12.3 Groundwater Potential Evaluation

Groundwater potential evaluation for the purpose of groundwater development plan was carried out based on the result of hydrogeological analysis and water balance analysis which were mentioned in the Chapter 5 and Section 12.1.

12.3.1 Indices for Groundwater Potential Evaluation

Four indices were selected to evaluate the groundwater potential from a hydrogeological point of view: i.e. well yield, drilling depth, static water level and total dissolved solid (TDS) as water quality. From a hydrological point of view, infiltration for groundwater recharge was also selected.

Selected indices are described with their feature and their distribution below. These data are summarized by sub-basins to count toward the basic plan for the water resources development and management. Distribution maps are shown to grasp the spatial distribution of each index with unified color scale; blue color shows high score and red color shows low score.

(1) Well yield

A well yield is a basic data which is necessary for designing water supply facility. In case that the yield is less than 0.5 m^3/ h, such wells are regarded as unusable. Handpump well needs at least 0.5 m^3/ h. For motor or engine pump well, their yield should be more than 1.5 m^3/ h for effective use.

Table 12-12 Well Yield by Sub-basins

No.	Name	Well Yield				
		Number of Sample	Ave. (m^3/h)	Max (m^3/h)	Min (m^3/h)	SD
1	Okok	59	1.99	12.00	0.00	1.93
2	Okere	113	1.84	10.11	0.00	1.80
3	Awoja	338	1.96	17.00	0.00	2.15
4	Lwere	209	1.66	13.73	0.00	2.00
5	Akweng	123	1.92	9.00	0.15	1.51
6	Abalang	151	2.06	10.90	0.00	1.90
7	Kyoga Lakeside	247	2.05	14.40	0.00	2.58
8	Mpologoma	1163	2.03	20.70	0.00	2.54
9	Lumbuye	278	2.07	19.20	0.00	2.55
10	Victoria Nile	460	1.74	18.23	0.00	2.36
11	Sezibwa	442	1.76	14.40	0.00	1.95
	Total	3583	1.92	20.70	0.00	2.31

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation

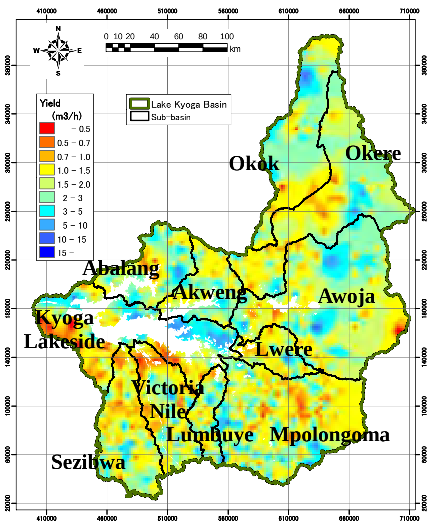

Figure 12-13 Distribution of Well Yield

In the distribution map of Figure 12-13, Abalang, Kyoga Lakeside, Mpolongoma and Lumbuye sub-basin have much yield; however, the standard deviation of them except Abalang sub-basin is large. Okok and Okere sub-basin have also high yield, but the well distribution is concentrated in some places. Lwere sub-basin has the lowest yield: 439.3 MCM/year. Although the maximum yield in all available data is 20.7 m^3/ h, this is not so high that groundwater is not suitable water source for urban water supply scheme.

(2) Static Water Level

A capability of lifting pump is determined by static water level (SWL) and required well yield. SWL is also related to the operation cost. To continue lifting groundwater from the deeper part, it needs more electric power or fuel. In case of handpump, deeper SWL needs more power to withdraw groundwater, and it takes longer time until water come out from well.

Table 12-13 Static Water Level by Sub-basins

No.	Name	Static Water Level				
		No. of Sample	Ave. (m)	Max. (m)	Min. (m)	SD
1	Okok	46	22.13	61.88	0.60	13.14
2	Okere	109	17.42	77.84	3.63	14.28
3	Awoja	318	11.89	91.50	0.30	11.10
4	Lwere	201	9.30	39.69	0.30	3.63
5	Akweng	119	10.30	55.20	2.09	6.10
6	Abalang	139	16.61	80.00	2.75	12.52
7	Kyoga Lakeside	210	23.12	97.60	1.50	13.98
8	Mpologoma	1041	10.72	94.55	0.15	6.68
9	Lumbuye	261	13.65	64.05	0.49	7.66
10	Victoria Nile	432	17.56	122.00	0.98	11.09
11	Sezibwa	364	17.82	48.00	0.36	9.50
Total		3240	14.12	122.00	0.15	10.21

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation

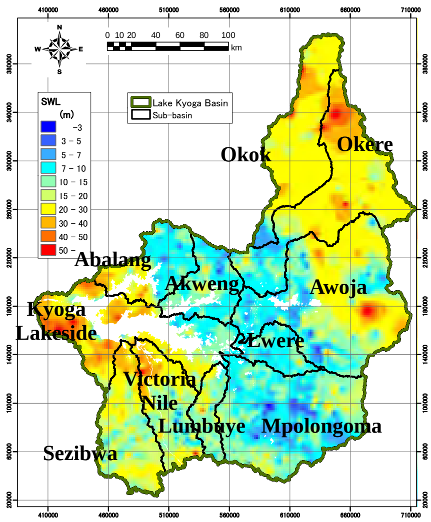

Figure 12-14 Distribution of Static Water Level

The shallowest average SWL is found in Lwere sub-basin. On the other hand, the deeper average SWL is distributed in Okok and Kyoga Lakeside sub-basin. In the distribution map of SWL as shown in Figure 12-14, there is a belt-like zone of shallow SWL from the north-west to the south-east in the middle of Kyoga Basin.

(3) Drilling Depth

A drilling depth is a parameter which affects to an initial cost of well construction. In the case of deep borehole (deeper than 20m), the drilling cost is directly proportional in general to its depth.

The drilling depth of Okok, Okere and Abalang sub-basin is deeper, especially; Okok sub-basin has fully deep drilling depth. On the other hand, Akweng, Mpolongoma and Lumbuye sub-basin show shallower. In the distribution map, there is a trend that the southern part of Lake Kyoga Basin is shallow, but deep in the northern part.

Table 12-14 Drilling Depth by Sub-basins

No.	Name	Drilling Depth				
		No. of Sample	Ave. (m)	Max. (m)	Min. (m)	SD
1	Okok	60	79.5	122.0	39.6	17.7
2	Okere	118	72.1	213.5	5.5	31.2
3	Awoja	338	71.1	198.3	6.0	30.5
4	Lwere	215	68.3	270.0	13.2	30.3
5	Akweng	124	58.9	125.1	22.0	16.3
6	Abalang	151	72.1	157.1	27.6	22.8
7	Kyoga Lakeside	250	65.9	170.2	11.9	23.6
8	Mpologoma	1,163	57.0	194.0	5.6	21.3
9	Lumbuye	278	53.6	160.7	11.0	21.3
10	Victoria Nile	460	61.0	213.5	8.2	27.5
11	Sezibwa	441	61.3	213.5	9.8	25.0
	Total	3,597	62.0	270.0	5.5	25.3

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation

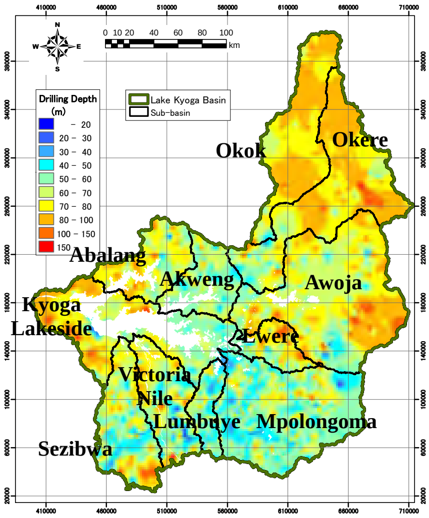

Figure 12-15 Distribution of Drilling Depth

(4) Water Quality (TDS)

Total dissolved solid (TDS) is an index of salinity in groundwater: high TDS water is felt saline by human. Generally, the suitable value of TDS is from 30 to 300 mg/L for potable water. Additionally, TDS is an important index as water quality standard, and is related to potable water and productivity of livestock or agricultural commodity. If TDS is very high value, the water must be treated.

Since the average value of TDS in the whole Lake Kyoga Basin is approximately 340 mg/L, most of the groundwater is suitable for drinking for human. However, in Abalang and Kyoga Lakeside sub-basins, the TDS value shows relatively high.

Table 12-15 Total Dissolved Solid by Sub-basins

No.	Name	Total Dissolved Solid				
		Number of Sample	Ave. (mg/L)	Max. (mg/L)	Min. (mg/L)	SD
1	Okok	24	466.9	1370.0	171.0	262.3
2	Okere	42	336.6	768.0	98.0	172.6
3	Awoja	87	315.3	1110.0	60.0	185.8
4	Lwere	61	287.2	2400.0	51.3	361.7
5	Akweng	47	304.9	2510.0	0.0	431.3
6	Abalang	41	685.9	4410.0	79.0	1133.1
7	Kyoga Lakeside	66	549.4	2814.0	64.0	562.3
8	Mpologoma	258	289.0	2230.0	1.1	252.1
9	Lumbuye	68	398.4	1980.0	104.0	348.2
10	Victoria Nile	88	301.6	1045.0	0.2	205.3
11	Sezibwa	88	188.6	846.0	45.0	134.9
	Total	870	337.7	4410.0	0.2	394.6

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation

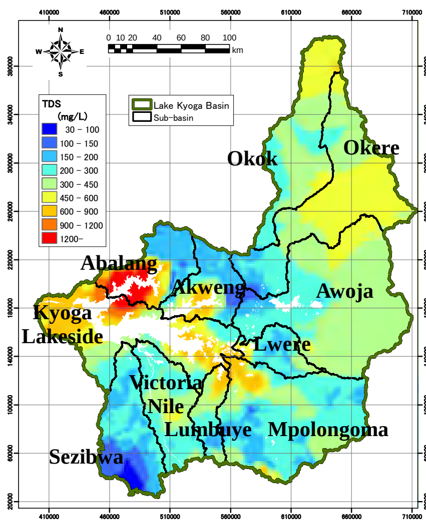

Figure 12-16 Distribution of Total Dissolved Solid

(5) Annual Possible Infiltration (Recharge)

Infiltration is related to usable and sustainable groundwater amount. In case of low infiltration value, even if a large amount of water can be withdrawn after drilling, the water volume will be decreasing gradually while it is being used, and it is at high risk against sustainable usage. To use the groundwater sustainably, an annual pumping amount should be control under annual recharge of groundwater. If pumping was continued more than sustainable amount, groundwater problem will be occurred, for example, water quality degradation, breakup of aquifer, ground settlement and so on.

Table 12-16 Annual Possible Infiltration by Sub-basins

No.	Name	Annual Possible Infiltration				
		Number of Pixel	Ave. (mm)	Max. (mm)	Min.* (mm)	SD
1	Okok	680,495	33.6	1213.3	-836.9	88.8
2	Okere	1,013,229	93.1	1709.8	-860.7	118.3
3	Awoja	1,356,453	234.2	3438.6	-683.2	276.0
4	Lwere	206,930	262.1	724.3	-21.9	110.4
5	Akweng	351,461	188.6	1249.9	-867.4	108.4
6	Abalang	406,658	254.2	1357.6	-901.3	144.2
7	Kyoga Lakeside	911,040	81.1	1259.3	-1027.6	133.7
8	Mpologoma	1,109,732	260.6	2899.5	-920.7	238.6
9	Lumbuye	187,609	241.0	1332.5	-904.5	106.1
10	Victoria Nile	442,175	211.8	1377.0	-926.1	136.7
11	Sezibwa	524,127	150.9	1560.9	-895.5	133.0
	Total	7,189,909	172.4	3438.6	-1027.6	163.5

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation
*: Negative values are calculated through numeric calculation for spatial analysis by pixels. The values themselves essentially have no meanings but indicate relatively very poor infiltrations.

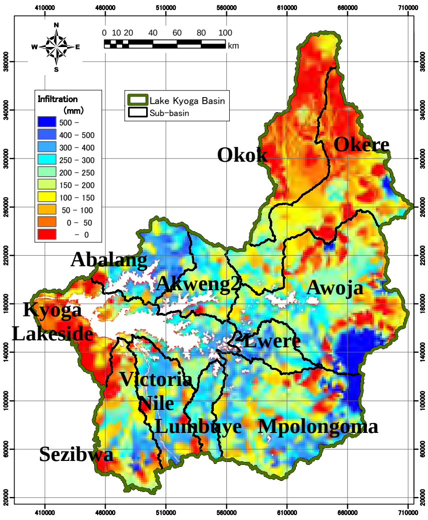

Figure 12-17 Distribution of Annual Possible Infiltration

The annual possible infiltration in Okok, Okere and Kyoga Lakeside sub-basins is shown very low value but high value is expected to Mpolongoma and Awoja sub-basin because the precipitation around Mt. Elgon is very high.

12.3.2 Groundwater Development Potential Evaluation

Evaluation score was set up by the values shown in Table 12-17 to indices which mentioned in previous section. By substituting the spatial distribution value of each index to evaluation score, comprehensive evaluation can be done with same level and by summation of each index. Although each index had same weight in this report, it is possible to evaluate groundwater potential practically by giving some weight corresponding to the importance of each index.

Table 12-17 Evaluation Scores of Each Index

Score		(1)Yield (m^3/h)	(2)Static Water Level (m)	(3)Drilling Depth (m)	(4)Water Quality [TDS] (mg/l)	(5)Infiltration (mm)
10	Better	15 <	< 3	< 20	< 30	500 <
9	↑	10 - 15	3 - 5	10 - 30	30 - 100	400 - 500
8		5 - 10	5 - 7	20 - 40	100 - 150	300 - 400
7		3 - 5	7 - 10	30 - 50	150 - 200	250 - 300
6		2 - 3	10 - 15	50 - 60	200 - 300	200 - 250
5		1.5 - 2	15 - 20	60 - 70	300 - 450	150 - 200
4		1 - 1.5	20 - 30	70 - 80	450 - 600	100 - 150
3	↓	0.7 - 1	30 - 40	80 - 100	600 - 900	50 - 100
2		0.5 - 0.7	40 - 50	100 - 150	900 - 1200	0 - 50
1	Worse	< 0.5	50 <	150 <	1200 <	< 0

Figure 4-15 shows the result as evaluation score distribution map based on the score shown in Table 4-12. In this map, blue color shows high potential, and red color shows low potential.

Table 12-18 Evaluated Score by Sub-basins

No.	Name	Evaluated Score				
		Sample No.	Ave.	Max.	Min.	SD
1	Okok	3129	20.49	33	13	2.93
2	Okere	4667	21.62	35	13	3.98
3	Awoja	6245	25.45	37	10	4.22
4	Akweng	950	28.16	38	18	2.65
5	Abalang	1612	28.32	35	15	3.31
6	Lwere	1875	25.87	38	12	6.26
7	Kyoga_Lakeside	4204	21.19	36	9	5.40
8	Mpolongoma	5117	28.99	41	18	3.18
9	Lumbuye	864	28.16	37	16	3.11
10	Voctoria_Nile	2037	25.71	39	14	4.07
11	Sezibwa	2418	25.92	38	15	4.16
	Total	33118	24.81	41	9	3.93

Ave: Average, Max: Maximum, Min: Minimum, SD: Standard Deviation

To formulate the groundwater development and management plan, it is very important to evaluate groundwater development potential in the Lake Kyoga Basin in hydrogeological and hydrological point of view. Groundwater potentials in Lwere, Akweng, Mpolongoma, and Lumbuye sab-basins are high. On the other hand, Okok, Okere, and Kyoga Lakeside sub-basins have low groundwater potential.

