Water and Sanitation Corporation (WASAC)
Republic of Rwanda

THE PROJECT FOR WATER SUPPLY MASTER PLAN FOR CITY OF KIGALI IN THE REPUBLIC OF RWANDA

FINAL REPORT (Pre-release Version)

VOLUME 2

Kigali Water Supply Master Plan

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Preface

The Final Report (F/R) of the Water Supply Master Plan for City of Kigali (KWSMP) consists of the following separated volumes, namely:

- Volume 1: Executive Summary
- Volume 2: Kigali Water Supply Master Plan
- Volume 3: Feasibility Study for the Project for Expansion of Karenge Water Supply System
- Volume 4: Feasibility Study for the Project for Construction of Masaka Water Supply System

This report is the “Volume 2: Kigali Water Supply Master Plan” of the F/R

THE PROJECT FOR WATER SUPPLY MASTER PLAN
FOR
CITY OF KIGALI
FINAL REPORT
Volume 2
Kigali Water Supply Master Plan

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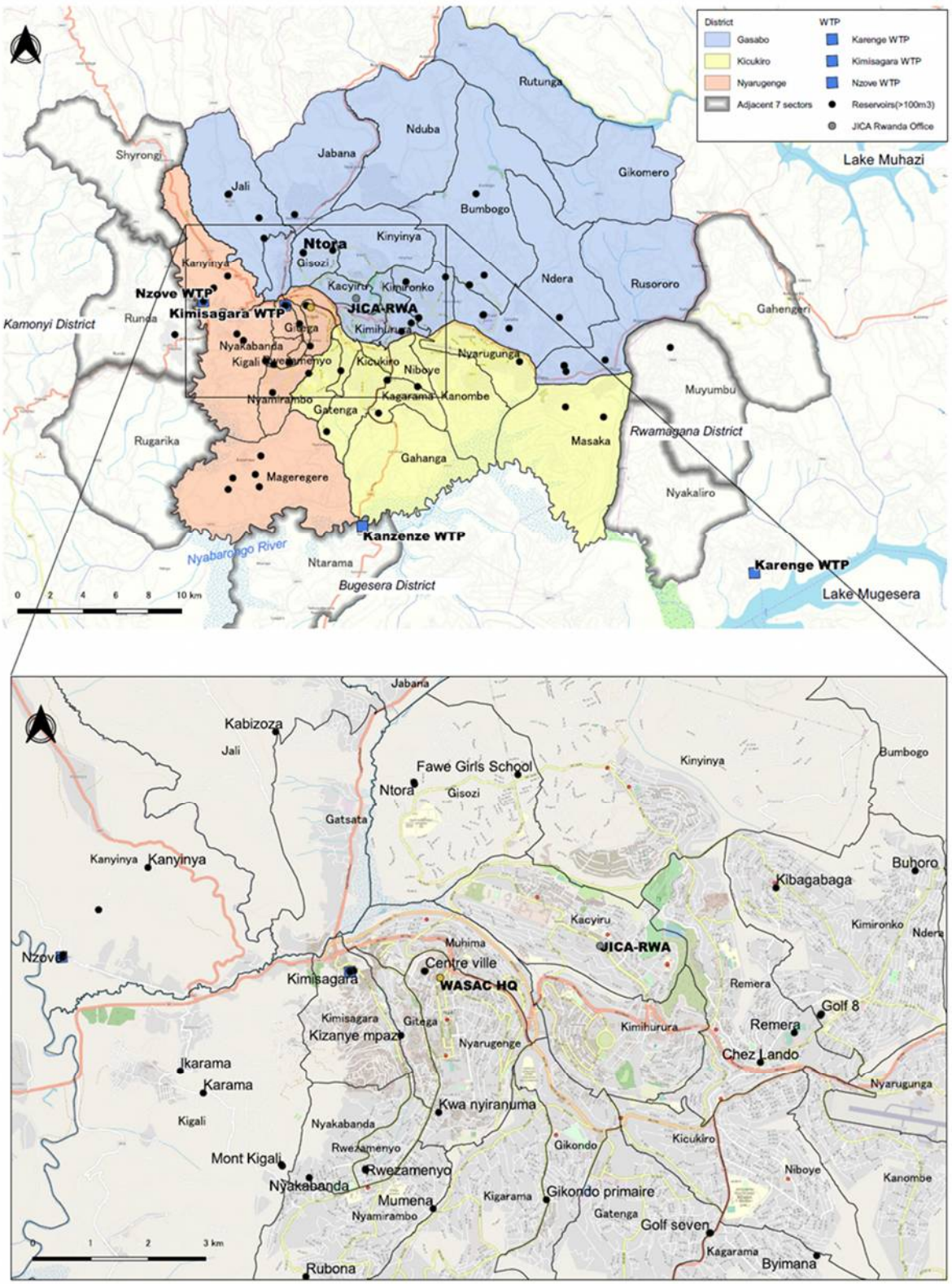
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Location Map



General Map of Kigali City Water Masterplan

Abbreviations

AfDB	African Development Bank
ATP	Affordability-To-Pay
BCP	Business Continuity Plan
BOT	Build-Operate Transfer
B/S	Balance Sheet
CACRO	Customer Account Collection and Recovery Operation
C/F	Cash Flow
CoK	City of Kigali
C/P	Counterpart
CW	Clear Water
DAF	Dissolved Air Floatation
DB	Design, Build
D/D	Detailed Design
DIP	Ductile Iron Pipe
DFID	Department for International Development
DF/R	Draft Final Report
DMA	District Metered Area
DPCG	Development Partners Coordination Group
EAC	East African Community
EDPRS	Economic Development and Poverty Reduction on Strategy
EIA	Environmental Impact Assessment
EICV	Fourth Integrated Household Living Conditions Survey
ESC	Environmental Social Consideration
F/R	Final Report
FRP	Fiber Reinforced Plastics
FS	Feasibility Study
FY	Fiscal Year
GDP	Gross Domestic Products
GOR	Government of Rwanda
Govt.	Government
GRDP	Gross Regional Domestic Products
HDPE	High-Density Polyethylene (Pipe)
HH	HouseHold
IC/R	Inception Report
IEE	Initial Environmental Examination
IFC	International Finance Corporation
IT/R	Interim Report
IWA	International Water Association
IWTR	International Water Treatment Rwanda
IWMP	Integrated Water Management Policy
IWRM	Integrated Water Resource Management
JCC	Joint Coordination Committee
JICA	Japan International Cooperation Agency
JST	JICA Study Team
JV	Joint Venture
KPI	Key Performance Indicator
MINALOC	Ministry of Local Government

MINEDUC	Ministry of Education
MININFRA	Ministry of Infrastructure
MINECOFIN	Ministry of Finance and Economic Planning
MoE	Ministry of Environment
MoH	Ministry of Health
MP (M/P)	Master Plan
MUSD	Million United States Dollars
NA	Not Applicable
NAPA	National Adaptation Programme of Action
NBS	National Biodiversity Strategy
ND (DN)	Nominal Diameter (Diamètre Nominal)
NGO	Non-Governmental Organization
NISR	National Institute of Statistic of Rwanda
NPV	Net Present Value
NR	National Road
NNYL	Lower Nyabarongo Catchment
NRW	Non-Revenue Water
NST	National Strategy for Transformation
NWSPIS	National Water Supply Policy Implementation on Strategy
O&M (OM)	Operation and Maintenance
OJT	On-the-Job Training
OMHRD	Operation and Maintenance, Human Resource Development
PBN	Project Brief Note
PBT	Pressure Break Tank
PC	Prestressed Concrete
PCM	Project Cycle Management
PG/R	Progress Report
PHC	Population and Housing Census
P/L	Profit and loss
PM	Planning Management
PPP	Public Private Partnerships
PR	Public Relations
PRV	Pressure Reduce Valves
PS	Permanent Secretary
PVC	Polyvinyl Chloride (Pipe)
QC	Quality Control
RC	Reinforced Concrete
RDB	Rwanda Development Board
RLMUA	Rwanda Land Management and Use Authority
RSB	Rwanda Standards Board
RTD	Reservoir, Transmission / Distribution
RURA	Rwanda Utilities Regulatory Authority
REMA	Rwanda Environment Management Authority
RW	Raw Water
RWF	Rwanda Franc
RWFA	Rwanda Water and Forestry Authority
SCADA	Supervisory Control and Data Acquisition
SEA	Strategic Environmental Assessment
SEZ	Special Economic Zone
SEZAR	Special Economic Zones Authority of Rwanda

SDGs	Sustainable Development Goals
SGP	Steel Galvanized Pipe
SHM	Stakeholder Meeting
SP	Steel Pipe
TBD	To be Determined
TBS	To be Scheduled
TOR	Terms of Reference
TSFI	Tariff System and Financial Improvement
UNICEF	United Nation Children Fund
USD	United States Dollar
UWSSD	Urban Water and Sewerage Services Department
WASAC	Water and Sanitation Cooperation
WASH	Water, Sanitation and Hygiene
WHO	World Health Organization
WRD	Water Resources Development
WTP	Water Treatment Plant
WSA	Water Supply Area

CoK M/P	City of Kigali Master Plan
AfDB M/P	National Water Supply and Sanitation Master Plan by AfDB
KWSMP	Kigali Water Supply Master Plan

CHAPTER 1 INTRODUCTION

1.1 INTRODUCTION

The Republic of Rwanda has made significant efforts to increase water coverage over the past few years and has committed to providing 100% coverage by the year 2024, thereby ensuring universal and equitable access to safe and affordable drinking water for the people aimed at achieving the Sustainable Development Goals (SDGs).

Urbanization is the emerging trend in the country including the City of Kigali (hereinafter referred to as "CoK"), the capital city. It was anticipated that the population of the CoK would increase rapidly from around 1.1 million in 2012 to 3.8 million in 2050 due to the large migration from rural areas. The City of Kigali Master Plan (CoK M/P), which has been finalized by 2020, adopts the city's actual development trends. In addition, seven sectors adjacent to the CoK, namely Shyorongi, Runda, Rugarika, Ntarama, Muyumbu, Gahengeri and Nyakaliro, are being developed rapidly as mainly residential purposes due to availability of land with lower cost compared to those within the city.

