at first, we calculate current rate of pollution load reaching the downstream, then calculate amount of emission load in the future based on the future population projection, and calculate how much pollution load will reach to downstream by multiplying the rate by the future emission load.

Concentration of load is calculated by dividing the future pollution load by the river flow volume. The estimated water quality item is BOD.

To be more precise, total pollution load discharged from each sub-basin is calculated by multiplying the current population by PDC (Pollution Discharge per Capita). The pollution load from runoff flows into a Lake is calculated by multiplying the average river flow by surveyed BOD at downstream (average). The runoff rate of pollution load is calculated by dividing the downstream flow of pollution load by the amount of pollution load discharged.

(Runoff rate of pollution load) = (Runoff pollution load at downstream) / (Total pollution load in the sub-basin)

(Runoff pollution load at downstream) = (Average BOD value measured in downstream) × (Average flow)

(Total pollution load in a sub-basin) = (Sub-basin population) × PDC

A relation between PDC and GNI in developing countries is shown in Figure 3-11. In Uganda, GNI is less than US$1000 (from World Children 2006, UNICEF white paper), so the estimated PDC is 7 kg/year. The results are shown in Table 3-16.

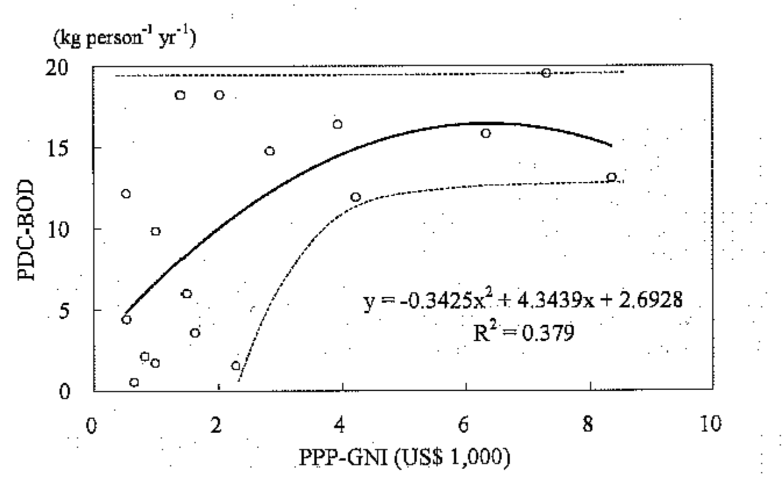
Then, BOD levels in the future are calculated as below;

Total pollution load in a sub-basin (in the future) = PDC × population (in the future)

Pollution load at downstream (in the future)

= Total pollution load in the sub-basin (in the future) × Runoff rate of pollution load

BOD level (in the future) = Pollution load at downstream (in the future)/Downstream flow



Source: A relation between PDC and economic level, Tsuzuki Yoshiaki、2007.10 Japan Society of Civil Engineers Vol.63）

Figure 3-11 PPP-GNI and PDC-BOD in Countries of the Asia-Pacific Region and Africa

Table 3-16 BOD Runoff Rate Estimated by the Result of Water Quality Survey

Sub-basin	BOD (mg/l)	BOD (mg/l)	Average Flow (m^3/sec)	Average Flow (m^3/year)	BOD Runoff Pollution Load (t/year)		BOD Pollution Discharge in 2008 (t/year)	**BOD Runoff Rate （%）**
	Upper	Lower			Upper	Lower		
(1) Okok	—	—	3.373	106,381,331	－	－	1,863	—
(2) Okere	—	2.5	5.385	169,823,551	－	425	2,862	14.83
(3) Awoja	3.6	4.6	19.591	617,815,404	2,224	2,842	8,349	34.04
(4) Lwere	7.8	5.1	6.081	191,761,532	1,496	978	2,677	36.54
(5) Akweng	2.5	2.4	10.420	328,599,469	821	789	2,669	29.55
(6) Abalan	－	－	12.648	398,882,519	－	－	2,704	—
(7) Kyoga Lakeside	8.0	－	7.062	222,718,667	1,782	－	4,553	39.14
(8) Mpologoma	5.6	3.6	24.291	766,034,807	4,290	2,758	21,590	12.77
(9) Lumbuye	4.2	4.6	3.608	113,769,965	478	523	3,296	15.88
(10) Victoria Nile	1.6	2.0	12.798	403,603,567	646	807	6,900	11.70
(11) Sezibwa	4.9	7.3	12.449	392,597,266	1,924	2,866	7,791	36.78
Total			117.706	3,711,988,078	13,660	11,987	65,254	18.37