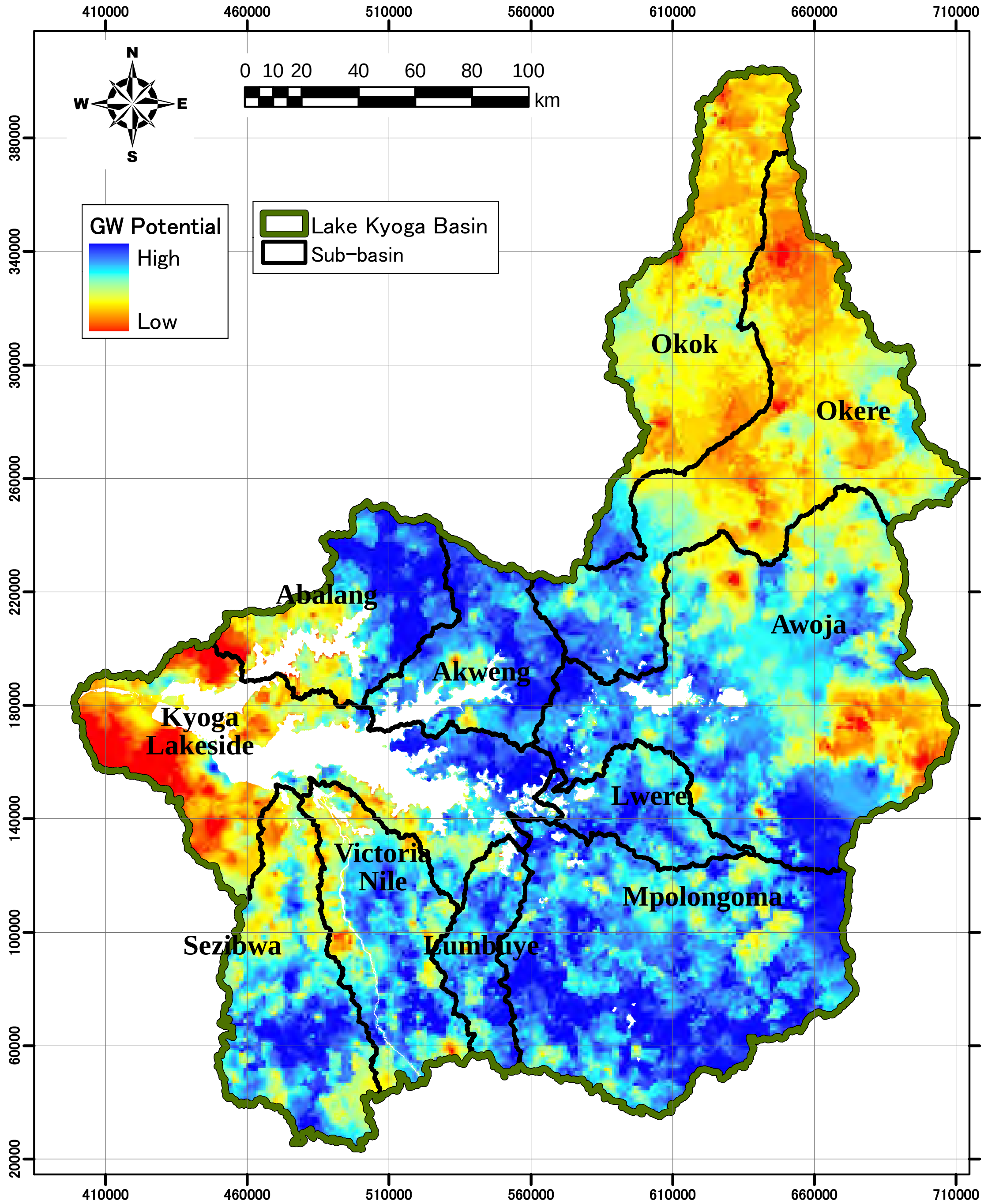

Figure 12-18 Distribution of Groundwater Development Potential Score

Appendix 13

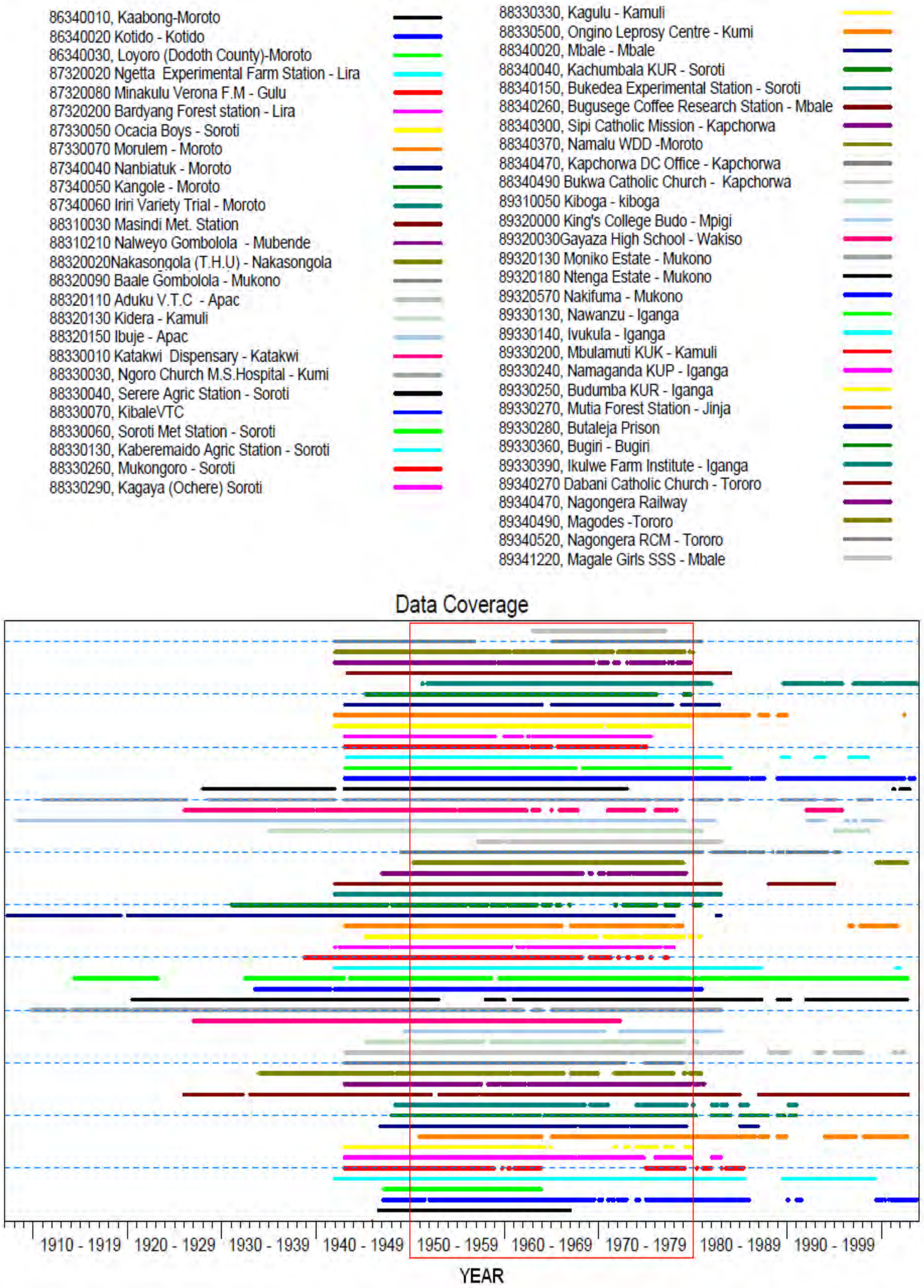

Figure 12-19 Rainfall Data Coverage by Rainfall Station

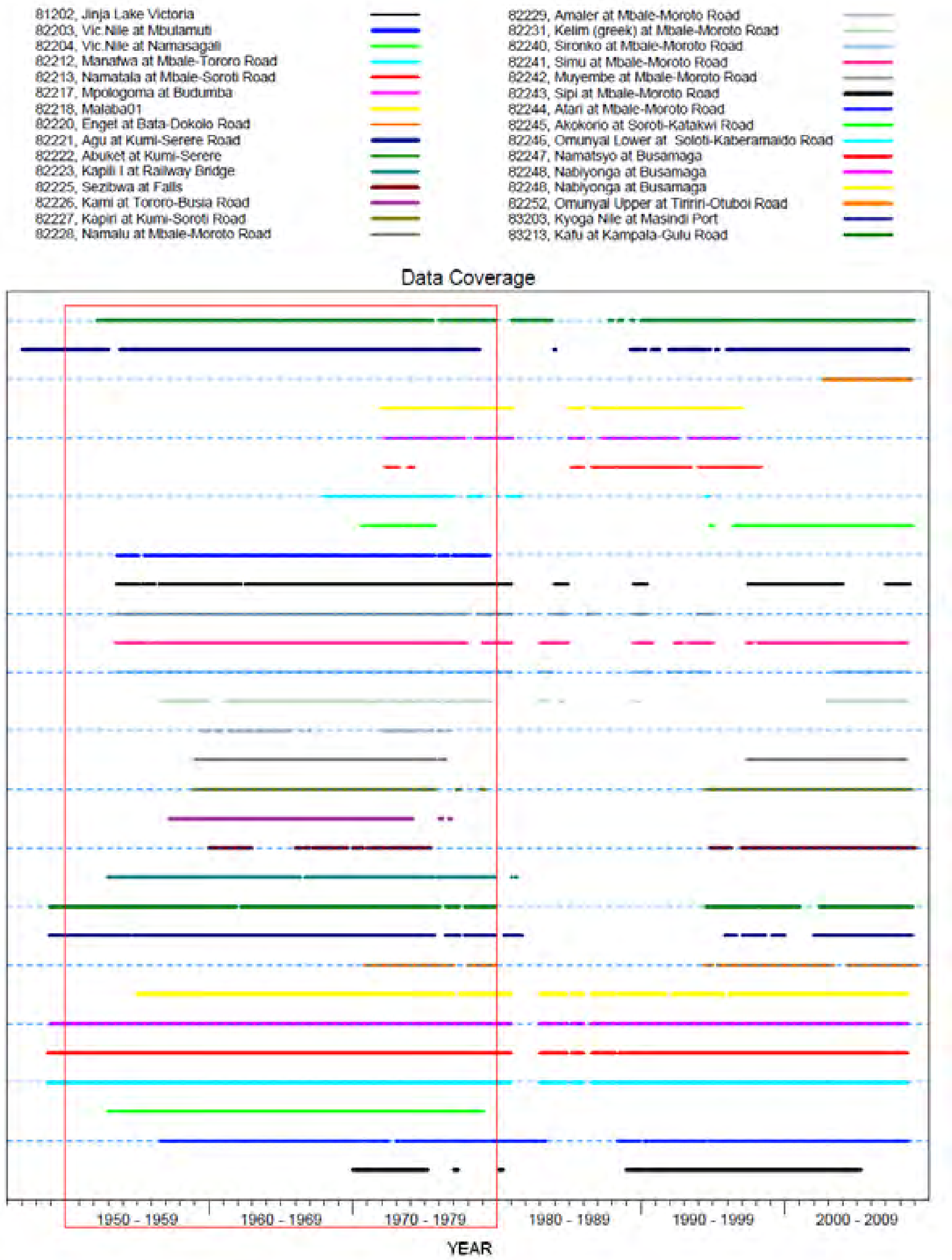

Figure 12-20 River Discharge Data Coverage by River Gauging Station

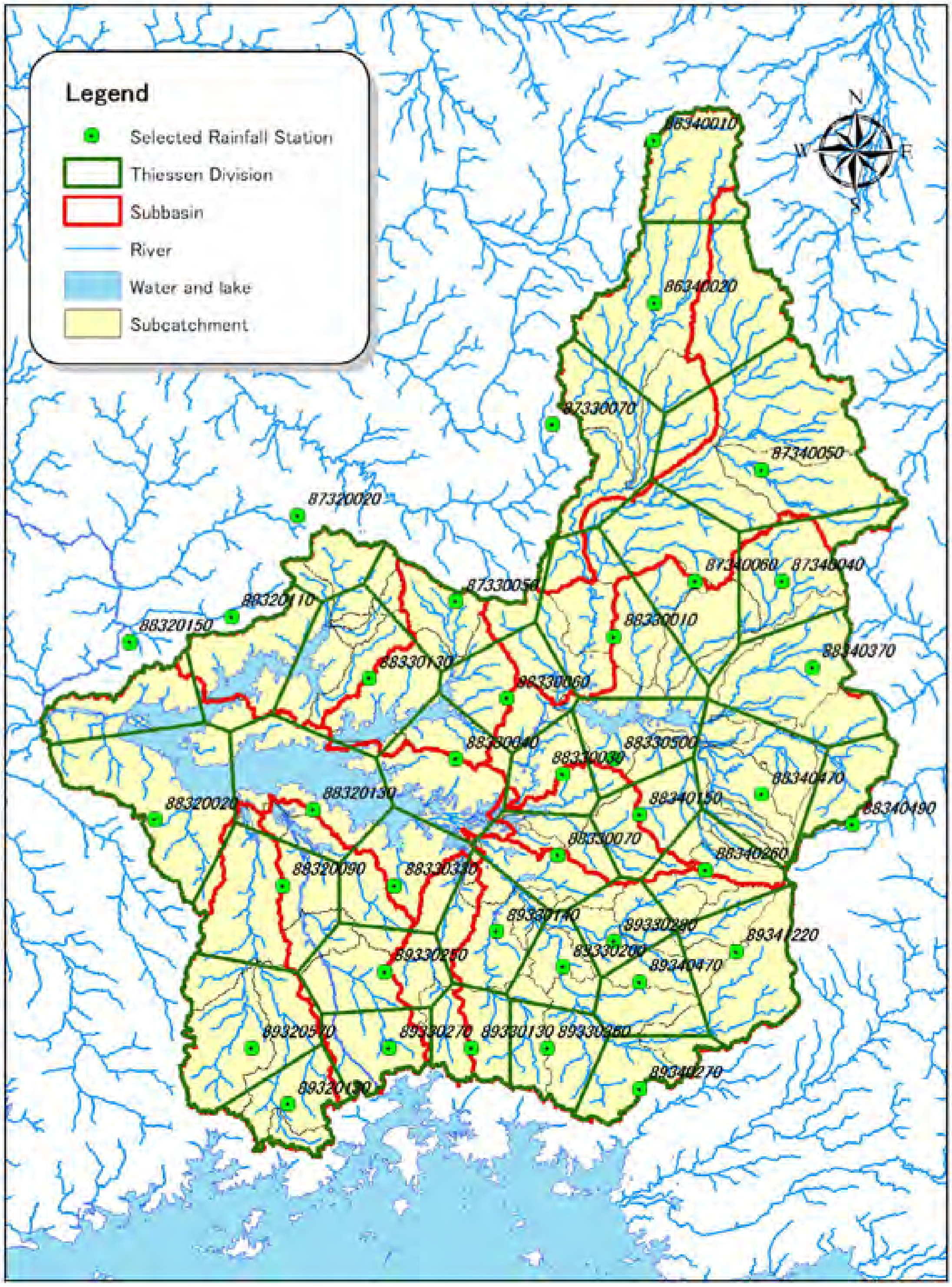

Figure 12-21 Thiessen Tesselation and Small-Basins

Table 12-19 Water Demand Condition in Each Small-Catchment

Unit: Million m^3 per year

Small-Basin	Sub-Basin	Present Water Demand (2008)						Future Water Demand (2035)					
		Domestic NWSC	Domestic Small Towns	Livestock	Crops	Fisheries	Total	Domestic NWSC	Domestic Small Towns	Livestock	Crops	Fisheries	Total
Catchment1	Kyoga Lakeside Zone	0.000	0.264	4.181	7.139	1.227	12.812	0.000	0.894	7.721	41.566	4.909	55.090
Catchment3	Okere	0.000	0.095	0.160	0.003	0.035	0.294	0.000	0.470	0.627	4.658	0.141	5.896
Catchment8	Okere	0.000	0.172	2.653	0.002	0.040	2.866	0.000	1.336	4.022	2.569	0.158	8.084
Catchment9	Okere	0.000	0.172	0.866	0.000	0.017	1.056	0.000	1.336	1.489	0.638	0.068	3.531
Catchment13	Okok	0.000	0.000	0.921	0.001	0.014	0.936	0.000	0.000	1.391	0.921	0.056	2.368
Catchment14	Okok	0.000	0.486	6.698	0.005	0.043	7.232	0.000	4.862	7.766	7.872	0.172	20.672
Catchment15	Okere	0.000	0.000	1.172	0.004	0.040	1.215	0.000	0.000	2.442	5.608	0.160	8.211
Catchment16	Okok	0.000	0.000	0.626	0.002	0.049	0.677	0.000	0.000	1.194	3.387	0.194	4.776
Catchment17	Awoja	0.000	0.015	0.924	0.000	0.010	0.950	0.000	0.092	1.293	0.735	0.042	2.162
Catchment20	Awoja	0.000	0.000	1.538	0.001	0.012	1.551	0.000	0.000	1.945	1.260	0.049	3.254
Catchment21	Awoja	0.000	0.000	0.470	0.003	0.015	0.487	0.000	0.000	0.987	4.122	0.060	5.169
Catchment22	Awoja	0.000	0.000	0.301	0.006	0.024	0.332	0.000	0.000	1.110	10.063	0.098	11.271
Catchment23	Awoja	0.000	0.000	1.039	0.001	0.034	1.074	0.000	0.000	1.489	0.945	0.138	2.572
Catchment25	Awoja	0.000	0.000	0.084	0.001	0.018	0.104	0.000	0.000	0.133	1.253	0.074	1.459
Catchment26	Awoja	0.000	0.000	0.135	0.002	0.034	0.170	0.000	0.000	0.170	2.956	0.134	3.260
Catchment27	Awoja	0.000	0.000	0.041	0.000	0.007	0.048	0.000	0.000	0.089	0.087	0.027	0.203
Catchment29	Awoja	0.000	0.000	0.332	0.000	0.040	0.372	0.000	0.000	0.613	0.780	0.160	1.554
Catchment30	Awoja	0.000	0.143	0.389	0.004	0.085	0.621	0.000	0.784	0.603	5.857	0.339	7.583
Catchment31	Awoja	0.000	0.488	0.210	0.003	0.053	0.754	0.000	1.656	0.264	4.613	0.211	6.744
Catchment32	Awoja	0.000	0.236	1.075	0.002	0.123	1.436	0.000	1.257	1.390	3.222	0.490	6.359
Catchment33	Awoja	0.026	0.000	1.001	0.006	0.053	1.085	0.082	0.000	1.643	8.828	0.211	10.764
Catchment34	Okere	0.011	0.027	0.421	0.005	0.213	0.677	0.035	0.416	1.328	8.091	0.852	10.722
Catchment35	Awoja	0.000	0.167	0.605	0.004	0.286	1.062	0.000	1.006	0.974	5.975	1.143	9.099
Catchment36	Lwere	0.000	0.104	0.414	3.588	0.062	4.168	0.000	0.574	0.530	6.746	0.247	8.097
Catchment37	Mpologoma	2.027	0.340	0.628	37.301	0.234	40.530	5.661	1.477	0.721	31.225	0.935	40.019
Catchment38	Mpologoma	0.000	0.000	0.161	0.001	0.025	0.187	0.000	0.000	0.190	1.338	0.099	1.627
Catchment39	Mpologoma	0.000	0.000	0.186	3.450	0.048	3.684	0.052	0.000	0.213	3.029	0.193	3.488
Catchment40	Mpologoma	0.000	0.126	0.508	21.072	0.168	21.874	0.000	0.449	0.584	17.367	0.672	19.071
Catchment41	Mpologoma	1.188	0.292	0.513	61.125	0.260	63.378	0.791	1.240	0.597	48.372	1.038	52.038
Catchment42	Mpologoma	0.000	0.329	1.103	22.838	0.948	25.219	2.025	1.195	1.562	28.503	3.793	37.079
Catchment43	Mpologoma	0.119	0.376	0.978	80.151	0.511	82.136	1.812	1.184	1.124	63.064	2.044	69.228
Catchment44	Mpologoma	0.000	0.000	0.198	16.419	0.071	16.688	0.000	0.000	0.304	12.896	0.286	13.486
Catchment45	Mpologoma	0.336	0.621	0.361	5.454	0.236	7.008	2.162	3.468	0.665	10.461	0.944	17.701
Catchment48	Mpologoma	0.000	0.000	0.063	7.026	0.029	7.117	0.000	0.000	0.102	5.503	0.114	5.718
Catchment49	Mpologoma	0.000	0.279	0.296	16.869	0.147	17.590	0.000	0.700	0.514	13.956	0.587	15.757
Catchment50	Mpologoma	0.000	0.343	0.405	24.124	0.223	25.094	0.000	1.503	0.505	19.432	0.892	22.333
Catchment51	Lwere	0.026	0.579	0.622	17.418	0.160	18.804	0.100	2.760	0.774	15.155	0.639	19.428
Catchment52	Lumbuye	0.336	0.211	0.229	0.415	0.182	1.372	2.162	0.909	0.450	2.568	0.728	6.817
Catchment53	Lumbuye	0.000	0.325	0.592	1.930	0.315	3.162	0.000	0.997	0.908	3.498	1.259	6.663
Catchment54	Victoria Nile	1.821	0.213	1.214	0.279	1.407	4.933	6.263	0.729	2.055	3.691	5.627	18.366
Catchment55	Victoria Nile	0.000	0.000	0.368	0.004	0.180	0.552	0.000	0.000	0.687	1.436	0.719	2.842
Catchment56	Victoria Nile	0.000	0.174	1.459	0.018	0.633	2.284	0.000	0.717	2.515	3.708	2.533	9.473
Catchment57	Sezibwa	0.000	0.000	0.078	0.016	0.127	0.220	0.000	0.000	0.147	0.209	0.508	0.864
Catchment58	Sezibwa	2.327	0.000	1.544	0.048	2.602	6.520	14.993	0.000	1.950	1.447	10.410	28.799
Catchment59	Sezibwa	2.250	0.582	0.623	0.094	0.905	4.454	14.269	1.947	1.359	3.619	3.619	24.813
Catchment60	Sezibwa	0.000	0.239	1.635	0.004	0.445	2.323	0.000	0.741	2.346	5.788	1.781	10.656
Catchment61	Akweng	0.000	0.000	0.317	0.042	0.217	0.575	0.000	0.000	1.095	4.311	0.868	6.274
Catchment63	Abalang	0.000	0.000	0.086	0.011	0.052	0.149	0.000	0.000	0.371	1.574	0.209	2.154
Catchment64	Abalang	0.122	0.000	0.616	0.178	0.538	1.454	0.649	0.000	2.657	5.555	2.154	11.015
Catchment65	Abalang	0.000	0.206	0.070	0.001	0.029	0.305	0.000	0.893	0.300	1.732	0.116	3.041
Catchment66	Abalang	0.000	0.000	0.210	0.003	0.083	0.296	0.000	0.000	0.753	4.944	0.332	6.029
Catchment67	Abalang	0.000	0.000	0.842	0.058	0.281	1.180	0.000	0.000	3.798	22.703	1.124	27.625
Catchment68	Akweng	0.000	0.063	0.936	0.008	0.661	1.668	0.000	0.432	2.144	12.612	2.643	17.830

CHAPTER 13 ISSUES ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT

13.1 Issues between IWRM and Water Resources Development Plan

Water resources in Uganda have been managed since 1999 based on the concept of IWRM which was adopted in "National Water Policy (1999)". However, there is a fundamental issue between water resources management under IWRM and water resources development hitherto known: namely, spatial expanse of them. The former has mainly river basin concept which focus on natural aspect of water resources.[1]

Meanwhile, water resources development has been planned and carried out in administrative units since before because water resources development plan or utilization plan has been formulated administrative-unit-wise. An advantage of this traditional way is to be able to use all kinds of statistic data stored administrative-unit-wise as basic information in order to formulate a water resources development plan. However, its deficit; it was the reason why IWRM was propounded, is not to be able to deal with the mutual influence that spans the border of administrative units as the small scale to international boundary as the large scale, because water resources settle quantitatively and qualifiedly in the river basin under natural conditions.

In Uganda," Water Resource Management Zone" called as the compromised idea in a manner is proposed. Four water management zones are set up considering eight major river basins and socio-economic conditions, and conforming to the district boundaries in Uganda; however, each zone consists several partial river basins has an issue: how to incorporate river basin management as a basic concept of IWRM.

Although the Study is just the challenge to formulate the basic plan of water resources management as the first full-scale approach to IWRM on Lake Kyoga Basin as one of the eight basins in Uganda, it has an issue to work out between the river basin set up objectively by natural conditions and administrative units defined subjectively by artificial or social conditions. As for concrete example, the related data from the compiled statistics by administrative units for the basic plan of water resources management have to be allocated to Lake Kyoga Basin and 11 sub-basins of it.

SIP: "Strategic Investment Plan for the Water and Sanitation Sub Sector (2009)" lists up eight urgent issues for water resources management in Uganda.

- Capacity for Water Resources Management

1. Another concept is groundwater basin, which differs from river basin through the view point of groundwater management. However, it is usually regarded as same as river basin because both water resources are generally in the same hydrological circulation.

- National and Regional Plans for Water Utilization
- Climate Change and Climate Variability
- Deterioration in Water Quality
- Water Resources Monitoring, Assessment and Regulation
- Dam Safety Management and Regulatory Framework
- Promoting Effective and Sustainable IWRM through WMZ
- Response to Water Related Emergency

13.2 Issues on the Surface Water Resources Development and Management

Fundamentals of water resources development and management are to understand available water resources, changes of demography, land use, socio-economy and suitable techniques on water use. This section describes issues related on surface water resources.

13.2.1 Existing Surface Water Evaluation Results and Their Issues to be Improved

(1) The Results in “Rapid Assess Water Resource Assessment (1995)”