According to the Fifth Integrated Household Living Conditions Survey (EICV5, 2016/1017) carried out in the country, the coverage of water supply in the CoK is 87%. Meanwhile, the big challenges that lie ahead in the future for the CoK and its adjacent seven sectors (the Study Area) pertain to catching up with the emerging demand due to the rapid-growing population in this area and to improve the quality of the water supply to a satisfactory level for the users. For example, insufficient water production, a large volume of water leakages that brings about intermittent water supply in some areas, and the deterioration of water sources that provoke a greater burden on water production. In an estimate, the non-revenue water (NRW) ratio is 38.8% (2018) in the CoK.

The Water Supply and Sanitation Corporation (WASAC) has the responsibility for providing water and sanitation in Rwanda. As for the Study Area, there are three main water treatment plants and more than 4,000 km of pipelines that need to be operated and maintained. One of the most important geographic features of the CoK is large elevation differences. The existing facilities were developed incrementally to catch up with the social demand. However, they still have plenty of room for improvement and meeting challenges. For instance, the present water supply system in the Study Area was developed without a comprehensive water supply plan and design criteria; therefore, a comprehensive plan is awaited for a long time duly considering various aspects including:

- The fact that the current distribution system, which lacks proper zoning arrangement according to the difference of elevation, forces WASAC to face difficulties while managing water distribution pressure adequately.
- The operation of some water reservoirs is unstable, and water cannot reach certain areas within the Study Area.
- The current water supply facilities have too complicated networks that cause difficulty in operation

and maintenance.
- There is also a concern that the Study Area may face insufficient supply capacity due to the rapid increase in water demand in the near future.

Under these circumstances, it is indispensable for WASAC to have one comprehensive master plan for the improvement of the existing water supply facilities and new facilities in a more efficient and effective manner in order to meet the rapid increase of water demand in the CoK. Therefore, WASAC officially requested JICA to support in the development of the Water Supply Master Plan for the CoK and its seven adjacent sectors (KWSMP).

In November 2018, JICA announced the implementation of the study to prepare the KWSMP and Japanese consultants a joint venture of Nihon Suido Consultants in association with Yachiyo Engineering, were selected as the JICA Study Team (JST) for preparation of the KWSMP. The JST commenced the Study work from March 5, 2019.

This Final Report (F/R) was prepared to finalize the Study since the commencement of the Study in March 2019 to September 2021, which includes the followings;
- KWSMP that was discussed and agreed at the JCC held in November 2020, with incorporating comments raised at the discussion with Ministers of MININFRA/ MINALOC/ MINECOFIN, and other concerned representatives including City of Kigali/ RWB/ RDB/ RURA/ Ministry of Environment/ Districts concerned.
- Feasibility Study (F/S) for the Project for Expansion of Karenge Water Supply System
- F/S for the Project for the Construction of Masaka Water Supply System

After the JCC of the DF/R in the latter half of August 2021, the JST has finalized it with incorporating comments raised by the JCC members by the middle of September to develop the Final Report (F/R) of the Study by the end of September 2021. The F/R has been submitted to JICA and it is shared with WASAC through JICA.

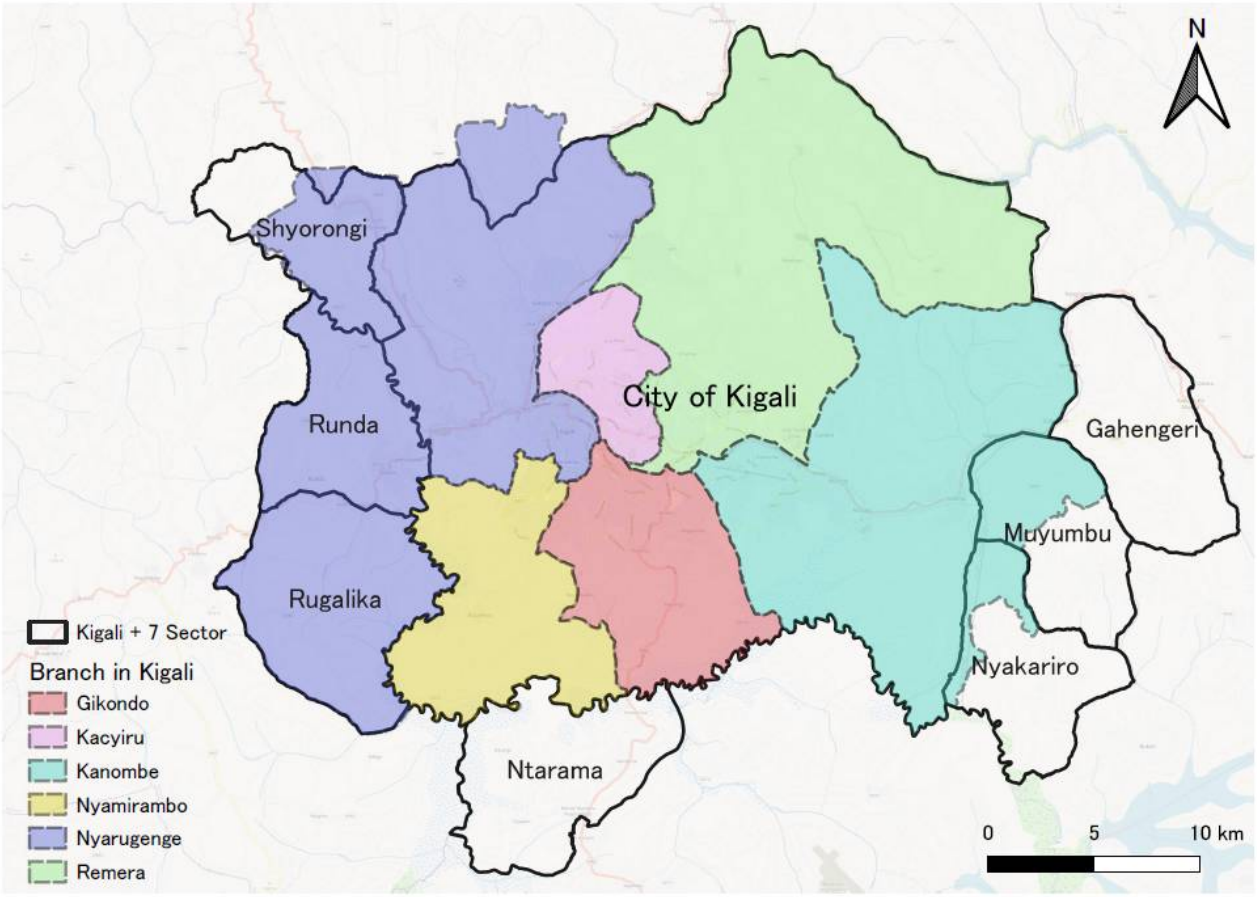
1.2 OBJECTIVE OF THE STUDY

The objectives of the study are as follows:
1. To develop the Water Supply Master Plan for the CoK and the seven adjacent sectors (KWSMP, which consists of the Master Scenario until 2050 and the 15-Year Investment Plan)
2. To conduct a feasibility study on the priority project(s) identified under the KWSMP
3. To pursue technology transfer to the counterpart personnel during the course of the Study.

1.3 STUDY AREA

The Study Area, that is the target area of the KWSMP covers the City of Kigali and its seven adjacent sectors, i.e., Shyorongi, Runda, Rugarika, Ntarama, Muyumbu, Gahengeri, and Nyakaliro. which are the

existing water supply area of 6 WASAC branches. The target area of the Masterplan is shown in **Figure 1.3-1**. The sectors covered by the 6 branches are listed in **Table 1.3-1**.



Source: JST

Figure 1.3-1 Study Area

Table 1.3-1 List of Branches and their Covered Area

WASAC Branch Name	District	Covered Sectors	Partially Covered Sectors
Kacyiru	Gasabo	Gisozi, Kacyiru, Kimihurura	Kinyinya
Remera	Gasabo, Kicukiro	Bumbogo, Gikomero, Kimironko, Nduba, Remera, Rutunga	Kinyinya, Ndera, Kicukiro, Niboye
Gikondo	Kicukiro	Gahanga, Gatenga, Gikondo, Kagarama, Kicukiro, Kigarama, Niboye	Mageregere
Nyamirambo	Nyarugenge	Mageregere, Nyakabanda, Nyamirambo, Rwezamenyo	Kigali, Kimisagara
Kanombe	Gasabo, Kicukiro, Rwamagana	Ndera, Rusororo, Kanombe, Masaka, Nyarugunga	Muyumbu, Nyakariro
Nyarugenge	Nyarugenge, Gasabo, Kamonyi, Rulindo	Gitega, Kanyinya, Kimisagara, Muhima, Nyarugenge, Gatsata, Jabana, Jali, Rugalika, Runda	Kigali, Shyorongi

Source: JST

1.4 EXPECTED OUTPUTS OF THE STUDY

Expected outputs of this study are as follows;

Output 1: Current conditions of existing water supply facilities and water supply services in the project site are assessed.

Output 2: Water demand in the project site is forecasted, and the water source utilization plan is developed.

Output 3: KWSMP is developed.

Output 4: Prioritized projects are identified from the 15-Year Investment Plan, and their feasibility studies are conducted.

Output 5: Capacity of WASAC's staff about water supply planning is strengthened.

CHAPTER 2 PROCEDURES OF THE STUDY

2.1 GENERAL

In the course of the Study, Progress Reports (PG/R) and Interim Report (IT/R) were prepared and submitted to WASAC. Then, Masterplan Report (MP/R) was prepared based on the contents of these past reports which were accepted by WASAC. The major contents of the individual reports are listed as below.