3.4.2 Prediction Results of Water Quality in the Future

Prediction implemented for 2015, 2020 and 2035 due to population date obtained about each sub-basin. The calculation is done for two cases;

Case 1; the PDC = 7kg/year/person as the present situation

Case 2; the PDC = 10kg/year/person as future situation taking into account the growth of GNI by 2020, 2035.

Runoff -rate of pollution load about Sub-basin 1 (Okok) and Sub-basin 6 (Abala) are not calculated because the water quality survey had not implemented in these sub-basins due to restriction of entrance to these two sub-basins. Instead of the calculation, we applied the runoff-rates of pollution load of Sub-basin 2 (Okere) and 5 (Akweng) to those for the Sub-basin 1 (Okok) and Sub-basin 6 (Abalang) due to the similarity of the basin characteristics.

The results are shown in Table 3-17 and 3-18.

Table 3-17 shows the results of case 1. In the yare 2035, there are 6 sub-basins whose BOD is over 10 mg/l. Table 3-18 shows the results of case 2. In the year 2035, there are 8 sub-basins whose BOD is over 10 mg/l. Especially, Sub-basin 7 (Kyoga Lakeside zone) is predicted that BOD will exceed the 30 mg/l.

Table 3-17 Results of the Rapid Prediction of Water Quality (BOD) – Case 1

Case I: Discharged Pollution Load per Capita is the same as present one)

Sub-basin	**BOD runoff Ration(%)**	**Average Flow (m3/year)**	Year 2015			Year 2020			Year 2035		
			Polluiton Discharge (t/year)	Runoff Pollution Load (t/year)	Predicted BOD Concentration (mg/l)	Polluiton Discharge (t/year)	Runoff Pollution Load (t/year)	Predicted BOD Concentration (mg/l)	Polluiton Discharge (t/year)	Runoff Pollution Load (t/year)	Predicted BOD Concentration (mg/l)
(1) Okok	**14.83**	106,381,331	2,505	372	3.5	3,107	461	4.3	7,199	1,068	10.0
(2) Okere	**14.83**	169,823,551	3,804	564	3.3	4,665	692	4.1	8,650	1,283	7.6
(3) Awoja	**34.04**	617,815,404	10,723	3,650	5.9	12,837	4,370	7.1	22,150	7,540	12.2
(4) Lwere	**36.54**	191,761,532	3,409	1,245	6.5	4,059	1,483	7.7	6,901	2,521	13.1
(5) Akweng	**29.55**	328,599,469	3,455	1,021	3.1	4,164	1,231	3.7	7,355	2,173	6.6
(6) Abalan	**29.55**	398,882,519	3,415	1,009	2.5	4,035	1,192	3.0	6,670	1,971	4.9
(7) Kyoga	**39.14**	222,718,667	6,191	2,423	10.9	7,343	2,874	12.9	12,292	4,811	21.6
(8) Mpologoma	**12.77**	766,034,807	26,801	3,423	4.5	31,323	4,001	5.2	45,171	5,770	7.5
(9) Lumbuye	**15.88**	113,769,965	4,191	665	5.8	4,977	790	6.9	8,356	1,327	11.7
(10) Victoria Nile	**11.70**	403,603,567	8,377	980	2.4	9,633	1,127	2.8	14,718	1,722	4.3
(11) Sezibwa	**36.78**	392,597,266	9,888	3,637	9.3	11,715	4,309	11.0	19,906	7,322	18.7
Total (average)	**18.37**	3,711,988,078	82,759	18,990	5.2	97,857	22,529	6.3	159,368	37,508	10.7