Following document include estimation of surface water resources.

- Uganda Water Action Plan, Water Resources Development and Management, Rapid Water Resources Assessment (DOC. 007), Ministry of Natural Resources, Directorate of Waster Development. 1995

Estimated surface water resources on drought water discharge are:

- average (over the period of record) flow in the driest month of the year
- lowest monthly flow on record
- one in five year minimum monthly flow as a measure of the dependable yield

As a result, the document describes a map of drought water resource distribution in Uganda by using the third data above mentioned. However, the map is so schematic that it can show only tendency of the distribution.

(2) Surface Water Resources Estimation in SIP

“Strategic Investment Plan for the Water and Sanitation Sub Sector (2009)”, SIP, contains estimation result of surface water resources. SIP has estimated available river water, lake water and rainfall runoff of each district based on observed rainfall and river flow discharge data. The outline and issues to be discussed in the estimation are shown below.

i) River Water Resource

The way of estimation in SIP is:

- To assume five (5) percent of average annual river discharge as available river water resources of districts where the river flows through,
- To allocate the river water resource to the districts where the river flow through at some ratio

The estimation results are summarized in Table 13-1.

The estimation in SIP is excellent work at present; however, it has following issues to be improved in future.

- The figure, five percent of annual river discharge, roughly corresponds to low water discharge in the estimation of the Study Team. The figure may not set aside the quantity of river maintenance flow.
- The used river water discharge is observed discharge itself at each river gauging station. This discharge has no contribution form downstream of the gauging station.
- Regarding River Nile, four districts take river water from River Victoria Nile, and one district takes water from River Kyoga Nile at two points in the plan. This means that about fifteen percent of the annual river discharge is allocated to river water source for the districts. River Nile is a so large river that the low water discharge is very stable. As a result, stable withdraw of the river water is possible through year-round. However, the withdrawal of water from River Nile is a sensible issue related to Nile Agreement.
- River Kyoga Nile is located outside of the Lake Kyoga Basin so that the use of the River Kyoga Nile water does not go hand in hand with the policy of integrated water resources management. This may come from the idea of Water Resources Management Zone adopted in SIP, which puts the base on districts boundaries.

Table 13-1 Evaluation of River Water Resources by SIP

Source River	Observation Point or Road Name	River Water Resource	Target Districts for Water Allocation	Allocation Ratio
R, Sio	-	350.80	Busia	100
R. Victoria Nile	Mbulamuti	35,368.14	Mukono, Jinja	50, 50
R. Victoria Nile	Namasagali	35,431.48	Kayunga, Kamuli	50, 50
R. Manafwa	Mbale – Tororo Road	279.01	Mbale, Tororo, Manafwa	30, 40, 30
R. Namatala	Mbale – Soroti Road	83.94	Mbale	100
R. Mpologoma	Budumba	595.79	Palisa, Namutumba	50, 50
R. Malaba	Jinja – Tororo Road	504.41	Tororo	100
R. Enget	Bata – Dokolo Raod	16.07	Lira	100
R. Angu	Kumi – Serere Raod	308.59	Kumi	100
R. Abulet	Kumi – Serere Road	202.17	Kumi	100
R. Sezibwa	Sezibwa Falls	62.77	Mukono	100
R. Kami	Tororo – Busia Road	36.97	Busia, Tororo	50, 50
R. Namalu	Mbale – Moroto Road	9.61	Nakapiripirit	100
R. Kelim	Mbale – Moroto Road	213.30	Sironko, Nakapiripirit	50, 50
R. Sironko	Mbale – Moroto Road	131.67	Sironko	100
R. Muyembe	Mbale – Moroto Road	101.71	Sironko	100
R. Sipi	Mbale – Moroto Road	104.56	Sironko	100
R. Akokorio	Soroti – Katakwi Road	873.31	Katakwi	100
R. Omunyai	Lower at Soroti – Kaberamaido Road	38.24	Soroti	100
R. Kyoga Nile	Masindi Port	32687.62	Apac	50
R. Kyoga Nile	Kamdini	30718.93	Apac	50
R. Tochil	Gulu – Lira Road	101.61	Lira	50
R. Kafu	Kampala – Gulu Road	514.12	Nakasongola	50
R. Mayanja	Kapeeka – Kayunga Road	265.35	Luweero	100
R. Kigwe	Semuto–Wobulenzi Road	0.30	Luweero	100

Source: SIP

ii) Rainfall Runoff

SIP estimates the possible storage rainfall runoff as follows by construction of storage facilities.

- "Annual rainfall in a district" x "the district area" x "the runoff coefficient" x "twenty five percent",
- Assumed storage facilities are dams and valley tanks.

The used runoff coefficient is shown in Table 13-2. This idea has following issues to be improved:

- A large part of the Lake Kyoga Basin consists of gently sloping hills so that the storage of the rainfall has low efficiency. It requires construction of a large numbers of storage facilities. .
- Rainfall runoff storage is estimated independently from river water resource. However, river water resource is a part of rainfall so that the large use of rainfall water results in decrease of river water resource. Therefore the storage of rainfall runoff should be done during high water stage of river water.

iii) Lake Water Resource

SIP selects some large lakes for withdrawal of water, and allocates the water to districts that have the Lake itself or are adjacent to the Lake. The assumed allocated water is as follows:

- 1,500 m^3/year : Lake Victoria, Lake Kyoga, Lake Albert,
- 100 m^3/year : Lake Opeta, Lake Bunyoni, Crator lakes

Three lakes, Lake Victoria, Lake Kyoga and Lake Opeta, are selected as lake water resource for Lake Kyoga Basin,. The quantity of withdrawal at each district is shown in Table 13-2 district-wise. Consequently, SIP allocated 13,500 m^3/year (= 1,500 m^3/year x nine districts) from Lake Victoria, 10,500 m3/year (= 1,500 m^3/year x seven districts) from Lake Kyoga and 300 m^3/year（100 m^3/year x three districts）from Lake Opeta to the Lake Kyoga Basin.

This idea has following issues to be improved:

- It requires coordination and adjustment among the countries related to Nile Agreement. Quantitative possibility of withdrawal from Lake Victoria and Lake Kyoga is discussed in the next section.
- Uganda has a wetland policy to conserve wetlands as natural environmental resource. Excess water use of water in Lake Kyoga and Opeta may result in deterioration of wetlands.
- Uganda has ratified Ramsar Convention for Lake Opeta as Lake Opeta Wetland System. It requires conservation and wise use of the wetland.

Table 13-2 Estimated Surface Water Resources Based on District Boundaries in SIP

District Name	Available Water From Various Sources									
	Surface Water				Runoff					Total
	Rivers	Lakes		Total	Annual Rainfall	Runoff Coefficient	Estimated Annual Runoff		Available for abstraction	Available for abstraction
	MCM/year				mm		mm	MCM/year	MCM/year	MCM/year
Abim	0	0		0	940	0.11	103	411	103	103
Amolatar	0	0		0	1322	0.11	145	256	64	64
Amuria	0	0		0	1398	0.11	154	356	89	89
Apac*	1,585	1500	Kyoga	3,085	1483	0.09	133	314	78	3,164
Budaka	0	0		0	1774	0.24	426	203	51	51
Bududa	0	0		0	1774	0.24	426	172	43	43
Bugiri*	0	1500	Victoria	1,500	1300	0.24	312	226	57	1,557
Bukedea	0	0		0	1203	0.11	132	161	40	40
Bukwa	0	0		0	1156	0.24	277	142	36	36
Busia	18	1500	Victoria	1,518	1401	0.24	336	233	58	1,577
Butaleja	0	0		0	1203	0.24	289	141	35	35
Dokolo	0	0		0	1483	0.11	163	299	75	75
Iganga*	0	1500	Victoria	1,500	1138	0.24	273	318	79	1,579
Jinja	884	1500	Victoria	2,384	1604	0.24	385	254	64	2,448
Kaabong	0	0		0	725	0.11	80	317	79	79
Kaberamaido	0	1500	Kyoga	1,500	1322	0.11	145	176	44	1,544
Kaliro	0	0		0	1148	0.24	276	320	80	80
Kampala	0	1500	Victoira	1500	1589	0.28	445	73	18	1,518
Kamuli	886	1500	Kyoga	2,386	1213	0.24	291	948	237	2,623
Kapchorwa*	0	0		0	1574	0.70	1,102	1,320	330	330
Katakwi*	44	100	Opeta	144	940	0.11	103	240	60	204
Kayunga	886	0		886	1091	0.28	305	426	107	992
Kotido*	0	0		0	705	0.03	21	112	28	28
Kumi*	26	1500	Kyoga	1,526	1322	0.11	145	177	44	1,570
Lira*	3	1500	Kyoga	1,503	1483	0.11	163	698	175	1,678
Luweero*	13	0		13	1054	0.28	295	1,124	281	294
Manafwa	4	0		4	1774	0.31	550	222	55	60
Mayuge	0	1500	Victoria	1,500	1283	0.24	308	315	79	1,579
Mbale*	8	0		8	1774	0.43	763	411	103	111
Moroto	0	0		0	1154	0.03	35	295	74	74
Mukono	887	1500	Victoria	2,387	1487	0.28	416	1,295	324	2,711
Nakapipirit	6	100	Opeta	106	708	0.15	106	617	154	260
Nakasongola	13	1500	Victoria	1,513	1046	0.03	31	98	24	1,537
Namutumba	15	0		15	1417	0.31	439	319	80	95
Pallisa*	15	1500	Kyoga	1,515	1148	0.11	126	80	20	1,535
Sironko	22	100	Opeta	122	1774	0.26	461	490	123	245
Soroti	2	1500	Kyoga	1,502	1352	0.11	149	365	91	1,593
Tororo	32	0		32	1481	0.11	163	186	46	78
Wakiso	0	1500	Victoria	1,500	1589	0.28	445	741	185	1,685

Source: SIP

13.2.2 Possibility of Lake Water Withdrawal Based on Existing Documents

(1) Possibility of Lake Water Withdrawal from Lake Kyoga

Existing considerations on water balance of Lake Kyoga were implemented with rainfall and river discharge data. In those considerations, total inflows are river discharge from River Victoria Nile, tributaries flow from own basin and over-lake rainfall; total outflows are over-lake evaporation and river discharge to River Kyoga Nile. The consideration results are shown in Table 13-3.