- Progress Report (PG/R), July 2019 (see **Appendix-1** for the minutes of the meeting (M/M) of its JCC meeting and **Appendix-2** for the M/M of its stakeholder meeting (SHM))
  - General features of the study area
  - Government and related development plans
  - Condition of the existing water supply system
  - On-going projects
  - Capacity development
  - Framework of the Masterplan

- Interim Report (IT/R), February 2020 (see **Appendix-3** for the M/M of its JCC[1])
  - General features of the study area (updated from PG/R)
  - Government and related development plans (updated from PG/R)
  - Condition of existing water supply systems (updated from PG/R)
  - Financial situation of WASAC
  - On-going projects (updated from PG/R)
  - Capacity development (updated from PG/R)
  - Framework of the Masterplan (updated from PG/R)
  - Water resources development plan
  - Socio-economic survey
  - Strategic environment assessment (SEA)
  - Master scenario
  - Candidate project for investment plan

- Masterplan Report (MP/R), September 2020 (See **Appendix-4** for the M/M of its JCC held in November 2020 and **Appendix-5** for the M/M of its SHM in August 2021.)
  - General features of the study area (updated/summarized from IT/R)
  - Future population and water demand (updated from IT/R)
  - Water supply visions towards 2050 (updated from IT/R)
  - Principles on 15-year investment plan
  - Master scenario towards 2050 (updated from IT/R)
  - 15-Year Investment Plan

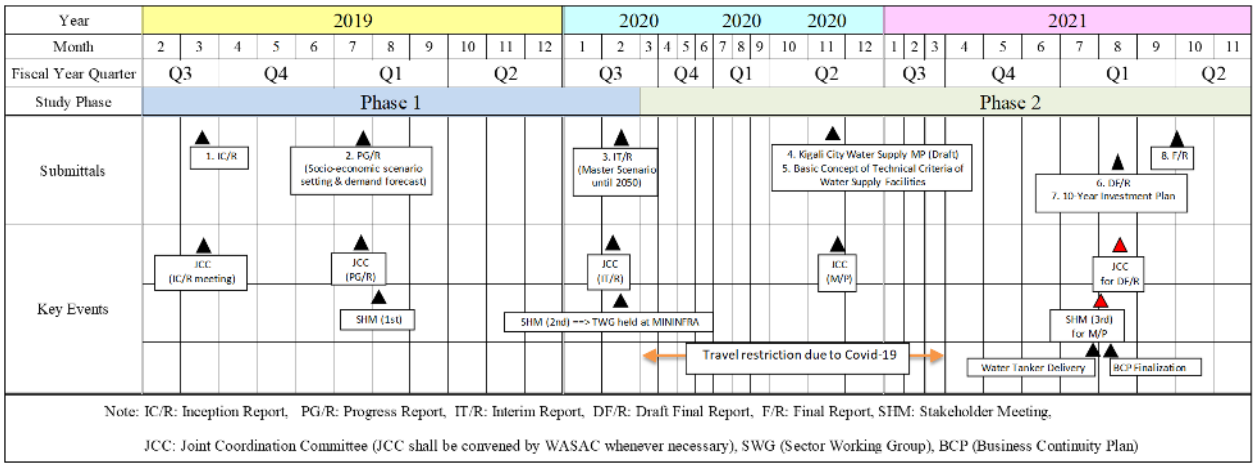
[1] SHM for ITR was canceled due to the WASAC's decision. Instead, a Thematic Working Group meeting was held in February 2020 chaired by MININFRA with presence of JICA Rwanda Office.

- ➢ Economic evaluation and financial condition of the plan
- ➢ Strategies for implementation
- ➢ Recommendations

- Draft Final Report (DF/R), August 2021 (this Report) (see **Appendix-6** for the M/M of its JCC)
  - ➢ The contents included in the IT/R and MP/R (updated to incorporate revision/new information after MP/R)
  - ➢ Feasibility Study (F/S) for Expansion of Karenge Water Supply System
  - ➢ F/S for Construction of Masaka Water Supply System

After the JCC for the DF/R, the JST will wrap up all the activity in Rwanda and will go back to Japan in the beginning of September 2021. Then the JST will wait for the comments of the Rwandan side until the middle of September and compile the Final Report (F/R) with reflecting the comments by the beginning of October 2021. After then, the F/R will be submitted to JICA and it will be shared to WASAC through JICA.

The overall schedule of the Study is as shown in **Figure 2.1-1**.



Source: JST

Figure 2.1-1 Study Schedule and Current Time-Basis Location

2.2 HISTORY OF THE STUDY IN BRIEF

Following are the history and background of the processes for developing the Masterplan:

- December 2017: In response to WASAC's official requested to the JICA for developing the Kigali Water Supply Masterplan, Records of Discussion were exchanged between the JICA and WASAC.
- March 2019: The study to develop the Masterplan was commenced. Kickoff meeting (Inception meeting) with Rwandan side was held.
- July 2019: A Joint Coordinating Committee (JCC) meeting was held to discuss on the contents of the Progress Report that covered the socio-economic framework including the water demand projection,

which were the basis for determining the Master Scenario 2050.

- August 2019: Stakeholder meeting (SHM) was held to share the above contents with the concerned stakeholders.
- October 2019: Discussion on the priority projects with WASAC's executives was held.
- February 2020:
  - JCC meeting was held to discuss on the content of the IT/R that covered the Master Scenario toward 2050 and to finalize the same. At this JCC meeting, several comments were raised including that the Water Resource Development Plan should include water balance study in the Study Area. The comments that were raised at the JCC meeting are shown in the **Appendix-3**, and the result of water balance study is presented as **Appendix-7**.
  - Thematic Working Group (TWG) was held and hosted by MININFRA to disseminate the content of the IT/R to the concerned organizations.
- June/July/August 2020: "Minutes of Meeting Concerning Covid-19 Response within the Framework of the Project for Water Supply Master Plan for City of Kigali and the Project for Strengthening Non-Revenue Water Control in Kigali City Water Network" were agreed between WASAC and JICA. As shown on the minutes, it was decided that a business continuity plan (BCP) for WASAC has been jointly prepared by WASAC's taskforce members for the BCP activities and the JST as a part of the Study activities. This activity involved not only for preparation of the BCP but also the procurement of a water tanker as well as an activity related to developing operation plan of the procured tanker (see **Appendix-30**).
- November 2021: On-line JCC meeting was held to discuss the content of the Kigali Water Supply Masterplan that includes 15-Year Investment Plan as well as the "Basic Technical Criteria of Waterworks Facility in Rwanda (see **Appendix-31**)". Its minutes of meeting is presented in **Appendix-4**.
- May 2021: On-line meeting was convened by the Minister of the MININFRA to discuss and disseminate the content of the 15-Year Investment Plan and the priority projects listed in it to the concerned ministers and other government organizations.
- August 2021:
  - JCC for the DF/R including F/Ss
  - Stakeholder meeting to disseminate the content of the Kigali Water Supply Masterplan and its 15-Year Investment Plan to the stakeholder members.
- September 2021:
  - Delivery of the water tanker that is donated by JICA under the BCP activities of the Study.

2.3 WORKING TEAM, JCC AND STAKEHOLDERS

The KWSMP has been prepared through collaborative work by JST, creating working teams according to the field of specialties as shown in **Table 2.3-1**, with reflecting decision and directions given by the members of the JCC as shown in **Table 2.3-2** as well as the comments given by the concerned stakeholders including representatives from the regional government office who can be regarded as the representative of

the users in its respective area and mass media who can widely distribute information related to the WASAC/JICA M/P to general public as listed in **Table 2.3-3**.

Table 2.3-1 List of Working Team

Working Team	
PM Team:	Planning Management
WRD Team:	Water Resource Development
WTP Team:	Water Treatment Plant
RTD Team:	Reservoirs, Transmission/Distribution
ESC Team:	Environment and Social Consideration
TSFI Team:	Tariff System and Financial Improvement
OMHRD Team:	Operation and Maintenance, Human Resource Development

Source: JST

Table 2.3-2 List of JCC Members

Category	Organization
Project Team	Management of WASAC including CEO as Project Director,
	Director of UWSS as Project Manager,
	Personnel from Counterpart team
	Members from JICA Study Team
Japanese Side	Embassy of Japan
	JICA Rwanda Representative
	JICA Tokyo Head Office
Rwandan Side	MININFRA
	MINECOFIN (joined after the Study had begun)
	Ministry of Environment
	REMA
	RWFA
	RURA
	RTDA
	REG
	Kigali City
	AfDB
	Districts of Bugesera, Gasabo, Kamonyi, Kicukiro, Nyarugenge, Rulindo, and Rwamagana

Source: JST

Table 2.3-3 List of Stakeholders

Organization
JCC members
Rwanda Housing Authority
University of Rwanda, School of Science & Technology
Local Administrative Entities Development Agency (LODA)
Institution of Engineers Rwanda
NGOs: Water Aid, Water for People
Development Partners
MINECOFIN
Rwanda Development Board (RDB)

Source: JST

CHAPTER 3 GENERAL FEATURES OF THE STUDY AREA

3.1 EXISTING CONDITIONS

3.1.1 Location

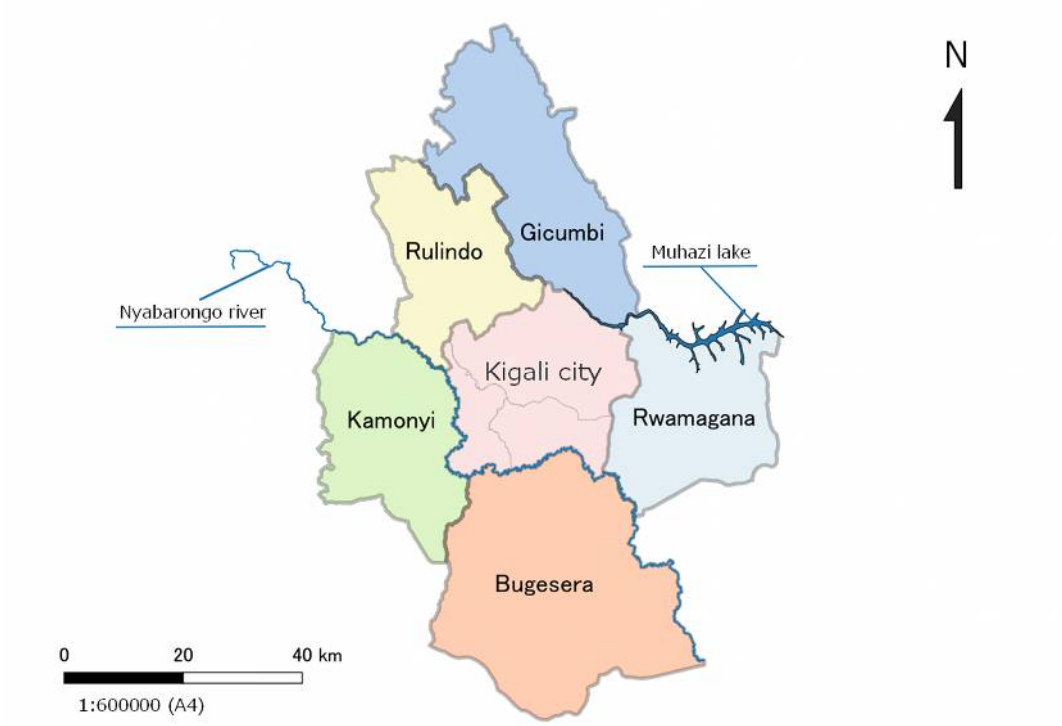
The CoK is the national capital city and is located in the center of the country covering an area of 730 km^2 as shown in **Figure 3.1-1**.