Table 3-18 Results of the Rapid Prediction of Water Quality (BOD) – Case 2

Case 2: Discharged Pollution Load per Capita increases in proportion to the population growth

Sub-basin	BOD Ranoff Rate (%) *1	**Average Flow (m3/year)**	Year 2020			Year 2035		
			Polluiton Discharge (t/year)	Runoff Pollution Load (t/year)	Predicted BOD Concentration (mg/l)	Polluiton Discharge (t/year)	Runoff Pollution Load (t/year)	Predicted BOD Concentration (mg/l)
(1) Okok	**14.83**	106,381,331	4,438	658	6.2	10,285	1,525	14.3
(2) Okere	**14.83**	169,823,551	6,664	988	5.8	12,357	1,833	10.8
(3) Awoja	**34.04**	617,815,404	18,338	6,242	10.1	31,643	10,771	17.4
(4) Lwere	**36.54**	191,761,532	5,798	2,118	11.0	9,859	3,602	18.8
(5) Akweng	**29.55**	328,599,469	5,949	1,758	5.3	10,507	3,105	9.4
(6) Abalan	**29.55**	398,882,519	5,765	1,703	4.3	9,528	2,816	7.1
(7) Kyoga	**39.14**	222,718,667	10,490	4,105	18.4	17,560	6,872	30.9
(8) Mpologoma	**12.77**	766,034,807	44,747	5,716	7.5	64,529	8,242	10.8
(9) Lumbuye	**15.88**	113,769,965	7,109	1,129	9.9	11,937	1,895	16.7
(10) Victoria Nil	**11.70**	403,603,567	13,761	1,610	4.0	21,026	2,460	6.1
(11) Sezibwa	**36.78**	392,597,266	16,736	6,156	15.7	28,438	10,460	26.6
Total (average)	**18.37**	3,711,988,078	139,795	32,184	8.9	227,668	53,582	15.4

3.4.3 Study of Water Quality Conservation Measures

According to prediction results, pollution load in many sub-basins will exceed 10mg/l in BOD, which causes emission of foul odours, and has become a difficult level for drinking water treatment. The installation of septic tanks for each household and sewage system for urban areas will be effective as counter measures. . However, installation of wastewater treatment facilities near urban areas such as oxidation ponds, are desirable as immediate measures.

Contamination will be effectively removed from higher concentrated pollution than diffused one by treatment. Therefore, treatment facilities should be constructed as nearer the pollution source as possible.

Table 3-19 shows how much water pollution should be removed to keep the current state of water quality in future.

Table 3-19 Removed Water Pollution for Maintaining Current Water Quality Condition (case 2)

Sub-basin	Year 2008	Year 2015		Year 2020		Year 2035	
	BOD Discharged Pollution Load (t/year)	Discharged Pollution Load (t/year)	Excess Pollution Load (t/year)	Discharged Pollution Load (t/year)	Excess Pollution Load (t/year)	Discharged Pollution Load (t/year)	Excess Pollution Load
(1) Okok	1,863	2,505	642	4,438	2,575	10,285	8,422
(2) Okere	2,862	3,804	941	6,664	3,801	12,357	9,494
(3) Awoja	8,349	10,723	2,374	18,338	9,990	31,643	23,295
(4) Lwere	2,677	3,409	732	5,798	3,121	9,859	7,182
(5) Akweng	2,669	3,455	786	5,949	3,280	10,507	7,838
(6) Abalan	2,704	3,415	711	5,765	3,061	9,528	6,825
(7) Kyoga	4,553	6,191	1,639	10,490	5,937	17,560	13,007
(8) Mpologoma	21,590	26,801	5,211	44,747	23,157	64,529	42,940
(9) Lumbuye	3,296	4,191	894	7,109	3,813	11,937	8,640
(10) Victoria Nil	6,900	8,377	1,478	13,761	6,862	21,026	14,126
(11) Sezibwa	7,791	9,888	2,097	16,736	8,944	28,438	20,646
Total	65,254	82,759	17,505	139,795	74,542	227,668	162,415

Note: Discharged pollution load at year 2020 and 2035 includes the effect of population and economic growth.