Table 13-3 Water Balance on Lake Kyoga in Existing Documents

Source	Inflow			Outflow		Storage (m^3/s)	Reference Period
	Victoria Nile (m^3/s)	Tributary flow (m^3/s)	Over-lake rainfall (m^3/s)	Over-lake evaporation (m^3/s)	Kyoga Nile (m^3/s)		
Hydromet[2]	914	92	176	242	930	10	1948-1970
COWI-DHI[3]	1,074	118	121.5	213.2	1,098	2.9	1950-2004
EIA Ltd[4]	1,212.88	55.98	155.86	181.28	1,242.14		1962-2003

The result can indicate following points:

- Discharges from River Victoria Nile and to River Kyoga Nile are almost equivalent, and the quantity is more than eighty percent of inflow to Lake Kyoga.
- Inflow from tributaries located in Lake Kyoga Basin is estimated less than ten percent of total inflow.
- The comparison between over-lake rainfall and over-lake evaporation says that the evaporation is 1.2 times to 1.8 times of the rainfall. It means water balance over the Lake is deficit. The deficit come up with inflows from own basin and River Victoria Nile.

This means that withdrawal from Lake Kyoga water is equivalent to withdrawal from tributaries and River Nile waters. Water use of the River Victoria Nile requires coordination and adjustment under Nile Agreement. Therefore, the quantity of a part of rainfall, which precipitated in Lake Kyoga Basin itself and finally reached to Lake Kyoga, has only possibility to use at Lake Kyoga from the point of view of water right. Therefore, it requires coordination among water usages at upper streams and Lake Kyoga.

(2) Possibility of Lake Water Withdrawal from Lake Victoria

Many researchers have studied water balance of Lake Victoria. The results of the studies are summarized in Table 13-4. Almost all researchers except Xungan et al (1998) set their reference period for water balance analysis where water levels in Lake Victoria were equivalent at beginning and end of the analysis period. This means no change of storage water volume in the period.

Uganda has smaller national land than other countries has in the Lake Victoria basin so that the contribution from own tributaries to the Lake water storage is also small. However, the difference

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[2] Hydrometeorological Survey of the Catchments of Lakes Victoria, Kyoga and Albert (1974)
[3] Study on the planned restoration of Lake Kyoga; Sub-report 1: Modelling of Lake Kyoga Flows (2007), COWI Uganda/MoWE, Kampala, Uganda
[4] Support to the Management of SUDD Blockage on Lake Kyoga(2004), EIALtd.

between over-lake rainfall and evaporation in the national territory of the Lake may be estimated as lake water resource of Uganda from the point of view of water right.

Fortunately, the over-lake rainfall was larger than over-lake evaporation; the difference reaches four to seventeen percent of the over-lake evaporation. Therefore, there is a possibility to use water without lowering of the lake water level on a long-term basis. On the other hand, it is not inevitable to decrease discharge from Lake Victoria into River Victoria Nile when the water use applied. .

Since 1954 (when the Nalubale dam was completed), water flow from the Lake has been constrained to mimic the natural outflows from the lake using a rating curve of "Agreed Curve" that correlates the flow of the Victoria Nile (at the Source of Victoria Nile) to the water level in the Victoria Lake. It means that use of Lake Victoria water requires coordination and adjustment among the countries related to Nile Agreement.

Table 13-4 Water Balance on Lake Victoria in Existing Documents

Source	Inflow		Outflow		Storage (mm)	Reference Period
	Tributary flow (mm)	Over-lake rainfall (mm)	Over-lake evaporation (mm)	Victoria Nile (mm)		
WMO (1974, 1981)	238	1,690	1,423 – 1,496	426		
Hastenrath st al. (1983)	250		1,500	400		
Spigel et al. (1996)	260	1,450	1,370	340		
Howell et al. (1988)	343	1,810	1,593	524		1956 – 1978
Flohn (1983)	280	1,690	1,470	450		1945 – 1984
Flohn st al. (1985)		1,630 – 1,660	1,470	500		1950 – 1979
Kite (1982)	420	1,660	1,590	570		1970 – 1974
Piper et al. (1986)	343	1,850	1,595	500		1956 – 1978
Balek (1997)	241	1,476	1,401	316		
Xungan et al. (1998)	338	1,791	1532	524	73	1956 - 1978

Lake area: about 68,000km^2

Source: The water balance of Lake Victoria, Xunggang Vin et.al, Hydrological Sciences, October1998

13.2.3 Hydrological Monitoring

Estimation of the surface water resources in SIP has issues above mentioned. The most fundamental issues are related to monitoring of rainfall and river discharges. These monitoring are base of the water resources estimation, however, the number of monitoring points are decreasing and the facilities are deteriorating now despite the effort of involved parties.

(1) Monitoring Network of Rainfall

Uganda has its rainfall observation data from the beginning of 1990. The Study Team summarized the beginning and terminating year of each observation points by obtained rainfall data (see Figure 13-1 and 13-2). These figures indicate following matters:

i) The Beginning Years of Rainfall Observation

- The construction of rainfall stations started from 1902, and two to three stations increased every year until 1940's.
- In 1943, about 200 stations were constructed, and from then on, about ten stations were constructed averagely every year until 1970.
- After 1979 (Uganda – Tanzania War), there are almost no stations constructed.

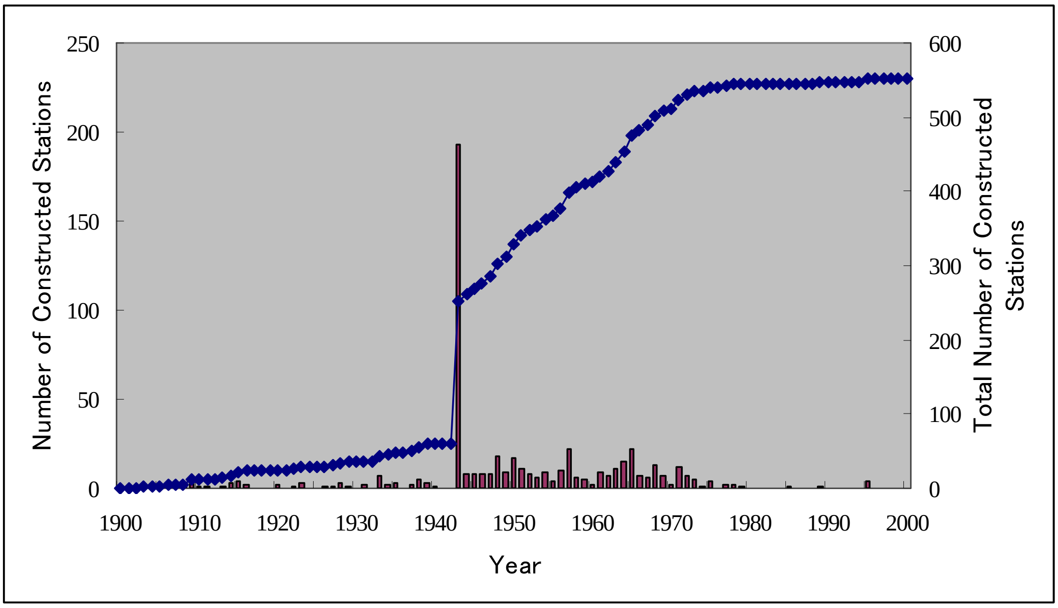


Figure 13-1 Histogram of the Beginning Years of Rainfall Stations

ii) The Terminated Years of Rainfall Observation

- In 1962 (at the time of Independence of Uganda) and 1976 to 1985, many stations terminated their observations.
- After 1985, number of termination of stations has decreased, and then increased again from 1990.

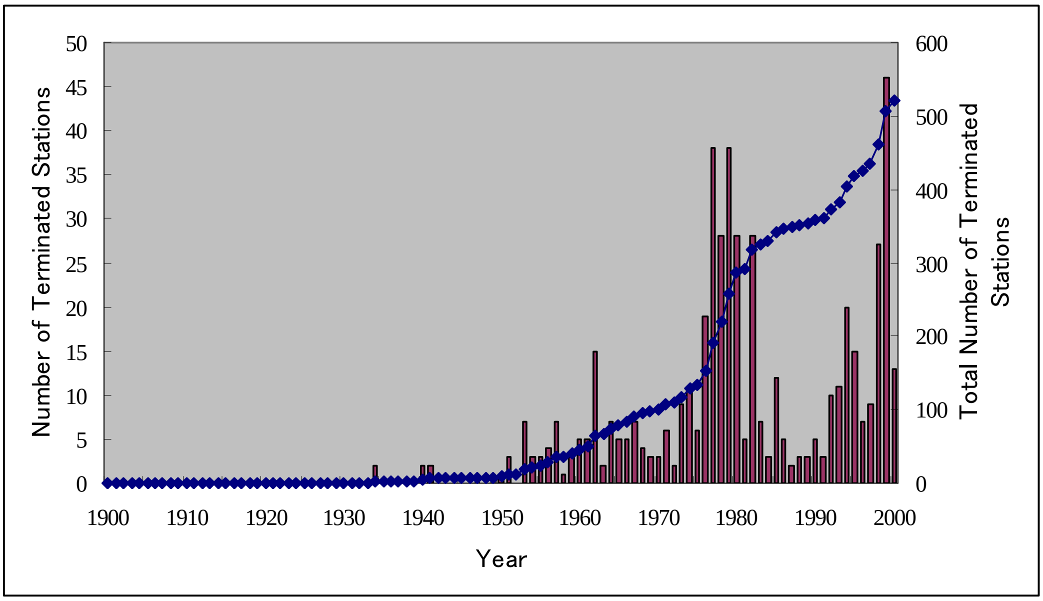


Figure 13-2 Histogram of the Terminated Years of Rainfall Stations

iii) Current Situation

It is believed that more than sixty stations have continued their monitoring work on rainfall. Information from counterparts says that each involved sector such as meteorology, agriculture, water resources development and management monitored rainfall with their own stations. And the government unified recently the monitoring system of meteorology, and the Department of Meteorology under the Ministry of Water and Environment (MoWE) became the responsible organization on meteorological observation, data collection and their management. However, actual situation is so far a way from the aimed goal. There are lack of observation and maintenance of monitoring stations due to shortage of budget. In addition, there is destruction of meteorological database due to computer virus.

These issues cause to prevent smooth data provision, and the meteorological information disclosure does not proceed. Exchange of the basic data is an essential issue in the process of the implementation of water resources development and management. Therefore, the improvement of rainfall monitoring system is a pressing issue for the step-up of IWRM.

Government of Uganda and donors have been fully aware of these issues, and they are going to implement following projects;

- Improvement of medium range and seasonal forecasts in Uganda (2008), fund by Government of Uganda; however, the Government has requested partial assistance due to shortage of the budget.
- Feasibility Study for the Proposed Department of Meteorological Services Modernization Project in Uganda (2010), Donor: US Trade and Development Agency.

(2) Monitoring Network of River Discharges

As described in Chapter 2, there are some gauging stations located in not suitable points for monitoring river discharge of each river. In addition, some sub-basins have no river gauging stations. Therefore, even though monitoring of river discharge has been continued during long period, but the monitoring data obtained is not always represented 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 their installed points and observation method of monitoring river discharge and their distribution.

13.2.4 Imbalanced Distribution of Surface Water Resources in the Basin

Estimation result in Section 13-2 shows that the available surface water resource through the year are different in each sub-basin (see Table 13-10). The distribution has a tendency that northern sub-basins has poor surface water resources, on the other hands, southern sub-basins has more surface water resources. It is necessary to take this prior condition into the basic plan of water resource development and management.

13.2.5 Effect of Climate Change on Surface Water Resources

As described in Chapter 2.3, IPCC Fourth Assessment Report pointed out that annual rainfall of East Africa including Uganda is likely to increase in the 21st century. Observed rainfall data of Uganda has not denied this regional rainfall projection. Furthermore, due to the largeness of Lake Kyoga Basin, flooding and droughts sometimes happen at a same season in different area in the basin; or, droughts/rainy year continues more than ten years at same areas.

Therefore, determination of standard drought water discharge for a specific 10 years always involves a risk of overestimate or underestimate. Determination of drought year for a recent 10 years also takes risk. As a result, it is recommendable to neglect increase of annual rainfall by climate change for avoiding overestimate of surface water resource, and to use as long period observation data as possible for rainfall and river discharge toward estimation of surface water resources.

13.2.6 Management of Surface Water Usage

DWRM has a power to allow water use of surface water resources at present. DWRM has built up a database on this water allocation to some extent; however, the updating of the database does not proceed. Therefore, it is difficult to grasp current situation of water use of surface water such as the quantities of withdrawal, the locations of intakes and their purposes for each river and lakes. Knowing current water use, the quantity and distribution of water resources are essential for IWRM. Therefore, it is necessary to strengthen maintenance system of the database on allocated water right and water usage to keep it up to date. In addition, it is necessary to share the information among water sectors for smooth allocation of the water resources as countermeasure against droughts

13.2.7 Summary of Issues on Surface Water Resources Development and Management

The important issues are summarized as follows from the considerations before mentioned.

- Given the new political dispensation in the Nile basin, the Nile Basin countries, in 1995, embarked on the process of negotiating and developing a new Nile Basin Cooperative Framework Agreement for the sustainable management and development of the shared Nile water resources. This process is still ongoing and it is envisaged that once these negotiations are successfully concluded, the resulting agreement will supersede all the existing Nile water agreements. However, it is not practical to put this hopeful agreement on the prior condition of a basic plan of the surface water resources development and management. Therefore, it is necessary to make the basic plan under the water resources supplied by rainfall precipitated in the Lake Kyoga Basin itself.

- It is necessary to build adequate water allocation system among water sectors for keeping economic efficiency, effectiveness and social equity.
- IPCC Fourth Report said that Climate Change in the 21st will cause increase of annual rainfall in East Africa. However, it can not give reliable rainfall quantity at any given future point in time so that it is reasonable not to put the rainfall increase effect into the basic plan.
- It is necessary to build up revised monitoring system on rainfall and surface water discharge, and information sharing system among water sectors: these are fundamentals for more precise water resources estimation.
- These monitoring data will bring more accurate estimation of water resources in future.
- On the other hands, to grasp current water use is also essential for IWRM so that the strengthening of maintenance system of the database on water allocation and the information sharing among water sectors are necessary.

13.3 Groundwater Resources

13.3.1 Issue on Groundwater Development Plan

(1) Groundwater Development Plan

There is no development plan of National or local level, and, planning is required early. Therefore, capacity development for planning of development plan is required at each district. Since groundwater should be main water source for rural area, capacity development for groundwater in each district water office (DWO) is recognized as prime task.

(2) Groundwater Mapping

Groundwater Mapping was formulated based on National Groundwater Database (NGWDB), and added information of shallow wells which was surveyed in field. It is including the groundwater potential map, the water source location map and so on. It is very useful for administrators in districts or for donors for planning groundwater development plan in the original purpose. However, since the data in NGWDB have some issues in the accuracy, the accuracy of those maps based on the NGWDB has some limitation too. Therefore, groundwater mapping should be updated by improved NGWDB with adding new data and reviewing existing data based on the result of WATSUP project.

(3) Groundwater Potential

Groundwater potential for Lake Kyoga Basin was analyzed in the Study based on the data of NGWDB. On the other hand, groundwater availability was calculated by following formula in SIP:

(Groundwater availability) = (Average yield in a well a day)*365* (Well density)*(Land Area),

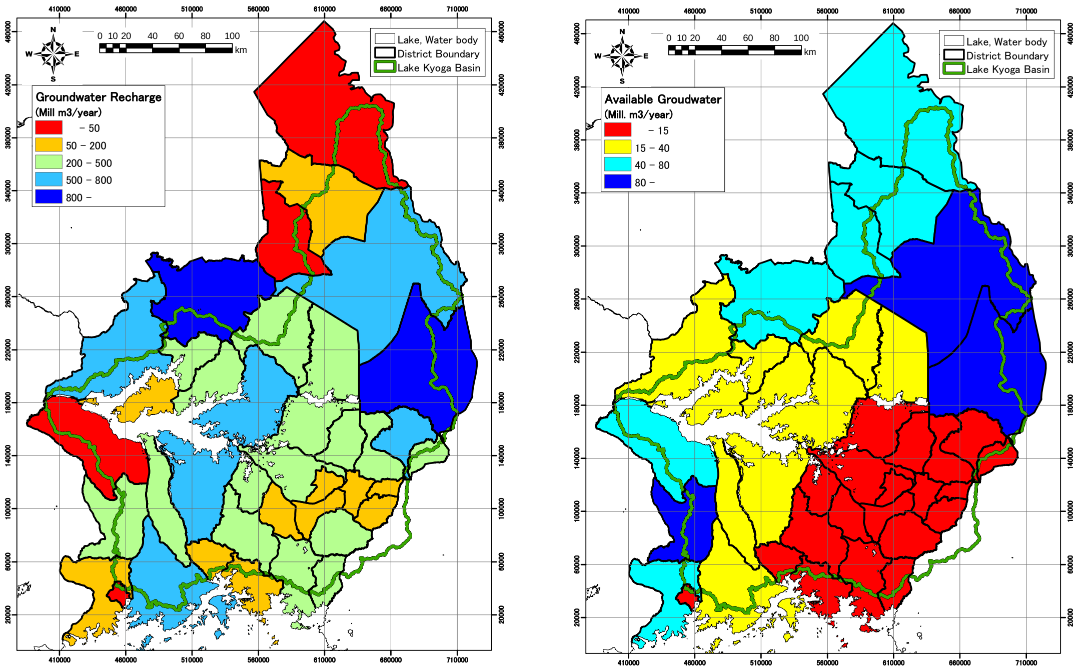
where, average yield in a well a day is used rough value like 50, 60, 70, and 100 m^3 , well density is substituted from success rate from 50 to 75 %.