Source: JST

Figure 3.1-1 Area of CoK and Rwanda

Figure 3.1-2 shows the geographical relationships between the CoK and the surrounding districts. The CoK is bordered by Rulindo and Gicumbi districts to the north, Rwamagana district to the east, Bugesera district to the south, and Kamonyi district to the west. The city is also located between Nyabarongo River in the southwest and Muhazi Lake in the northeast.



Source: JST

Figure 3.1-2 CoK and the Surrounding Districts

The CoK is a hilly area having extreme vertical difference of over 200 m. There are hill-tops where many houses and buildings exist to lower areas where there are water sources including rivers and wells.

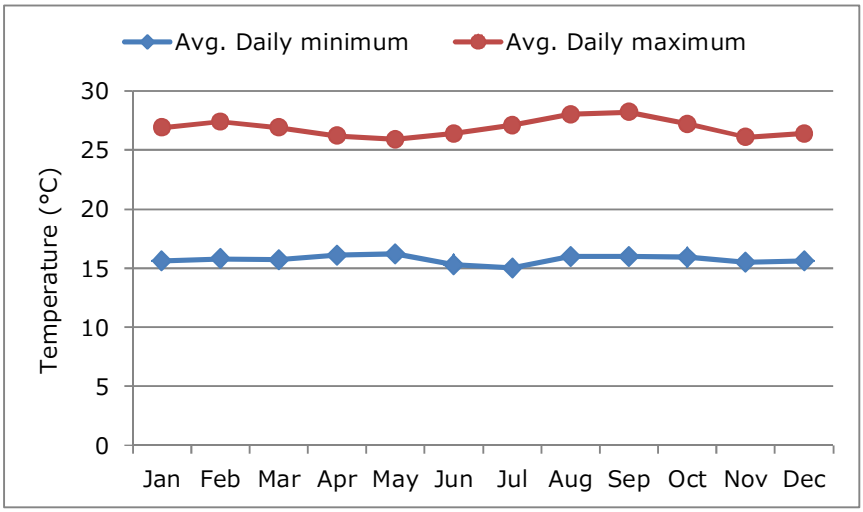
3.1.2 Climate

The CoK has a temperate tropical climate with lower temperatures though the country lies a few degrees south of the equator due to its high altitude (1,433 m–1,645 m). The seasons experienced in the city comprise of the small dry season (Jan–Feb), large rainy season (Mar-May), large dry season (Jun–Sep) and small rainy season (Oct–Dec). The monthly temperature (maximum and minimum), the monthly rainfall and rainy days of CoK are shown in **Table 3.1-1**, **Figure 3.1-3** and **Figure 3.1-4**.

Table 3.1-1 Monthly Temperature, Monthly Rainfall and Rainy Days of CoK

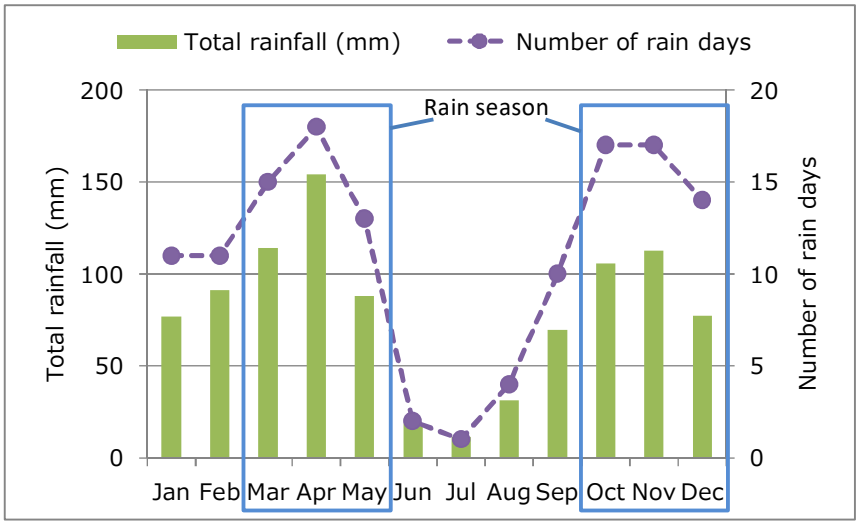
Month	Temperature (°C)		Total rainfall (mm)	Number of rainy days	Season
	Avg. Daily minimum	Avg. Daily maximum			
Jan	15.6	26.9	76.9	11	Small dry season
Feb	15.8	27.4	91	11	
Mar	15.7	26.9	114.2	15	Large rain season
Apr	16.1	26.2	154.2	18	
May	16.2	25.9	88.1	13	
Jun	15.3	26.4	18.6	2	Large dry season
Jul	15	27.1	11.4	1	
Aug	16	28	31.1	4	
Sep	16	28.2	69.6	10	
Oct	15.9	27.2	105.7	17	Small rain season
Nov	15.5	26.1	112.7	17	
Dec	15.6	26.4	77.4	14	
Ave	15.7	26.9	79.2	11.1	

Source: Kigali State Environment and Outlook Report 2013



Source: Kigali State Environment and Outlook Report 2013

Figure 3.1-3 Temperature of Daily Minimum and Maximum of CoK



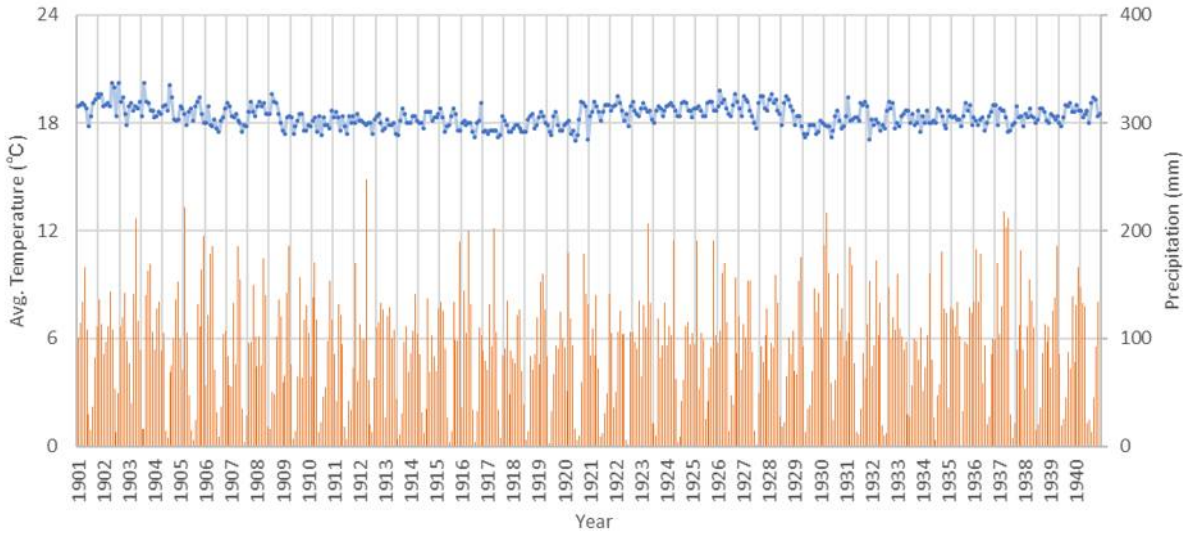
Source: Kigali State Environment and Outlook Report 2013