In the Study, an annual groundwater recharge was calculated by multiplying annual possible infiltration (height in a unit area: mm) by land areas. Table 13-5 shows the comparison between the result of the Study and SIP. Total groundwater recharge estimated by the Study is 12,766 MCM/year, and groundwater availability is predicted by assuming 10% of it can be practically exploitable. This is almost similar value of SIP as shown in the table; however, availability by districts is not always same. In the result of SIP, it is far from the impression of measurement result of rainfall, especially, groundwater availability in Karamoja area seems to be over estimated in spite of very little annual rainfall in the area.

Table 13-5 Comparison of Groundwater Availability between the Study and SIP

No.	District Name	Study Result				SIP		
		Infiltration (mm)	Land Area (km^2)	Recharge (MCM/year)	Groundwater availability (MCM/year)	Average yield (m^3/day)	BH density ($/km^2$)	Groundwater availability (MCM/year)
1	Abim	N.G	2352.6	N.G	N.G	50	0.75	54.4
2	Amolatar	180	956.5	171.9	17.2	50	0.75	24.1
3	Amuria	189	2581.2	489.0	48.9	70	0.60	35.5
4	Apac	133	3982.5	531.2	53.1	50	0.50	21.4
5	Budaka	130	410.6	53.3	5.3	50	0.50	4.4
6	Bududa	586	273.9	160.5	16.1	50	0.50	3.7
7	Bugiri	217	1568.5	339.8	34.0	50	0.50	6.6
8	Bukedea	243	1054.1	256.5	25.7	50	0.50	11.1
9	Bukwa	633	525.6	332.8	33.3	50	0.50	4.7
10	Busia	288	730.9	210.9	21.1	50	0.50	6.3
11	Butaleja	192	655.4	125.9	12.6	50	0.50	4.5
12	Dokolo	329	997.2	328.5	32.9	50	0.75	25.1
13	Iganga	234	1669.6	391.3	39.1	50	0.60	12.7
14	Jinja	203	674.7	137.1	13.7	50	0.60	7.2
15	Kaabong	N.G	7263.6	N.G	N.G	50	0.75	54.4
16	Kaberamaido	255	1330.1	339.0	33.9	70	0.60	18.6
17	Kaliro	264	788.2	208.2	20.8	50	0.50	10.6
18	Kamuli	237	180.9	673.7	67.4	50	0.50	29.7
19	Kapchorwa	486	1206.2	586.6	58.7	50	0.50	10.9
20	Katakwi	146	2309.4	336.7	33.7	70	0.60	35.5
21	Kayunga	174	1585.6	275.4	27.5	60	0.50	15.3
22	Kotido	26	3628.9	95.9	9.6	50	0.75	72.5
23	Kumi	264	1645.2	433.8	43.4	50	0.50	11.1
24	Lira	310	4403.8	1366.0	136.6	50	0.75	58.6
25	Luweero	92	2221.7	205.2	20.5	100	0.70	97.3
26	Manafwa	309	580.8	179.3	17.9	50	0.50	3.7
27	Mayuge	161	1088.7	175.1	17.5	50	0.60	11.2
28	Mbale	149	518.2	77.3	7.7	50	0.50	4.9
29	Moroto	79	8517.6	670.8	67.1	70	0.60	130.6
30	Mukono	205	3385.5	695.0	69.5	60	0.50	34.1
31	Nakapipirit	153	5833.6	895.0	89.5	70	0.60	89.1
32	Nakasongola	5	3265.9	17.5	1.8	100	0.70	79.4
33	Namutumba	212	810.9	171.9	17.2	50	0.50	6.6
34	Pallisa	265	1506.0	398.6	39.9	50	0.50	10.1
35	Sironko	418	1093.9	457.7	45.8	50	0.50	9.7
36	Soroti	212	2832.5	599.5	60.0	70	0.60	37.6
37	Tororo	236	1193.8	282.1	28.2	50	0.50	10.4
38	Wakiso	51	1913.2	97.0	9.7	100	0.70	42.5
		Total		**12,765.8**	**1,276.6**	Total		**1,106.2**

N.G: Negligible



(a) Groundwater Availability the Study (b) Groundwater Availability by SIP

Figure 13-3 Comparison of Groundwater Availability between the Study and SIP

In the Study, groundwater recharge was analyzed by the water balance calculated by albedo and topography analysis estimated by satellite image analysis, because the meteorological, hydrological and hydrogeological data are insufficient. In near future, it is necessary to improve their monitoring network system satisfactorily to consider the climate change too. However, water resource management can't wait for accumulation of their data; therefore, this technique using satellite image data as provisional and practical method is effective. Capacity development for DWRM's staff is needed to conduct this kind of analysis by themselves.

13.3.2 Issue on Groundwater Management Plan

There are some issues on groundwater management plan in the role of DWRM as an organization in charge. Now, DWRM is conducting for groundwater management mainly, (1) issue of permission for drilling well, (2) receipt of borehole completion report, (3) issue of permission for groundwater pumping, (4) groundwater monitoring and so on. Additionally, (5) establishment of Water management zone (WMZ) is scheduled in near future.

(1) Permission for Drilling Borehole and Borehole Completion Report

Drilling company has to register to DWRM to receive the permission for drilling borehole and to submit the borehole completion report every three month. However, many low accuracy data can be found on the pumping test according to the review of the reports. The definitions of yield are different among the drilling companies, because the guideline about the pumping test has not been established yet. For example, the suitable pumping rate is defined as 80 % of limit pumping rate based on step draw down test in Japan. Guidelines of borehole drilling and pumping test should be formulated and efforts to make the drilling companies to keep the guidelines are needed in order to improve NGWDB.

(2) Groundwater Monitoring

Only three groundwater monitoring stations are functioning in Lake Kyoga Basin so far. To grasp the fluctuation of quantity and quality of groundwater resources, the role of groundwater monitoring is essentially important. The number of monitoring station is required at least each one station at the typified place in the 11 sub-basins.

(3) Permission for Groundwater Withdrawal

Water balance analysis is fundamental matter for water resources management. Therefore, to grasp groundwater withdrawal volume as sort of expenditure is so important that DWRM should monitor withdrawal volume of bulk water-users in particular through granting groundwater withdrawal permission.

(4) Water Management Zone

The main roles of the WMZ are shown below;

(i) Implementing Integrated Water Resource Management (IWRM),

(ii) Bringing practical WRM much closer to the users,

(iii) Models for the assessment of water balance, water quality and pollution loading, and

(iv) Community participation.

In terms of IWRM, water balance is not analyzed administrative-boundary-wise but basin or catchment-wise. Since DWRM is in charge of water balance analysis, it is very important to increase their ability of water balance analysis as a part of “Capacity for Water Resources Management” listed up by SIP.

13.4 Conservation of Ambient Water Quality

13.4.1 Quality of Water Source and Issue

As we discussed in chapter 4, the water environment in the area is not favorable. Although there is relatively less significant problem in water quality, the shortage of water for human activity is a much more severe problem.

The problems on the water quality are outlined as follows:

(1)Groundwater (Deep well, Shallow well, Spring)

The problem on ground water is that there is widespread contamination of Coliforms in many deep wells, shallow wells, and protected springs. These facts suggest that these is a large amount of fecal contamination which derives from livestocks, and that the contaminated water go through the ground and reaches to the underground water resources. Concerning deep well, the possible cause of the contamination is the influx of surface water, due to the inappropriate blockage of contaminated water on the surface and the faulty sealing.

The common way of detoxicating contaminated water is boiling, which inevitably leads to the further consumption of fuels, and probably leads to the deforestation.

In several wells , the level of iron and fluorine was elevated, although most of them were below the rural maximum allowance concentration. Since each well has different variety of compounds, we can deal with the problem of excessive inorganic compounds by digging additional well nearby.

(2) Surface water (Rivers and ponds)

The current problem is the slight elevation of organic compounds in urban area. BOD was not significantly high in most cases. However, this situation is likely to change dramatically in near future, due to the population growth and economical growth. Especially, water resource is likely to deteriorate, due to the excessive demand of water in the future and the pollution by sewage water as a consequence of population growth. To be able to deal with these situations in the future, it is necessary to keep good quality of rivers and ponds as possible water resources.

In conclusion, the biggest problem is the maintenance of water quality. Further deterioration of water quality must be avoided in order to deal with future population growth.

13.4.2 Need for Ambient Water Quality Standards and Water Quality Monitoring

In Japan, 30 to 40 years ago, there was a serious problem of water pollution with economic development. Therefore, various legal regulation related to environment were legislated, and sewer construction, water quality monitoring and environmental education were implemented.

The resulting lesson is to restore the environment after it was contaminated, it takes enormous cost and time-consuming, but it takes some initial cost, it still has cheaper it was to forestall and prevent pollution.

Uganda is projected rapid population growth and economic development. As a result, the environment especially water quality will be badly polluted. Therefore, as water quality monitoring and maintain system should be taken before it become a serious pollution, consider critical to monitor the state of pollution on a regular basis.

In Uganda, many of groundwater use are shallow groundwater like shallow wells and springs. Therefore, it is feared that groundwater will be polluted by polluted surface water. It means that the available water resources are decrease.

As for prevent these situation, it is important to install septic tank and to construct sewerage, and to increase public awareness by education.

However, to confirm if these measures are working effectively, it is necessaly to ensure by regular water quality monitoring. And it's also needed to designate the ambient water quality standard and classification of water bodies.

13.4.3 Ambient Water Quality Standard and Monitoring System in Japan

Establishing ambient water quality standard is one of the criteria for maintaining water quality. The ambient water quality standard for lakes and rivers in Japan consists of various items and they are categorized into two groups as shown in Tables 16-1 and 16-2. One is for life environment. Items in this category include parameters such as pH, SS, DO, and E.coli. concentration. The other category is for public health and it includes items such as pesticides and heavy metals which are harmful to human.

As shown in Table 16-1, there are different standards for different types of waters for life environment. The goal is to maintain the value of each item, and these standards apply to any public waters, such as rivers and lakes, that need to be protected from contamination. Designation of a standard for each water is at local government's discretion except for those important ones designated by the central government.

The standard for public health is common to every public water and is more strictly enforced than the life environment standards. The standards for public health were originally established to regulate drainage of water contaminated by heavy metal. However, the number of items in the standard has increased to address pesticides and different types of chemicals from high-tech industry.

Local governments are responsible for monitoring water quality, and they evaluate water quality for the life environment standards and the public health standards at least annually and monthly, respectively.

13.4.4 Necessity of Ambient Standard and Water Quality Monitoring in Uganda

In Uganda there are drinking water quality standards, effluent standards, but environmental standards have not been set up yet. For rivers, lakes, and other types waters, water quality monitoring has been implemented, but measurement points and frequency of measurement have not been set up in a systematic manner. Rapid growth of the economy and population is expected in Uganda which will lead to increase of waste water and hence pollution of public water.

To combat the expected water pollution, a variety of measures are needed, and evaluation of those measures is as important as execution of them for maximizing their effectiveness. Water quality monitoring is the only way for evaluation of the water pollution prevention measures. It unveils excess and deficiency of the measures taken. Protection of clean surface water is essential for cost-effective supply of clean water in Uganda and it also provides protection of the agriculture and fishery industries. Establishing ambient water quality standards and periodic monitoring of water quality at various locations are the keys for supporting the measures for protection of surface water in Uganda.

Ambient water quality standards need to be set up for the Lake Kyoga basin. Currently, standards for living environment are more important than public health standards in the basin since the area has not been industrialized and pesticides are not widely used at this point. However, with the future development of the area in consideration, it is advisable to set up public health standards as well which include toxic heavy metals and pesticides. It is also recommended that the central government classify Lake Kyoga itself, its adjacent lakes, Ramsar wetlands, river of Victoria Nile, and other important waters, and that the rest are classified by local governments.

Table 13-6 Water Quality Standards in Japan (Living Environment)

■ Environmental quality standards for conservation of the living environment

1. Rivers (excluding lakes)

A

Item class	Water use	Standard value				
		Hydrogen-ion concentration (pH)	Biochemical oxygen demand (BOD)	Suspended solids (SS)	Dissolved oxygen (DO)	Total coliform
AA	Water supply class 1, conservation of natural environment, and uses listed in A-E	6.5 ≤ pH ≤ 8.5	≤ 1 mg/L	≤ 25 mg/L	≥ 7.5 mg/L	≤ 50 MPN/100mL
A	Water supply class 2, fishery class 1, bathing and uses listed in B-E	6.5 ≤ pH ≤ 8.5	≤ 2 mg/L	≤ 25 mg/L	≥ 7.5 mg/L	≤ 1,000 MPN/100mL
B	Water supply class 3, fishery class 2, and uses listed in C-E	6.5 ≤ pH ≤ 8.5	≤ 3 mg/L	≤ 25 mg/L	≥ 5 mg/L	≤ 5,000 MPN/100mL
C	Fishery class 3, industrial water class 1, and uses listed in D-E	6.5 ≤ pH ≤ 8.5	≤ 5 mg/L	≤ 50 mg/L	≥ 5 mg/L	—
D	Industrial water class 2, agricultural water, and uses listed in E	6.0 ≤ pH ≤ 8.5	≤ 8 mg/L	≤ 100 mg/L	≥ 2 mg/L	—
E	Industry water class 3 and conservation of environment	6.0 ≤ pH ≤ 8.5	≤ 10 mg/L	Floating matter such as garbage should not be observed.	≥ 2 mg/L	—

Remarks: 1. Standard values are based on daily average values. The same applies to the standard values of lakes and coastal waters.
2. At intake for agriculture, pH shall be between 6.0 and 7.5 and DO shall be more than 5mg/l. The same applies to the standard values of lakes.

Notes: 1. Nature conservation: Conservation of sightseeing and other environments
2. Water supply class 1: Purify water using filters and other simple means
Water supply class 2: Purify water using sedimentation filters and other ordinary means
Water supply class 3: Purify water using pre-treatment and other advanced methods
3. Fishery class 1: For such oligosaprobic members of the Salmonidae (salmon/trout) species as Salmo masou and Salvelinus leucomaenis, and marine products for fishery class 2 and 3
Fishery class 2: For such alpha-oligosaprobic marine products as the Salmonidae (salmon/trout) species, sweetfish, and marine products for fishery class 3
Fishery class 3: For such beta-oligosaprobic marine products as carp and crucian
4. Industrial water class 1: Water purified using sedimentation and other ordinary means
Industrial water class 2: Purify water using chemical additives and other advanced means
Industrial water class 3: Purify water using special means
5. Environmental conservation: Limit of not disrupting the day-to-day lives of the population

2. Lakes (natural lakes and reservoirs that have 10 million cubic meters of water or more)

A

Item class	Water use	Standard value				
		Hydrogen-ion concentration (pH)	Chemical oxygen demand (COD)	Suspended solids (SS)	Dissolved oxygen (DO)	Total coliform
AA	Water supply class 1, fishery class 1, conservation of natural environment, and uses listed in A-C	6.5 ≤ pH ≤ 8.5	≤ 1 mg/L	≤ 1 mg/L	≥ 7.5 mg/L	≤ 50 MPN/100mL
A	Water supply classes 2 and 3, fishery class 2, bathing, and uses listed in B-C	6.5 ≤ pH ≤ 8.5	≤ 3 mg/L	≤ 5 mg/L	≥ 7.5 mg/L	≤ 1,000 MPN/100mL
B	Fishery class 3, industrial water class 1, agricultural water, and uses listed in C	6.5 ≤ pH ≤ 8.5	≤ 5 mg/L	≤ 15 mg/L	≥ 5 mg/L	—
C	Industrial water class 2 and conservation of the environment	6.0 ≤ pH ≤ 8.5	≤ 8 mg/L	Floating matter such as garbage should not be observed.	≥ 2 mg/L	—

Notes: 1. Conservation of the natural environment: conservation of sightseeing and other environments
2. Water supply class 1: Purify water using filters and other simple means
Water supply class 2/3: Purify water using sedimentation filters and other ordinary means, and pre-treatment and other advanced methods
3. Fishery class 1: For such marine products inhabiting oligotrophic lakes as sockeye salmon, and marine products for fishery class 2 and 3
Fishery class 2: For such marine products inhabiting oligotrophic lakes as the Salmonidae (salmon/trout) species, sweetfish, and marine products for fishery class3
Fishery class 3: For such marine products inhabiting oligotrophic lakes as koi and crucian carp
4. Industrial water class 1: Water purified using sedimentation and other ordinary means
Industrial water class 2: Purify water using such advanced means as chemical additives and special purification means
5. Conservation of the environment: Limit of not disrupting the day-to-day lives of the population (including things likes walks along the beach)

B

Item class	Water use	Standard value	
		Total nitrogen	Total phosphorus
I	Conservation of natural environment and uses listed in II-V	≤ 0.1 mg/L	≤ 0.005 mg/L
II	Water supply classes 1, 2, and 3 (except special types), fishery class 1, bathing, and uses listed in III-V	≤ 0.2 mg/L	≤ 0.01 mg/L
III	Water supply class 3 (special types) and uses listed in IV-V	≤ 0.4 mg/L	≤ 0.03 mg/L
IV	Fishery class 2 and uses listed in V	≤ 0.6 mg/L	≤ 0.05 mg/L
V	Fishery class 3, industrial water, agricultural water, and conservation of the environment	≤ 1 mg/L	≤ 0.1 mg/L

Remarks: 1. Standard values are set in terms of annual averages.
2. Standard values are applicable only to the lakes and reservoirs where phytoplankton bloom may occur, and standard values for total nitrogen are applicable to lakes and reservoirs where nitrogen limits phytoplankton growth.
3. Standard values for total phosphorus are not applicable to agricultural water uses.