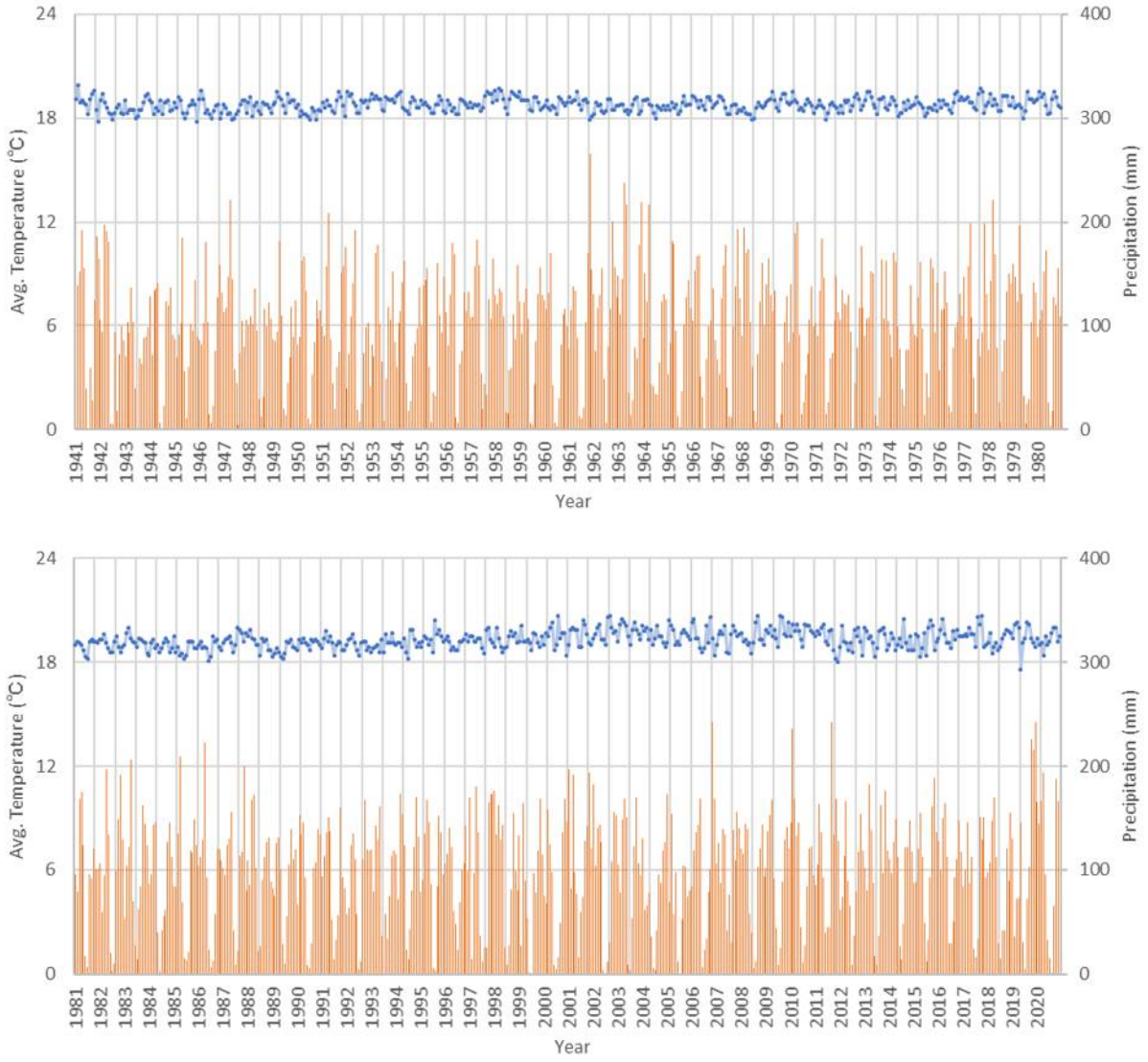
Figure 3.1-4 Total Rainfall and Number of Rain Days of CoK

Figure 3.1-5 shows monthly total rainfall and the average temperature of the CoK from 1901 to 2016. The findings from this data are as follows;

- frequency of occurrence of more than 200 mm of monthly total rainfall is increasing during the last 10 years
- the average temperature is also increasing over the same period (shown in **Table 3.1-2**)

Table 3.1-3 shows drought events observed in Rwanda from 1910 to 2016. The country has experienced drought after every few years especially in the Eastern, Southern provinces. The drought in 1910, 2003 and 2006 affected more than 1,000,000 persons.





Source: based on the data of World Bank Group / Climate Change Knowledge Portal

(https://climateknowledgeportal.worldbank.org/download-data)

Figure 3.1-5 Monthly Total Rainfall and Average Temperature of Rwanda from 1901 to 2020

Table 3.1-2 Average Temperature in Rwanda

Year	Avg. temperature (°C)
1901-1930	18.4
1931-1960	18.6
1961-1990	18.9
1991-2020	19.4

Source: based on the data of World Bank Group / Climate Change Knowledge Portal

(https://climateknowledgeportal.worldbank.org/download-data)

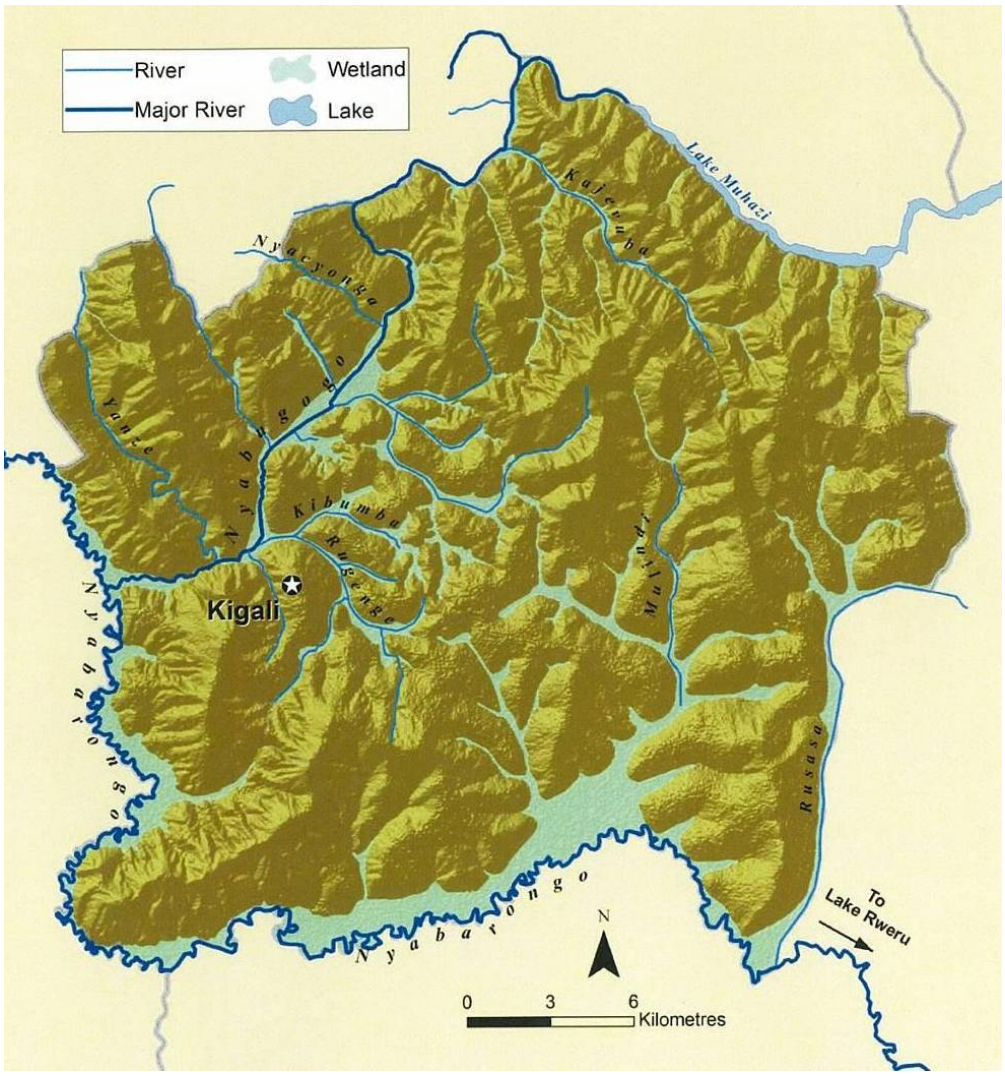
Table 3.1-3 Major Recent Drought Events in Rwanda

Year	Affected zone	Death	Affected population
1910	Kibungo / Zaza (EP)	0	1,700,000
1976-1977	National	0	420,000
1984	National	0	60,000
1989	Gikongoro, Gitarama and Butare (SP)	237	82,000
1996	Gikongoro (SP)	0	894,545
1999- Early 2000	Umutara, Kibungo (EP), Kigali (Central), Gitarama, Butare and Gikongoro (SP)	0	267,000
2003	Kigali rural, Gashora, Bugesera, Kibungo, Umutara (EP), Butare Gikongogo and Gitarama (SP)	0	1,000,000
2005	National	-	-
2006	Kibungo, Umutara and Bugesera (EP), Butare, Gikongogo and Gitarama (SP)	0	1,011,200
2014	Bugesera and Kayonza (EP)	-	-
2016*	Kayonza, Kirehe and Nyagatare (EP)	-	44,000

Source:
Third National Communication under the United Nations Framework Convention on Climate Change (U.N.F.C.C.C)
*WFP operation database.
Note: EP = Eastern Province, SP = Southern Province

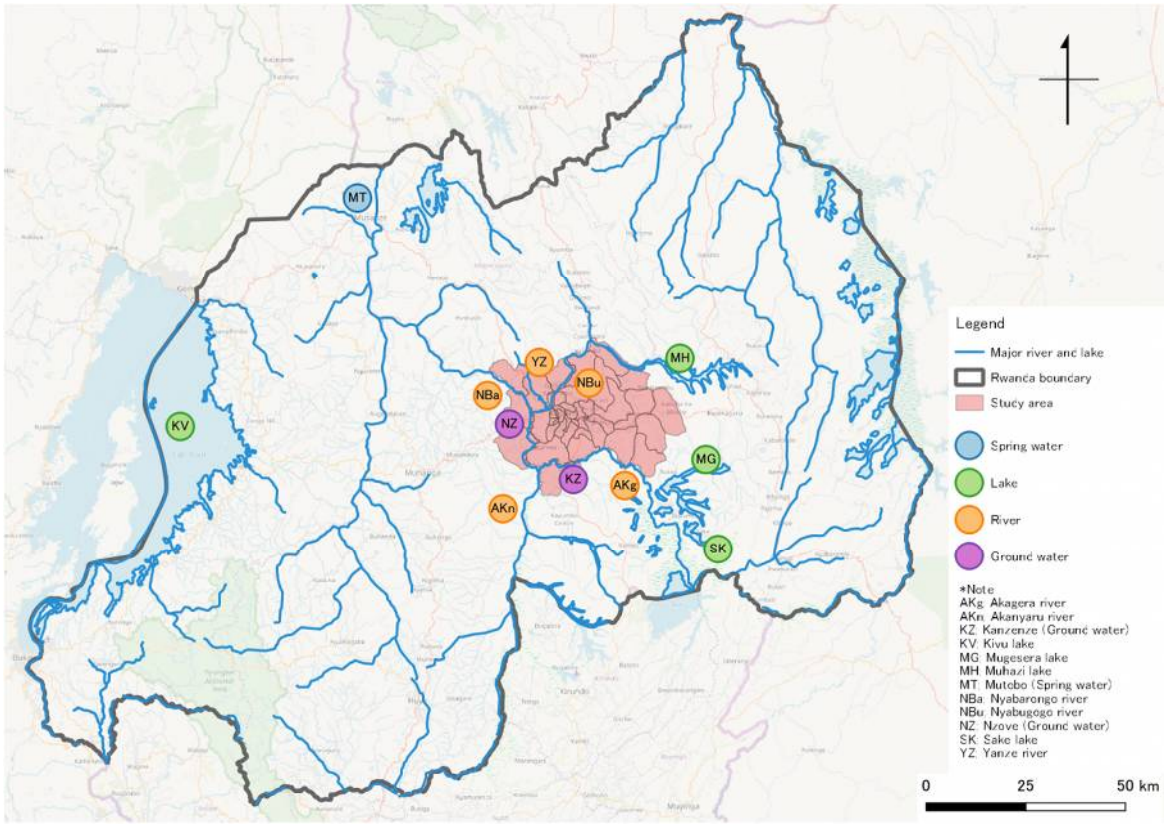
3.1.3 Major River and Lake and Other Water Source in the Study

Nyabarongo River is the major river of the CoK and is the main watercourse running from northwest to southeast of the city. Nyabugogo River crosses the northern part of the city from Muhazi Lake which is a major lake located in the northeast of the city. Nyabugogo River joins to Nyabarongo River at the most westerly point of the city. The network of rivers and wetlands are shown in **Figure 3.1-6**. **Figure 3.1-7** shows the locations of major rivers, lakes, groundwater and spring water in the Study Area.