Notes: 1. Conservation of the natural environment: Conservation of sightseeing and other environments
2. Water supply class 1: Purify water using filters and other simple means
Water supply class 2: Purify water using sedimentation filters and other ordinary means
Water supply class 3: Purify water using pre-treatment and other advanced methods (a "special item" is a special purification means capable of removing odor-producing substances)
3. Fishery class 1: For such marine products as the Salmonidae (salmon/trout) species, sweetfish, and marine products for fishery class 2 and 3
Fishery class 2: For such marine products as smelt and marine products for fishery class 3
Fishery class 3: Such marine products as koi and crunian carp
4. Conservation of the environment: Limit of not disrupting the day-to-day lives of the population (including things likes walks along the beach)

Table 13-7 Water Quality Standards in Japan (Human Health)

■ Environmental quality standards for human health

Standards

Item	Standard values
Cadmium	≤ 0.01 mg/L
Total cyanide	Not detectable
Lead	≤ 0.01 mg/L
Hexavalent chromium	≤ 0.05 mg/L
Arsenic	≤ 0.01 mg/L
Total mercury	≤ 0.0005 mg/L
Alkyl mercury	Not detectable
PCBs	Not detectable
Dichloromethane	≤ 0.02 mg/L
Carbon tetrachloride	≤ 0.002 mg/L
1,2- Dichloroethane	≤ 0.004 mg/L
1,1-Dichloroethylene	≤ 0.02 mg/L
Cis 1.2-Dichloroethylene	≤ 0.04 mg/L
1,1,1- Trichloroethane	≤ 1 mg/L
1,1,2- Trichloroethane	≤ 0.006 mg/L
Trichloroethylene	≤ 0.03 mg/L
Tetrachloroethylene	≤ 0.01 mg/L
1,3-Dichloropropene	≤ 0.002 mg/L
Thiram	≤ 0.006 mg/L
Simazine	≤ 0.003 mg/L
Thiobencarb	≤ 0.02 mg/L
Benzene	≤ 0.01 mg/L
Selenium	≤ 0.01 mg/L
Nitrate nitrogen and nitrite nitrogen	≤ 10 mg/L
Fluoride	≤ 0.8 mg/L
Boron	≤ 1 mg/L

Monitored substances and guideline values

Categories	Guideline values
Chloroform	≤ 0.06 mg/L
trans1,2-Dichloroethylene	≤ 0.04 mg/L
1,2- Dichlor propane	≤ 0.06mg/L
p- Dichlor benzene	≤ 0.2 mg/L
Isoxathion	≤ 0.008 mg/L
Diazinon	≤ 0.005 mg/L
Fenitrothion (MEP)	≤ 0.003 mg/L
Isoprothiolane	≤ 0.04 mg/L
Oxine copper (organocopper)	≤ 0.04 mg/L
Chlorothalonil (TPN)	≤ 0.05 mg/L
Propyzamide	≤ 0.008 mg/L
EPN	≤ 0.006 mg/L
Dichlorvos (DDVP)	≤ 0.008 mg/L
Fenobucarb (BPMC)	≤ 0.03 mg/L
Iprobenfos (IBP)	≤ 0.008 mg/L
Chlornitrofen (CNP)	–
Toluene	≤ 0.6 mg/L
Xylene	≤ 0.4 mg/L
Diethylhexyl phthalate	≤ 0.06 mg/L
Nickel	–
Molybdenum	≤ 0.07 mg/L
Antimony	≤ 0.02 mg/L
Vinyl chloride monomer	≤ 0.002 mg/L
Epichlorohydrin	≤ 0.0004 mg/L
1,4-Dioxane	≤ 0.05 mg/L
Total manganese	≤ 0.2 mg/L
Uranium	≤ 0.002 mg/L

Remarks
1. Standard values are for annual average values. However, the value for total cyanide is the maximum value.
2. "Not detectable" means that when the substance is measured by the specified method, the amount is less than the quantitative limit defined by that method.
3. The standard values for boron and fluoride are not applied to coastal waters.

13.5 Analysis of Water Balance between Demand and Water Resources in Lake Kyoga Basin

It is necessary to understand a fundamental condition of Lake Kyoga Basin to formulate the Basic Plan, namely: the balance between water demand and sustainably usable water resources volume in 2035 as the target year of the plan. The result of demand-and-supply balance analysis is as follows.

13.5.1 Water Demand

An increase of water demand is prominent in Uganda having fifth biggest growth rate of population in the world: 3.3%. According to "Strategic Investment Plan for the Water and Sanitation Sub-sector (MoWE 2009)", the population of the Basin in 2008: approximately 9.32 million will become 2.5 times: approximately 22.8 million and the water demand in 2008: 435.6 MCM/year will become 1.94 times: 844.1 MCM/year in 2035 as shown in Figure 13-5. As for the growth ratio of water demand by items, "Domestic Rural" will become approximately five times of the current demand; however, "Crops" of agricultural water which accounts more than 75% at present will only 40% increase.

The ratio of each sub-basin's water demand toward whole water demand of the Basin in 2035 are from Mpologoma 43.3% to Lumbuya 2.4% as shown in Figure 13-6 and their growth rates from 2008 to 2035 on total water demand are from Abalan 12.2 to Mpologoma 1.1 times as shown in Figure 13-6. The differences among sub-basins are remarkable.

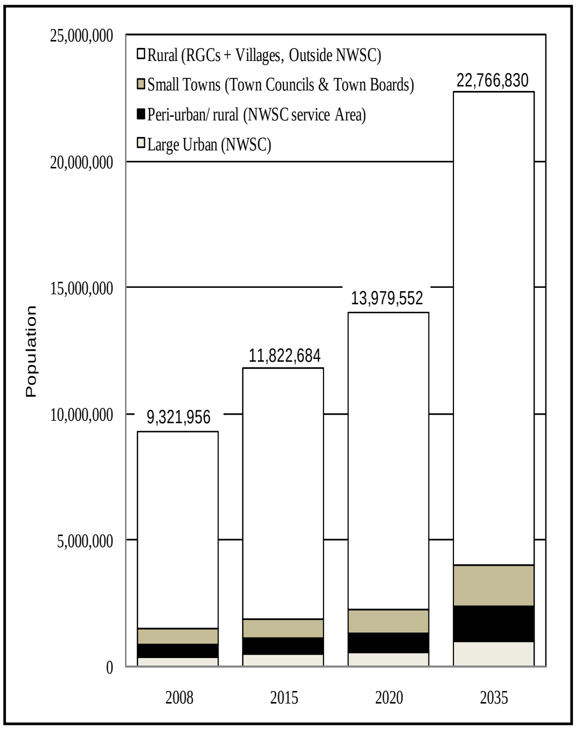


Figure 13-4 Population Frame of Lake Kyoga Basin

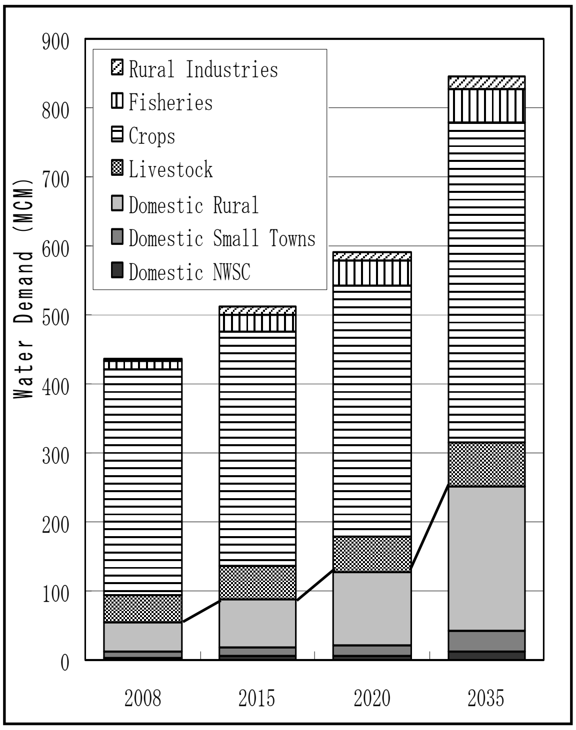


Figure 13-5 Sector Water Demand of Lake Kyoga Basin

13.5.2 Exploitable Water Resources

It is very important factor to formulate the Basic Plan to assess how much water is exploitable within the Basin.

(1) Surface Water

Exploitable surface water volume of each sub-basin is estimated with 3-year drought water discharge and 3-year drought water discharge as illustrated in Figure 13-7. Since a maintenance flow discharge in Uganda is defined as one percent of mean flow discharge, the maintenance volume has been already deducted from them. The figure indicates that the northern part of the Basin: Okok and Okere sub-basin is under the very sever condition of surface water resources.

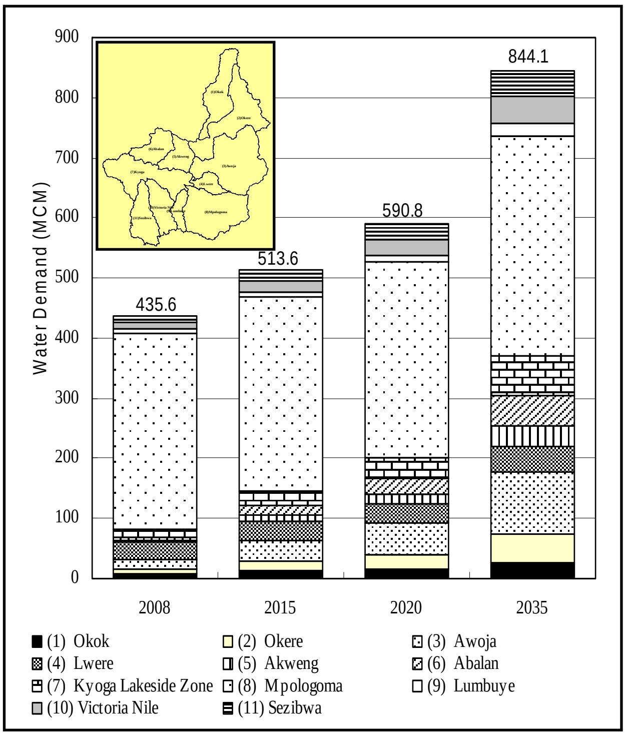


Figure 13-6 Water Demand of Each Sub-Basin

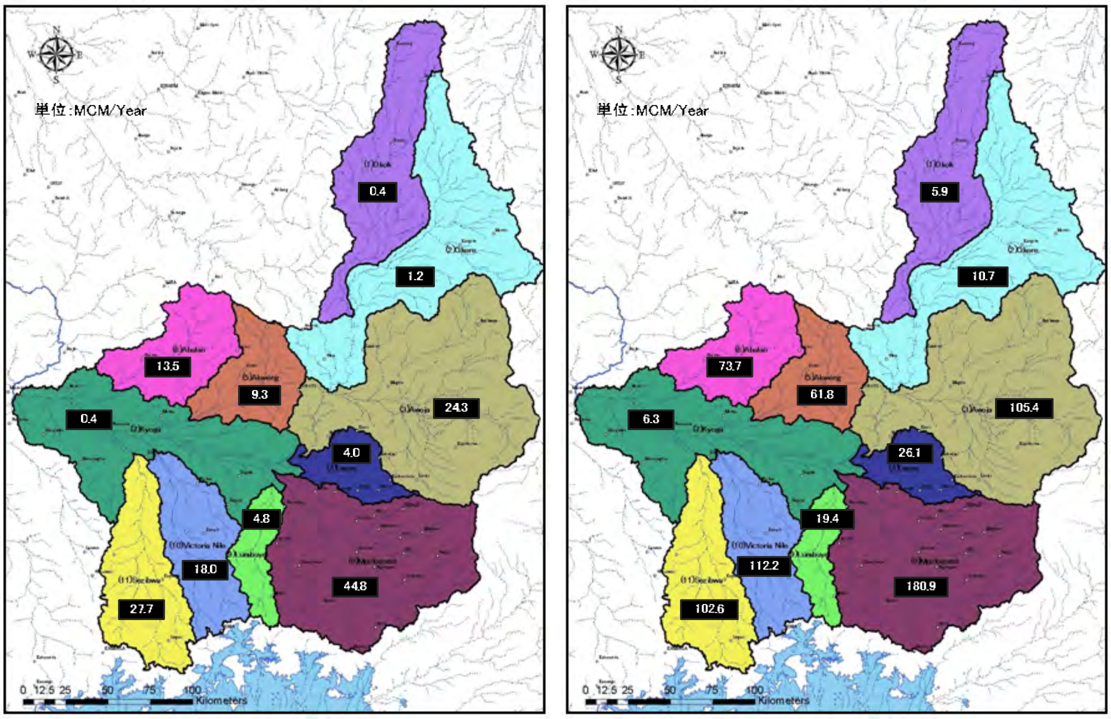


Figure 13-7 Estimated Exploitable Surface Water Volume in each Sub-basin with 3-Year Drought Water Discharge (left) and 3-year Low Water Discharge (right)

(2) Groundwater

In the case of groundwater, total exploitable volume in the Basin is estimated as approximately 1,000MCM/year in normal year and 500MCM/year in drought year under the following assumptions. Figure 13-8 shows exploitable groundwater volume each sub-basin and indicates that the northern two sub-basins are also under the very sever condition.

- Average Effective Porosity = 15.5%
- Average Recharge Rate = 22%
- Practical Development Rate = 10%
- Drought Factor = 50%

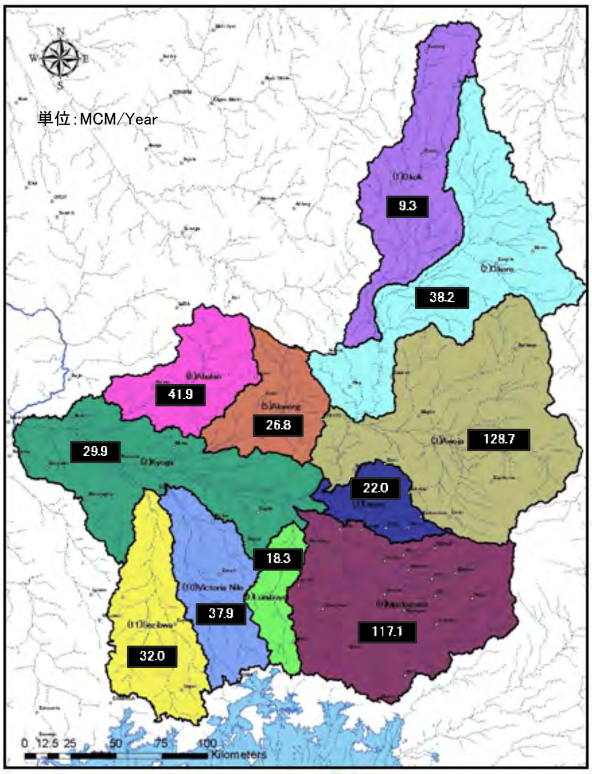


Figure 13-8 Exploitable Groundwater Volume in each Sub-basin in Drought Year

Although the above-mentioned estimation may have accuracy issues, however; it is possible to think that nobody can take an optimistic view on water resources conditions until the target year. Then, it is necessary to take into consideration the relationship between water resource's potentiality and future water demand in the Basin in order to formulate the Basic Plan.

13.5.3 Balance between Water Resources and Water Demand

A relationship between a trend of future water demand and exploitable water resources in the Basin and sub-basins as the fundamental conditions prior to the Basic Plan is descried below.

(1) Lake Kyoga Basin

The extension of water demand and the exploitable volume of water resources in the whole Lake Kyoga Basin are shown in Figure 13-9, which implies their balance in 2008 as a current condition and, in 2015, 2020 and 2035

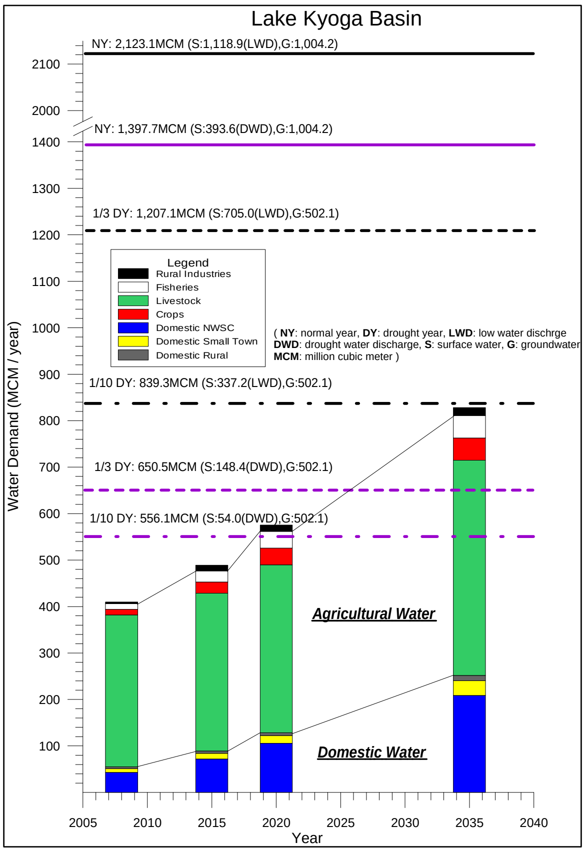


Figure 13-9 Supply and Demand Relationship in Lake Kyoga Basin

as future conditions. Although supply and demand relationship has no problem in a normal year, 556.1 MCM/year summing up surface water resources estimated with 10-year drought water discharge and groundwater in drought year can not cover the future water demand before 2020. Since it is unreasonable to formulate the Basic Plan based on 1/10 probable drought year because much excessive investment is needed in a shot period, 1/3 probable drought year was adopted into the Basic Plan of this study. In that case, the exploitable water volume: 650.5MCM/year can manage to cover water demand quantitatively until around 2025; however, since agricultural water, which occupies more than half of total water demand, depends almost on surface water, it is necessary to consider not only quantitative comparison but also water type of water sector as described below.

(2) Sub-basins

Water supply-demand balances of each sub-basin in Lake Kyoga Basin are shown in Figure 13-11.

Total exploitable water volumes of each sub-basin were calculated to sum up surface water volume estimated by 3-year drought water discharge and exploitable groundwater in drought year. According to the results, deficiency of water resources will be happened by the target year 2035 in five sub-basins: Okok, Okere, Lwere, Kyoga Lakeside Zone and Mpologoma.

On the other hand, water demand for crops, which is majority of agricultural water, is not constant but seasonally changed by the pattern of planting crops that closely correspond to the pattern of rainfall. Figure 13-10 is a typical cropping calendar of Pallisa and Bugili and suggests that the water demand period of crops is seven months per year. Therefore, if 3-year low water discharge that means exploitable for 275 days a year (9 months) is adopted to estimate exploitable surface water resources for agricultural water use, the total water volume will rise to black dotted line in Figure 13-9 and, Lwere and Okere out of above-mentioned five sub-basins have no problem quantitatively. However, according to the water balance assessment considering water quantity and water type in Table 13-9, shortage of water will occur in agriculture sector of the five sub-basins after all. As for domestic water, if groundwater development goes well, the water demand growth in all sub-basins can be nearly covered. Supply and demand conditions of each sub-basin are as follows.

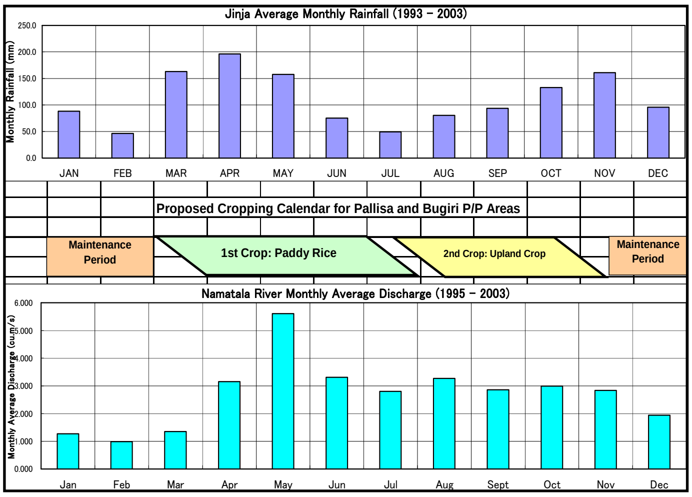


Figure 13-10 Typical Crop Calendar of Pallisa and Bugiri District

a) Okok

Since surface water resource for agriculture is near to the limitation of its demand even now, future water demand expected to be about three times until 2035 will not be covered. As for domestic and industrial water withdrawing groundwater resources, it might reach the limit in 2035.

b) Okere

In terms of quantity of water resources, water demand in 2035 will be managed to be covered; however, it is difficult to do by surface water resources after 2015 because of six time's increase of agricultural water demand until 2035.

c) Lwere

Most of the water demand in this sub-basin is for crops. Fortunately, it levels off in the future; however, the supply-demand balance in the current situation is a delicate situation. Future domestic water demand in 2035: more than five times of the current demand could be covered by groundwater development.

d) Kyoga Lake-side Zone

Since the drainage area of this sub-basin is split into small catchments due to topographical conditions, surface water resources are scarce. Agricultural water demand closes to limit of surface water resources even now. Therefore, it is very difficult to cover the future demand, which will become 5.5 times of present demand in 2035.

e) Mpologoma

Mpologoma having more than 2.5 million people at present is the most active sub-basin in Lake Kyoga Basin in terms of economic activity. Its water demand is incomparably bigger than any other sub-basins and crop water especially accounts 90% of the current total water demand. According to SIP, agricultural water demand in this sub-basin plans to be cut about 10% rather than the current demand by water-savings until the target year. However, it seems that crop condition is disturbed by insufficient crop water even now because even 3-year low water discharge can cover only 2/3 of the demand.

Predicted water shortage in these sub-basins is mainly agricultural water as shown in Table 13-8. Above-mentioned prediction implies that nobody can take an optimistic view on water resources conditions in the target year, and then the Basic Plan was formulated under such circumstances.

Table 13-8 Estimated Water Shortage in Five Sub-basins

Unit: MCM/year

Sub-basin Name	2008		2015		2020		2035	
	GW for Domestic & Industrial Water	SW for Agricultural Water	GW for Domestic & Industrial Water	SW for Agricultural Water	GW for Domestic & Industrial Water	SW for Agricultural Water	GW for Domestic & Industrial Water	SW for Agricultural Water
(1) Okok				3.2		5.2	0.5	10.9
(2) Okere				0.7		5.7		19.9
(4) Lwere		0.3						1.7
(7) Kyoga Lakeside Zone		2.2		11.8		19.5		40.5
(8) Mpologoma		122.6		100.0		89.8		89.4

GW: groundwater, **SW**: surface water, **MCM**: million cubic met

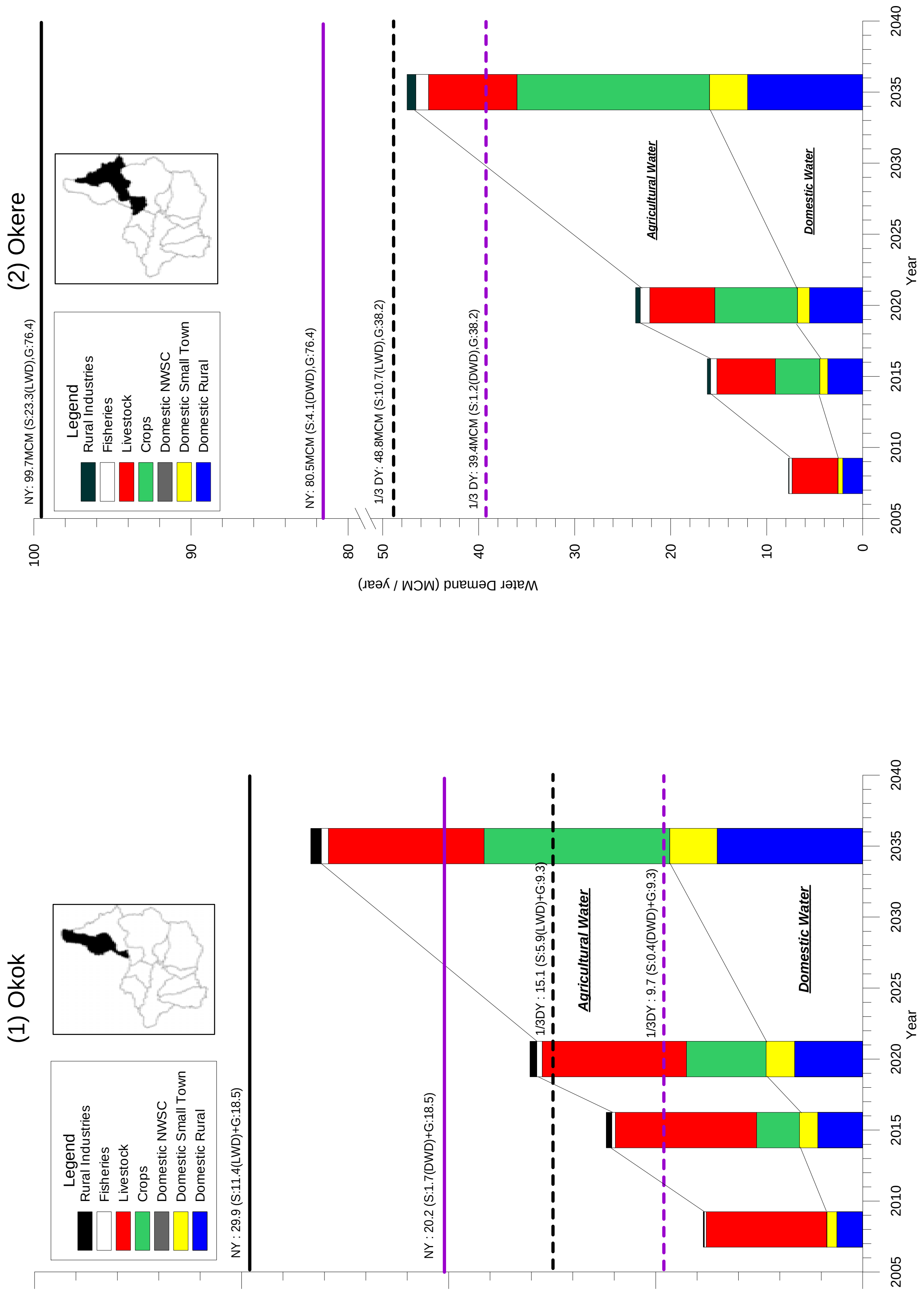


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (1)

(**NY**: normal year, **DY**: drought year, **LWD**: low water discharge, **DWD**: drought water discharge, **S**: surface water, **G**: groundwater)

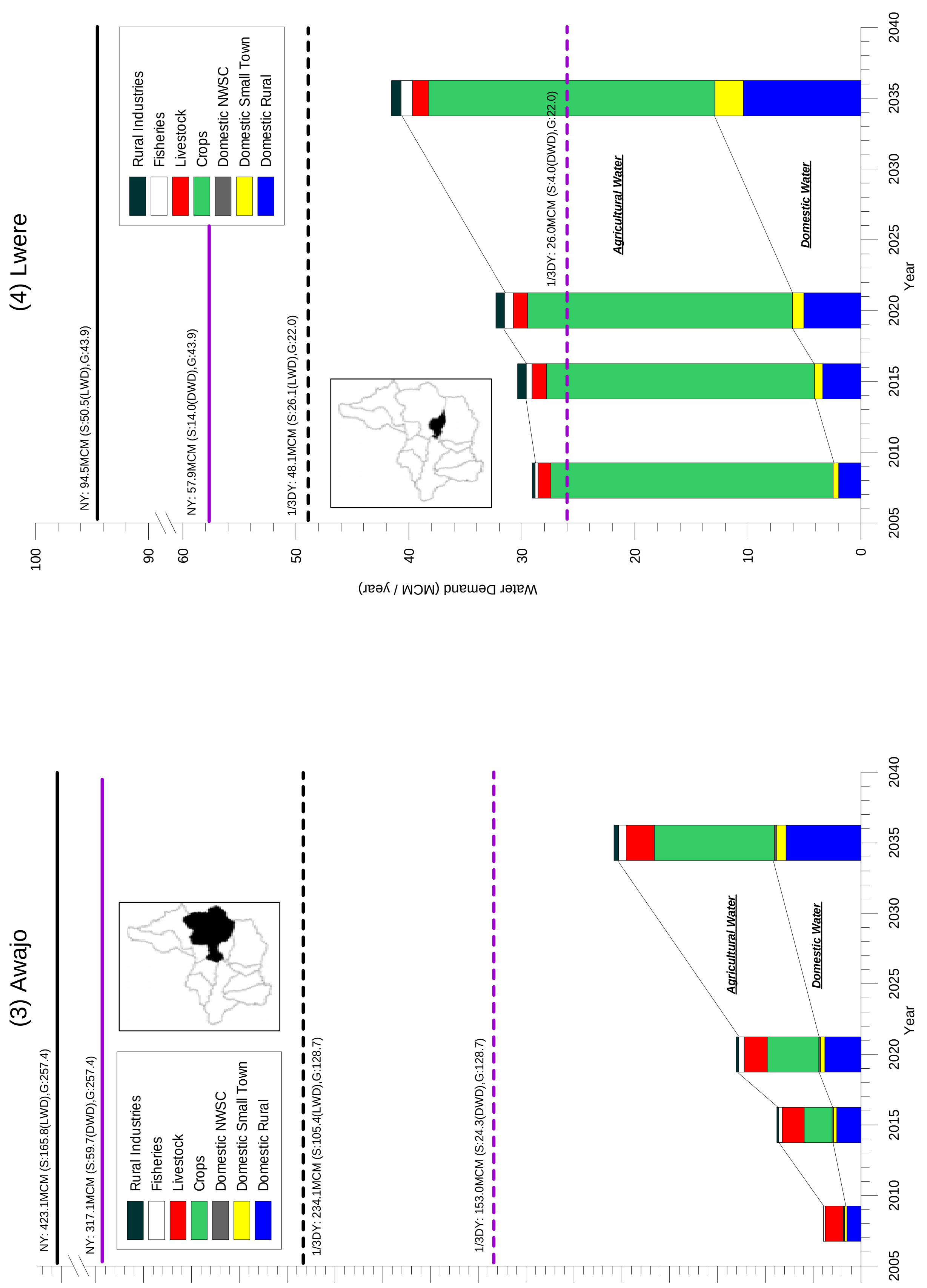


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (2)

(**NY**: normal year, **DY**: drought year, **LWD**: low water discharge, **DWD**: drought water discharge, **S**: surface water, **G**: groundwater)

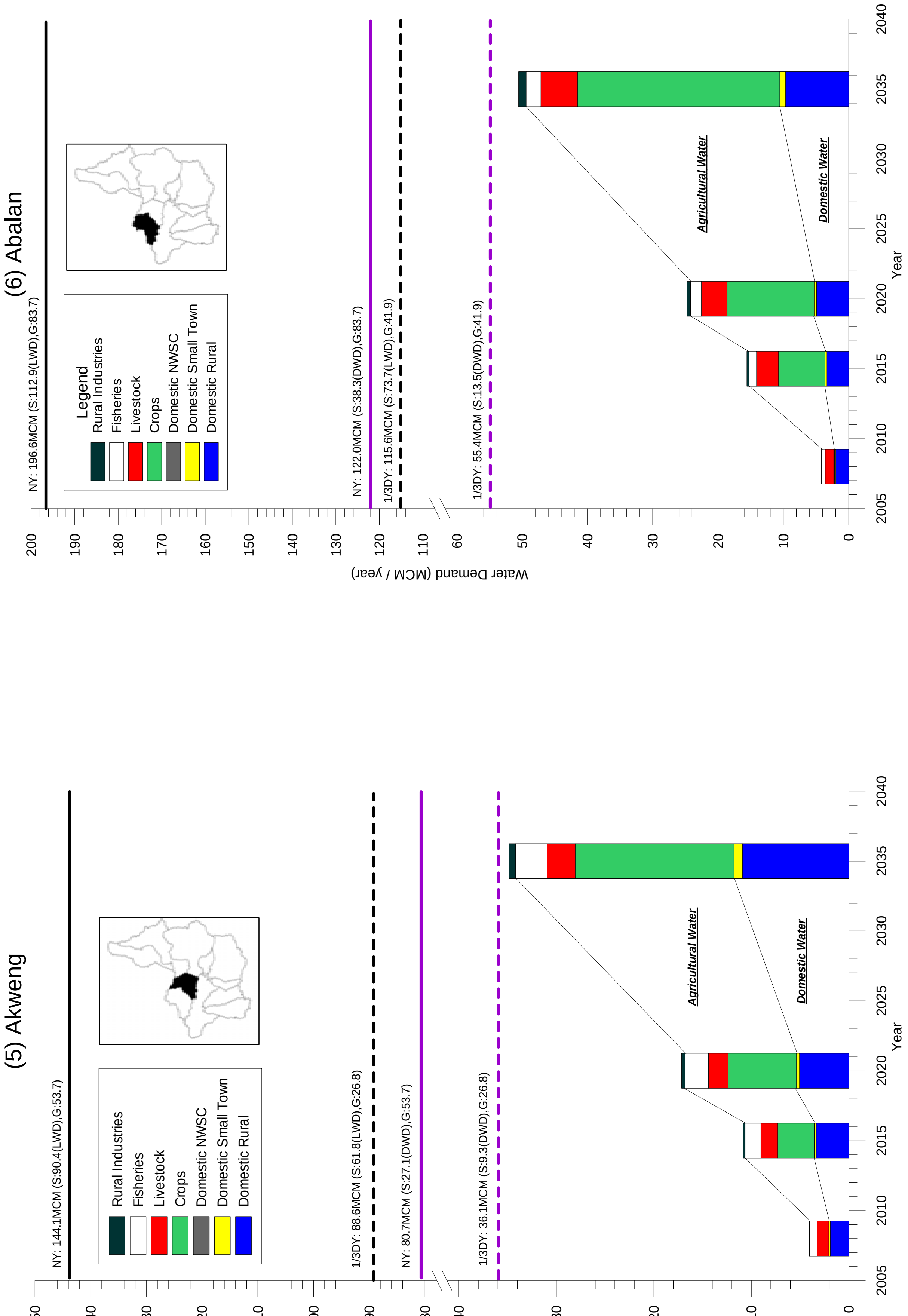


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (3)