Source: Kigali State Environment and Outlook Report 2013

Figure 3.1-6 Network of Rivers and Wetlands in CoK



Source: JST

Figure 3.1-7: Major Rivers, Lakes and Other Water Sources in the Study Area

3.1.4 Administrative Units

The Republic of Rwanda is divided into 5 tiers of administrative units, namely: 1) Province, 2) District, 3) Sector, 4) Cell and 5) Village. The responsibilities of each unit are presented in **Table 3.1-4**.

Table 3.1-4 Responsibilities of Each Administrative Unit

Administrative Units	Responsibilities and Functions
1) Province	• Serves as a coordinating organ to ensure the efficiency and effectiveness of Central Government planning, execution and supervision of the decentralized services. • The Provincial Coordination Committee (PCC) is the decision making organ. The PCC is composed of the Governor, the Permanent Secretary, the Chairperson of Councils of District, the Coordinators of Departments in Province and the Heads of decentralized services at Province.
2) District	• District is the basic political-administrative unit of the country under the Province to accomplish its political, administrative, social economic affairs and cultural duties determined by law. • The district is governed by the District Council, the Executive Committee and the Security Committee. • The District Council is composed of councilors elected at the Sector level and so on; each Sector is represented by one councilor.
3) Sector	• Sector is the third level of administration, where people participate through their elected representatives called a counselor. • The Sector Council is a political organ for policy-making decisions, including approval of Sector action plans and programs and ensuring the follow-up of the implementation.

4) Cell	• All residents in the Cell aged above 18 are members of the Cell Council, which identifies, discusses and prioritizes the problems of the Cell, and takes decisions for the resolution. • The organ is managed by competent technicians who handle and address these technical and political matters.
5) Village	• Village is the smallest organ and closest to the resident. The leaders are volunteers elected. • The organ identifies the problems, priorities and needs of the people at a grassroots level.

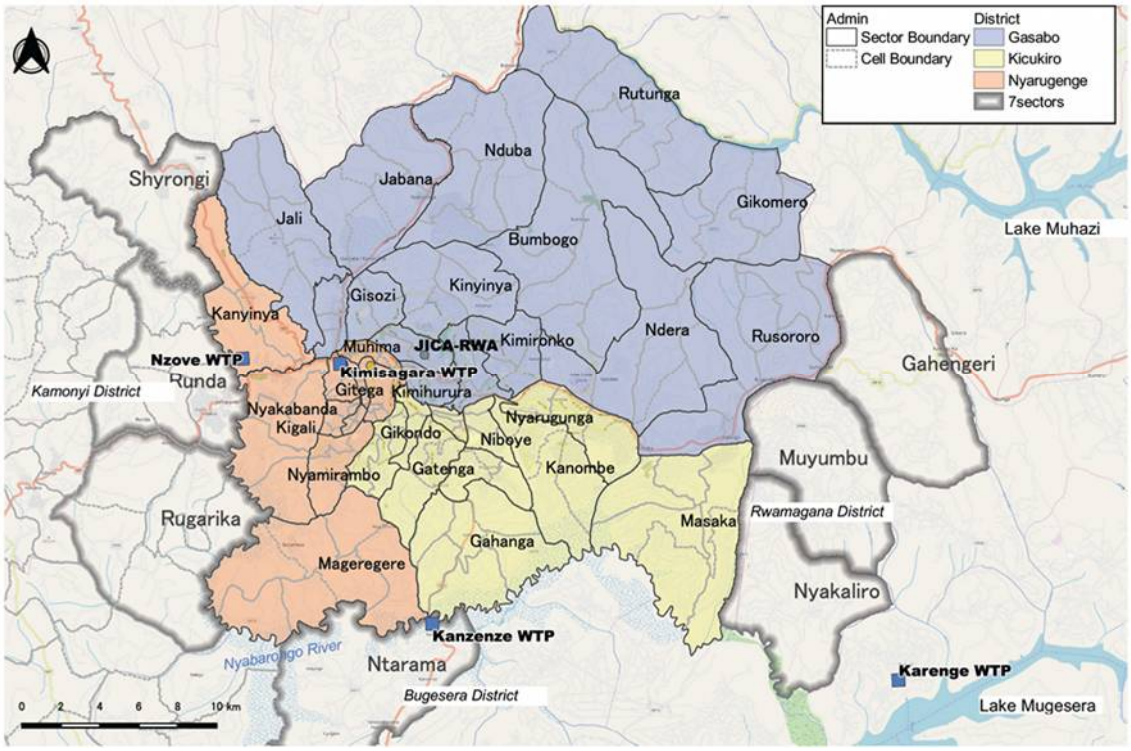
Source: Elaborated by JST based on the information from the website of the Ministry of Local Government, and "Law determining the organization and functioning of the District, 2006".

The number of Sectors, Cells and Villages of each District of the CoK is shown in **Table 3.1-5**. District and sector boundaries are as shown in **Figure 3.1-8**.

Table 3.1-5 Number of Administrative Units under the Districts of CoK

Districts	Sectors	Cells	Villages
Gasabo	15	73	494
Kicukiro	10	41	355
Nyarugenge	10	47	327
Total	35	161	1,176

Source: Statistical Year Book, 2017, NISR



Source: JST

Figure 3.1-8 District and Sector Boundaries of CoK

3.1.5 Relevant Policy and Regulations

Following policies and regulations are relevant to environmental control and usage permits in Rwanda:

- General Provisions
  - Constitution

- o National Policy on Environment and Climate Change (2019)
- o Environment Law (2018)
- o Ministerial Order establishing the list of projects that must undergo environmental impact assessment (2019)

- Environmental Protection
- o National Biodiversity Policy (2011) and National Biodiversity Strategy (2015)
- o Biodiversity Law (2013)
- o Guidelines for Environmental Impact Assessment for Water Resources Management in Rwanda (2009 March REMA)

- Water Resource (Source)
- o Integrated Water Resources Management Policy (2018)
- o Law determining the use and management of water resources (2018)
- o Ministerial Order determining the list of water pollutants (2013)
- o Ministerial Order determining the procedure for declaration, authorization and concession for the utilization of water (2013)

- Land Use
- o Land Policy in Rwanda (2019)
- o Urbanization Policy (2015)
- o Land Law (2013)
- o Expropriation Law (2015)

- Water Supply and Sanitation
- o National Water Supply Policy (2016)
- o Sanitation Policy (2016)
- o National Standards for chemicals used for the treatment of water intended for human consumption (2018)
- o Official Gazette n°20bis of 14/05/2018[1]
- o Rwanda Standards EAS 12: 2018, Potable Water-Specification

- PPP
- o LAW Nº14/2016

3.1.5.1 General Provisions

The fundamental figure pertaining to environmental requirements is addressed in the Country's Constitutions. It guarantees that everyone has the right to live in a clean and healthy environment, and that everyone has the duty to protect, safeguard, and promote the environment. Further, it mandates the protection and sustainable management of the environment and encourages the rational use of natural resources. Sectoral policies, laws, and institutional setups were formulated for ensuring compliance with the above-mentioned constitutional statement.

The first environmental policy was adopted by the cabinet in November 2003 and was recently revised

[1] 'Official Gazette n°20bis of 14/05/2018' stipulates general requirements including the operator's eligibilities and responsibilities.

(June 2019) to include climate change and other emerging issues and opportunities. The policy goal is Rwanda to be a nation that has a clean and healthy environment, resilient to climate variability and change that supports a high quality of life for its society.

It has the overall objective of improving the human well-being, the judicious utilization of natural resources, and the protection and rational management of ecosystems for sustainable development. The policy has resulted in the National Organic Law on Environment enacted in 2005 and revised in 2018, and guides laws related to environmental impact assessment. In addition, the new law, as well as ministerial orders associated with it, provides guidance on environmental management, protection, and procedures for environmental assessment. It requires all projects, programs, and plans to undergo environmental assessment and to obtain the required environmental certificates before its implementation.

Under the Ministry of Environment (MoE), the Rwanda Environment Management Authority (REMA) has the legal mandate for national environmental protection, conservation, promotion, and overall management, including advisory to the government on all matters related to the environment and climate change. The REMA is the authority to oversee environmental assessment requirements pertaining to policies, plans, and development programs and issues the required approvals. However, the responsibility for reviewing the Environmental Impact Assessment (EIA) was transferred to the Rwanda Development Board (RDB) to ensure ease of investment in the country.

3.1.5.2 Environmental Protection and Permissions

The National Biodiversity Strategy (hereafter NBS) (2015) has a long-term vision which is in line with the Convention on Biological Diversity (CBD) strategic plan to 2020 and states that “by 2040, national biodiversity will be restored and conserved, thereby contributing to the economic prosperity and human well-being through delivering benefits essential for the Rwandan society in general”. Further, the Biodiversity law (2013) determines modalities for management and conservation of biological diversity within Rwanda and guide biodiversity planning and monitoring, management of ecosystems, endangered and invasive species, bioprospecting-access and benefit-sharing as well as permitting provisions.

The MoE and the REMA also cover the Environmental Protection and Permissions issues as well.

3.1.5.3 Water Resource

The Integrated Water Resources Master Plan (hereafter IWRMP) is the latest development in Government’s consistent and continuous efforts to strengthen the water resources management sub-sector. It replaces the 2004 policy and has been necessitated by the ill-alignment between the 2004 policy and water law No. 62/2008, which embraced many modern and cutting-edge principles of sustainable water resources. Additionally, the government has been introducing reforms in the water sector that have significantly changed the context for water resources management and rendered the 2004 policy out of date. With the promulgation of a law establishing The Rwanda Water Resources Board (RWB) with the mandate to lead the management of water resources across sectors, there is potential to achieve a

coordinated approach to water resources management, in line with the integrated water resources management concept. In order to address the capacity limitations being faced by the sector, it will require concerted efforts in resource mobilization, human resource development and institutional capacity building.

3.1.5.4 Land Use and Management

The land policy seeks to establish a land tenure system that guarantees tenure security for all Rwandans and provides guidance to the necessary land reforms with a view to good management and rational use of national land resources. The policy is relevant to the WASAC/JICA M/P to be proposed given that some of the activities that will be implemented at a later stage may require additional land, which might cause involuntary resettlement and land acquisition. The land acquisition is governed by both the Land Law (2013) and the Expropriation Law (2015). These two laws set the requirement and procedures for land acquisition, expropriation and transfer for public interest and other types of land acquisition.

The WASAC/JICA M/P is also aligned to the national urbanization policy which guides urbanization to efficiently use and manage its natural resources while promoting sustainable development, reinforce its system of urban areas and human settlements for local economic development based on local potentialities and inter-linkages, promote densification for cost-effective public investment and infrastructure service delivery. In terms of water and sanitation, the policy focuses on the provision of improved water and sanitation services and such services have to be accessible by all. It also aims at ensuring an equitable and adequate average of urban water service provision and a regular supply of water adequately meeting the demand.

The Rwanda Land Management and Use Authority (RLMUA), which is under the Ministry of Environment, plays a critical role in land administration and in defining land ownership and modalities for land transfer. Through the district land bureau, the RLMUA leads the process of land acquisition when it involves the construction of infrastructure such as water treatment plants, water storage reservoirs, forwarding infrastructure, etc. on private land.

3.1.5.5 Water Supply and Sanitation

The objective of the National Water Supply Policy (2016) is to ensure increasing sustainability and access to safe and clean water by improving operations and maintenance of existing water supply infrastructure and providing new water facilities. The policy also seeks to ensure safe, reliable, and affordable urban water supply services for all and at the same time striving for financial sustainability.

The water supply policy is further supplemented by the Sanitation Policy (2016) which aims at ensuring expanded access to safe and sustainable sanitation services through: establishment of District sanitation centers providing a wide range of sanitation technologies; improvement on operation and maintenance of sanitation facilities; and rendering assistance to the Districts and the CoK to plan and design projects with the objective to mitigate urban stormwater issues.

While the Ministry of Infrastructure (MININFRA) sets up policies, regulations as well as strategic actions for sustainable water supply and sanitation, the Water and Sanitation Corporation (WASAC) is the leading institution and is mandated to deliver water and sanitation utility, to deliver new infrastructure for efficient and effective service delivery; to build a strong people capability; and meet key national milestones. The WASAC, together with the CoK, is expected to play a critical role during the preparation and implementation of this WASAC/JICA M/P and its associated instruments, including strategic environmental assessment.

3.1.5.6 Institutional Framework at Different Administrative Levels

(1) Water Supply

i. Central Government Level

The following **Table 3.1-6** shows the main institutions that are involved at the Central Government level for implementing water supply development activities, with their respective roles and responsibilities:

Table 3.1-6 Roles and Responsible Institutions at Central Level in Water Supply

Roles	Responsible Institutions
Policies formulation	MININFRA, MOE, MoH, MINALOC and MINEDUC
Sector planning, Coordination, Monitoring & Evaluation, Capacity building	MININFRA, WASAC
Public financing	MINECOFIN, MoH
Project planning and implementation	The District with the support of WASAC
Service provision and O&M	Districts/PPP and Districts w/WASAC
Independent regulation	RURA, REMA, RSB and MoH

Source: National Integrated Water Supply and Sanitation Master Plans for Rwanda

ii. District Level

The WASAC is the main service provider pertaining to urban water supply and sanitation services. However, the cooperative operation is required with the local government for the following areas:
1) Provision of access to basic water services, 2) Implementation of water supply and contracting private operators for O&M and 3) Preparation and implementation of consolidated district development plans.

iii. Private Sector Level

The private operators are involved in the execution of projects in the sector as contractors for infrastructure development and O&M through delegated management contracted by the districts.

(2) Sanitation

i. Central Government Level

Table 3.1-7 shows the main institutions at the Central Government level, with their respective roles and responsibilities in order to implement the Sanitation Policy.

Table 3.1-7 Roles and Responsible Institutions for Sanitation Policy

Roles	Responsible Institutions
Planning, Policy, Strategy	MININFRA, MoH, MINEDUC, MINALOC, REMA, District
Standard	MININFRA, MoH, REMA, RSB, RURA
Sector coordination	MININFRA, MINALOC, WASAC
Public financing	MoH, MINEDUC, MINALOC (Districts)
Demand Generation	MoH, MINEDUC, REMA, MINALOC (Districts)
Project Implementation	The District with the support of WASAC
Monitoring and Evaluation	MoH, MINEDUC, MINALOC (Districts)
Service and O&M	MoH, MINEDUC, WASAC, MINALOC (Districts), Private service providers
Independent regulation	RURA, REMA, RSB and MoH

Source: National Integrated Water Supply and Sanitation Master Plans for Rwanda

ii. City/District Level

The district administrations and the CoK assume a leading role on the execution and supervision of activities within their territory and on the development of the appropriate management capacities.

iii. Private Sector Level

The private operators participate in the execution of projects of the sub-sector as contractors for infrastructure operation and maintenance, through delegated management contracted by the Districts. They are also encouraged and supported to develop capacities for investment, construction and service delivery in sanitation and solid waste management.

3.1.5.7 International Regulatory Framework

The WASAC/JICA M/P is prepared with support from the government of Japan through the Japan International Cooperation Agency (JICA). For this reason, the WASAC/JICA M/P and its associated instruments such as SEA shall comply with the JICA guidelines pertaining to the environmental and social considerations and at the same time will also comply with the National regulations.

In addition, it is critical that the WASAC/JICA M/P reflects on key international environmental and social requirements relevant to the investment to be proposed under it. Furthermore, the WASAC/JICA M/P and the SEA will draw best practices and comply with the World Bank Environmental and Social Framework (ESF) and the African Development Bank Integrated Safeguards System (ISS). A gap analysis will be made and measures to bridge the gap if any shall be duly provided.

3.1.5.8 Other Permitting Requirements

Other permitting requirements relevant to the preparation and implementation of the proposed WASAC/JICA M/P include requirements and procedures for obtaining VISA for the socio-economic survey. The National Institute of Statistics (NISR) in Rwanda as the leading agency for statistical data requires any institution to obtain a survey visa if the Study covers the entire province or the CoK. The visa is issued based on the objective of the Study, its coverage and the proposed sampling plan.

3.1.6 Socio-economic Conditions

3.1.6.1 Population

Table 3.1-8 presents the Year 2012 census population of the CoK that characterizes:

- Demography: 11.7% of Rwanda people live in the CoK
- Population density: 1,552 people/km^2, 3.7 times that of the average density of Rwanda.
- Urban population rate (%): 75.9% (For reference, the urban population rate of Rwanda is 16.5%).

The NISR defines URBAN as areas that are mostly inhabited with developed social/economic infrastructure such as educational institutions, electricity, water supply, commercial markets and financial institutions.

The sector-wise population is presented in **Appendix-8**.

Table 3.1-8 Population of CoK

Districts	Sectors	Land Area (km^2)	2012 Census Population (.000)				Density
			Urban	(Urban Rate)	Rural	Total	Person /km^2
Gasobo	10	429	365.4	69.0%	164.2	529.6	1,234
Kicukiro	15	167	279.9	87.9%	38.6	318.5	1,911
Nyarugenge	10	132	214.0	75.2%	70.6	284.6	2,124
Total	35	729	859.3	75.9%	273.4	1,132.7	1,552
Ref: Rwanda	416	26,338	1,737.6	16.5%	8,778.3	10,515.9	415

Source: NISR

3.1.6.2 Land Use

Table 3.1-9 presents the land use for the CoK updated and summarized in the CoK M/P. Agriculture use is still predominant in the CoK; followed by natural area and residential uses.

Table 3.1-9 Summary of Land Use in CoK

Land use	km^2	%
1. Residential	67.58	9.2
2. Commercial	2.85	0.4
3. Mixed use	0.22	0.0
4. Public facilities	13.74	1.9
5. Industries	4.41	0.6
6. Nature area	141.98	19.4
7. Agriculture	461.37	63.1
8. Open space	2.171	0.3
9. Water bodies	2.905	0.4
10. Infrastructure/roads	20.84	2.8
11. Water bodies	13.46	1.8
Total	731.35	100.0%

Source: Kigali Master Plan 2050, 2019 edition

3.1.6.3 Economic Profile

(1) Gross Regional Domestic Products

The Gross Regional Domestic Products (GRDP) for the CoK is not available in Rwanda. For this reason,

the Gross Domestic Products (GDP) of Rwanda is presented instead in **Table 3.1-10.** Considering the number of establishments and employment studied under the following clause (2), the contribution of the CoK to the GDP is estimated at more than 20%.