(**NY**: normal year, **DY**: drought year, **LWD**: low water discharge,
DWD: drought water discharge, **S**: surface water, **G**: groundwater)

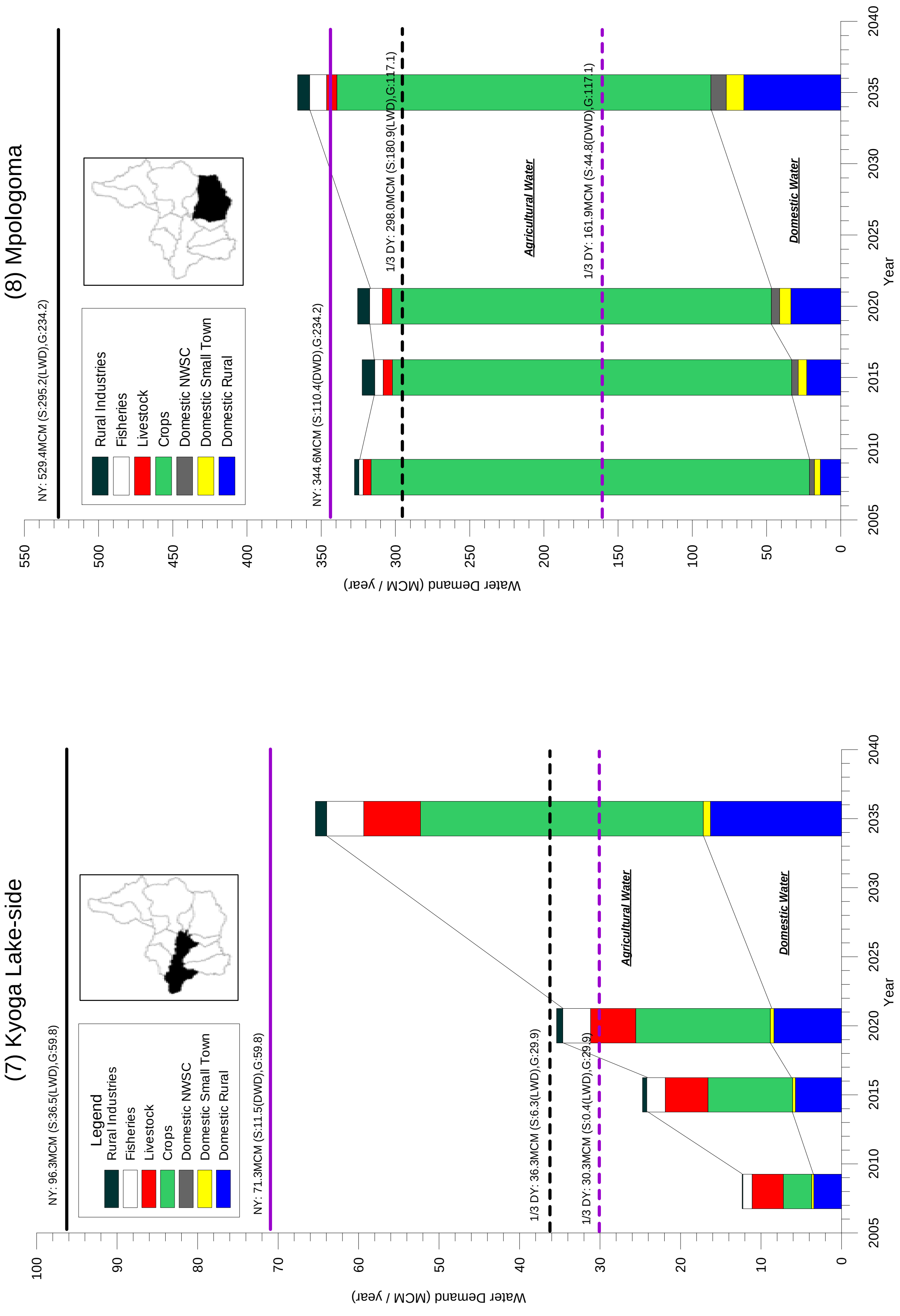


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (4)

(**NY**: normal year, **DY**: drought year, **LWD**: low water discharge,
DWD: drought water discharge, **S**: surface water, **G**: groundwater)

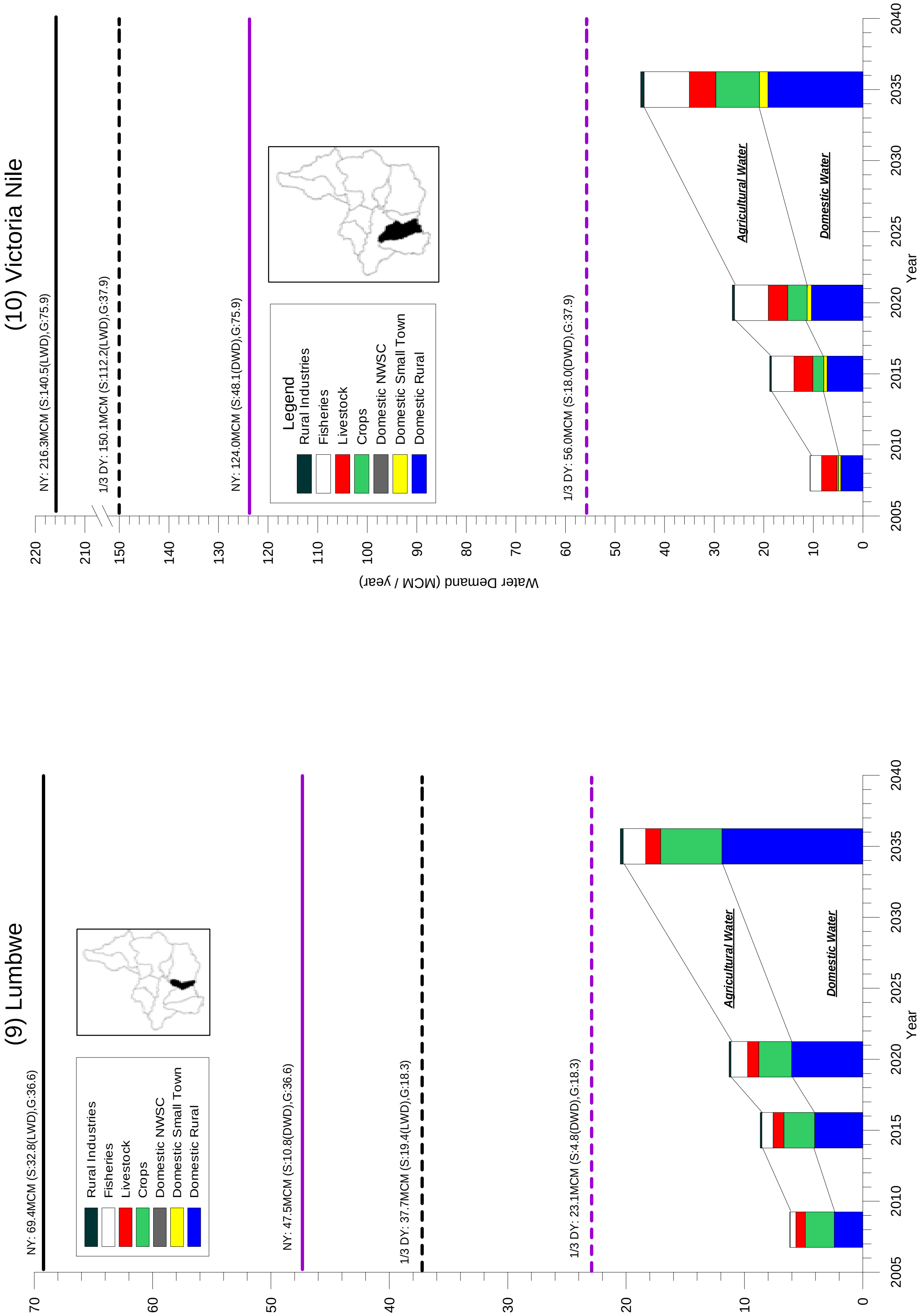


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (5)

(**NY**: normal year, **DY**: drought year, **LWD**: low water discharge, **DWD**: drought water discharge, **S**: surface water, **G**: groundwater)

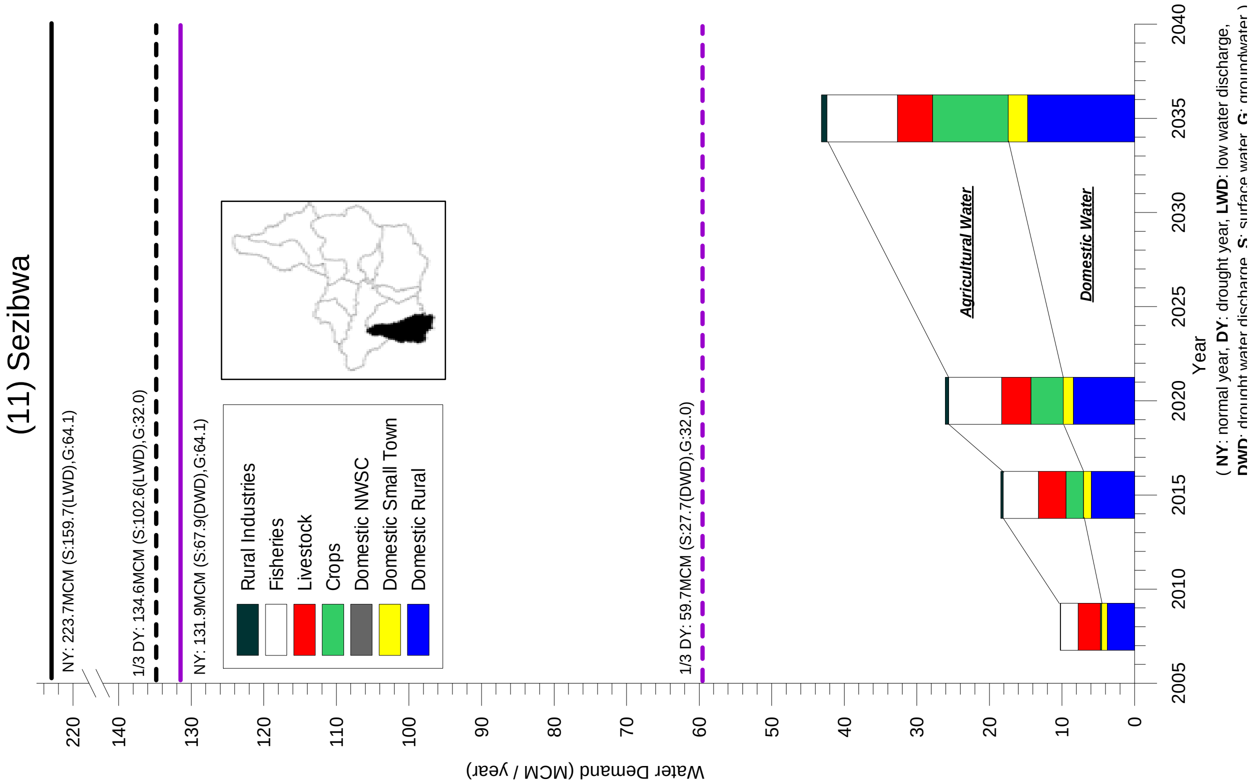


Figure 13-11 Trend of Water Demand and Exploitable Water Resources (6)

Table 13-9 Evaluation of Water Balance in Each Sector

Sub-basin Name	Water Demand (MCM/year)																Exploitable Water Resource (MCM/year)									
	2008				2015				2020				2035				Normal Year					1/3 Drought Year				
	Domestic Water	Agricultural Water	Industrial Water	Total	Domestic Water	Agricultural Water	Industrial Water	Total	Domestic Water	Agricultural Water	Industrial Water	Total	Domestic Water	Agricultural Water	Industrial Water	Total	Surface Water		GW	Total		Surface Water		GW	Total	
																	DWD	LWD		DWD	LWD	DWD	LWD		DWD	LWD
(1) Okok	1.7	5.9	0.1	7.7	3.1	9.1	0.3	12.4	4.7	11.1	0.3	16.1	9.3	16.8	0.5	26.7	1.7	11.4	18.5	**20.2**	**29.9**	0.4	5.9	9.3	**9.7**	**15.1**
(2) Okere	2.6	5.1	0.1	7.7	4.5	11.4	0.3	16.2	6.8	16.4	0.5	23.7	16.0	30.6	0.9	47.5	4.1	23.3	76.4	**80.5**	**99.7**	1.2	10.7	38.2	**39.4**	**48.8**
(3) Awoja	6.8	8.3	0.1	15.2	11.5	22.4	0.7	34.5	16.9	33.6	1.0	51.5	35.2	65.1	2.0	102.2	59.7	165.8	257.4	**317.1**	**423.1**	24.3	105.4	128.7	**153.0**	**234.1**
(4) Lwere	2.4	26.4	0.3	29.1	4.1	25.5	0.8	30.4	6.1	25.5	0.8	32.3	12.9	27.8	0.8	41.5	14.0	50.5	43.9	**57.9**	**94.5**	4.0	26.1	22.0	**26.0**	**48.1**
(5) Akweng	2.0	2.0	0.0	4.1	3.5	7.1	0.2	10.9	5.4	11.4	0.3	17.2	11.8	22.4	0.7	34.9	27.1	90.4	53.7	**80.7**	**144.1**	9.3	61.8	26.8	**36.1**	**88.6**
(6)Abalan	2.2	2.0	0.0	4.2	3.6	11.6	0.3	15.6	5.3	18.9	0.6	24.8	10.6	38.8	1.2	50.5	38.3	112.9	83.7	**122.0**	**196.6**	13.5	73.7	41.9	**55.4**	**115.6**
(7) Kyoga Lakeside Zone	3.7	8.5	0.1	12.3	6.1	18.1	0.5	24.7	8.9	25.8	0.8	35.4	17.2	46.8	1.4	65.4	11.5	36.5	59.8	**71.3**	**96.3**	0.4	6.3	29.9	**30.3**	**36.3**
(8) Mpologoma	17.8	303.5	3.0	324.3	28.6	280.9	8.4	317.9	41.1	270.7	8.1	319.9	77.2	270.3	8.1	355.6	110.4	295.2	234.2	**344.6**	**529.4**	44.8	180.9	117.1	**161.9**	**298.0**
(9) Lumbuye	2.4	3.7	0.0	6.2	4.1	4.5	0.1	8.7	6.0	5.1	0.2	11.3	11.9	8.3	0.3	20.5	10.8	32.8	36.6	**47.5**	**69.4**	4.8	19.4	18.3	**23.1**	**37.7**
(10) Victoria Nile	4.9	5.7	0.1	10.7	7.9	10.6	0.3	18.8	11.3	14.7	0.4	26.4	20.9	23.2	0.7	44.8	48.1	140.5	75.9	**124.0**	**216.3**	18.0	112.2	37.9	**56.0**	**150.1**
(11) Sezibwa	4.6	5.6	0.1	10.3	7.0	11.0	0.3	18.4	9.8	15.8	0.5	26.1	17.4	25.0	0.7	43.1	67.9	159.7	64.1	**131.9**	**223.7**	27.7	102.6	32.0	**59.7**	**134.6**
Total	51.2	376.8	3.8	431.7	84.0	412.1	12.4	508.5	122.2	448.9	13.5	584.5	240.2	575.2	17.3	832.7	393.6	1,118.9	1,004.2	**1,397.7**	**2,123.1**	148.4	705.0	502.1	**650.5**	**1,207.1**

Shortage of Water Resource   Marginal of Water Resource Coverage   **DWD**: drought water discharge, **LWD**: low water dicharge, **GW**:groundwater