Table 3.1-10 Gross Domestic Products of Rwanda (RWF in billion)

Items		2014	2015	2016	2017	2018
GDP	At current prices	5,466	5,968	6,672	7,600	8,189
GDP growth	At 2014 prices	*6.2%*	*8.9%*	*6.0%*	*6.1%*	*8.6%*
GDP per capita	1000 RWF	497	530	579	644	677
	US$	728	736	735	774	787
% of each economic sector	Agriculture	29%	28%	29%	31%	29%
	Industry	17%	17%	16%	16%	16%
	Services	47%	48%	47%	46%	48%
	Adjustments	7%	7%	7%	7%	7%

Source: NISR

(2) Establishments in the CoK

i. Number of Establishments

CHAPTER 3 **Table 3.1-11** shows the total number of establishments in Rwanda. The establishment is categorized into 20 economic activities such as manufacturing and private/public service entities: 95% of them are owned by individuals (sole proprietorship) in Rwanda. The total number of establishments amounts to 190,288; among them, about 80 percent of the establishments are classified under two major economics activities, namely wholesale and retail (50.5%) and accommodation and food services (27.3%). In the CoK, the number of establishments increased by 33% during the last 3 years from 2014 through 2017. Consequently, 22.8% of the establishment in Rwanda concentrates in the CoK in 2017.

Table 3.1-11 Number of Establishments

Area	2014		2017		Change
	Nos.	%	Nos.	%	%
Rwanda	154,236	100	190,288	100	23.3
Kigali City	32,619	21.1	43,392	22.8	33.0
Gasabo	12,337	8.0	16,195	8.5	31.3
Kicukiro	8,091	5.2	11,323	6.0	39.9
Nyarugenge	12,191	7.9	15,874	8.3	30.2

Note: Establishment is categorized by 20 economic activities. 95% of them are owned by individuals in Rwanda (sole proprietorship).

Source: Establishment Census, 2014 and 2017, NISR

ii. Number of Workers in Establishments

Table 3.1-12 represents the number of workers employed by the establishments, which is 616,737 nos. in 2017. The table shows that 34.4% of workers in Rwanda are employed in the CoK. It is obvious that the business size of establishments in the CoK is bigger than that of Rwanda and it can employ more workers. In addition, it is noted that there has been 31% increase in the number of employments in Rwanda between 2014 and 2017.

Table 3.1-12 Distribution of Workers

Area	Number of Workers	%
Rwanda	616,737	100.0
CoK	212,611	34.4
Gasabo	73,327	11.9
Kicukiro	55,392	8.9
Nyarugenge	83,892	13.6

Source: Establishment Census, 2014 and 2017, NISR

iii. Labor Force

The NISR has started the labor force survey since 2016. **Table 3.1-13** presents the result of the survey. During the past two years (2017 and 2018), the unemployment rate in Rwanda is slightly declining while at the same time employment to population rate is increasing.

Table 3.1-13 Labor Force and Unemployment

Area	Items	Aug 2016	Aug 2017	Aug 2018
Rwanda	Labor force participation rate	50.6%	52.9%	55.2%
	Unemployment rate	18.8%	17.8%	14.3%
CoK	Labor force participation rate	67.1%	66.5%	67.5%
	Unemployment rate	17.8%	20.3%	18.7%

Source: Labor Force Survey Trends, NISR

3.1.6.4 Poverty Conditions

The poverty index for the CoK is not available at the moment. As such, the index of Rwanda is presented in **Table 3.1-14**. The index has been continuously declining; the same trend could also be expected in the CoK.

Table 3.1-14 Poverty Index of RWANDA

Indicator Name	2005/06	2010/11	2013/14	2016/17
	EICV2	EICV3	EICV4	EICV5
1. Poverty	56.7	44.9	39.1	38.2
2. Extreme Poverty	35.8	24.1	16.3	16.0

Source: EICV 5, Main Indicator, NIRS

3.1.6.5 Social Figure of the CoK Citizens

According to the EICV5 study, 77.3% of the CoK Citizens are living under an unplanned urban housing area. One-third of the people are migrants from other areas (Migrated during the last five years, 33.3%). S/he has access to improved drinking water (95.6%). Compared with the rural area, the CoK citizens are enjoying relatively better conditions of health as the reports on illness are low. (Rural 33.9%, CoK 26.3%)

- Living under unplanned urban housing area (77.3%),
- Migrated from other areas during the last five years (33.3%)
- Access to the improved drinking water (95.6%)
- Reports on illnesses over the past 4 weeks (26.3%)

Source: EICV5 Thematic Report Environment and Natural Resources

The current trends observed from the EICV5 (comparison between the EICV4 year 2014 and EICV5 year 2017) are as follows. Access to improved water has undergone a transition from unimproved/other drinking water source (EICV4: 15.5% EICV5: 4.2%) to a public standpipe one (EICV4: 35.6% EICV5: 41.5%). Piped into dwelling/yard, slowing grows (EICV4: 36.8% EICV5: 34.0%). Citizens' habitat type is changing from the isolated rural housing (EICV4: 13.4% EICV5: 2.9%), to the modern planned area (EICV4: 2.6% EICV5: 17.4%). In terms of migration amongst different types of habitats, it may be occurring not just between isolated rural housing and the modern planned area. Most likely it is occurring to the unplanned urban housing to the modern planned area and then from the isolated rural housing to the unplanned urban housing. In the CoK, the poverty rate is significantly reducing.

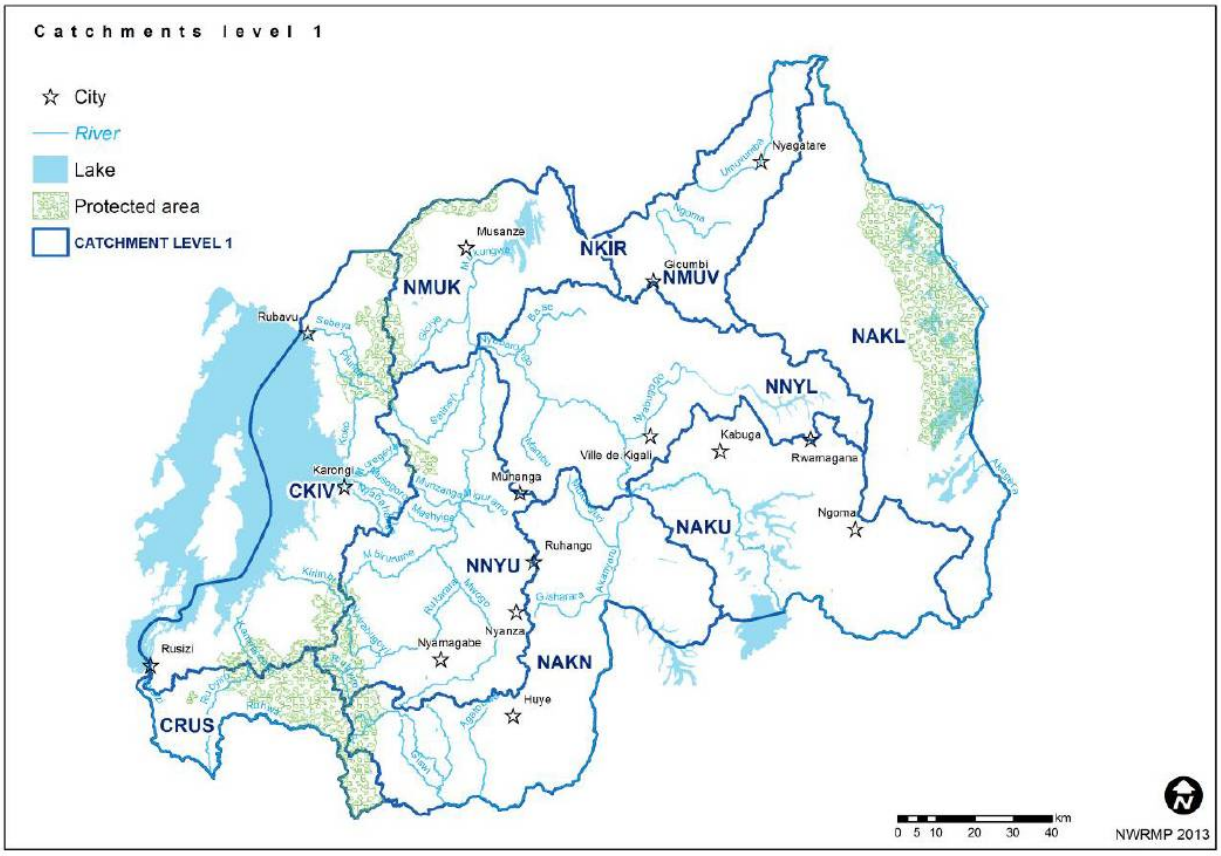
- Improved access to improved drinking water (EICV4: 84.5%, EICV5: 95.9%)
- Migration to the modern planned area (EICV4: 2.6%, EICV5: 17.4%)
- Poverty has reduced under the index (EICV4 20.9%, EICV5: 13.9%)

Source: EICV5 Thematic Report Environment and Natural Resources

3.1.7 Geology, Hydrology and Hydrogeology

Rwanda is a plateau country called "the land of a thousand hills," the CoK as the capital of Rwanda is also a city having hills. In Rwanda, bedrocks are generally composed of metamorphic and granitic rocks belonging to the Precambrian Period, which are distributed all over the country as well as the CoK. Metamorphic rocks are mostly schists produced by low to medium pressure metamorphic actions of sandy to muddy sediments. Granitic rocks are intrusive rocks originating from metamorphic actions.

Rwanda is divided into 9 Level 1 Catchment division as shown in **Figure 3.1-9** and **Table 3.1-15**. The hydrological information on the level 1 Catchment unit is shown in **Appendix-9** .



Source: Rwanda National Water Resources Master Plan MINIRENA-RNRA October 2015

Figure 3.1-9 Level 1 Catchment Division of Rwanda

Table 3.1-15 Code and Water Resource Name

Code NWRMP *	**CKIV**	**CRUS**	**NNYU**	**NMUK**	**NNYL**	**NAKN**	**NAKU**	**NAKL**	**NMUV**
Water Resource Name:	Lake Kivu	Rusizi	Upper Nyaborongo	Mukungwa	Lower Nyabarongo	Akanyaru	Upper Akagera	Lower Akagera	Muvumba

*NWRMP = National Water Resources Master Plan

Source: Rwanda National Water Resources Master Plan MINIRENA-RNRA October 2015

The CoK is included under the Lower Nyabarongo Catchment (NNYL). The catchment area is 3,305 km². Details of the NNYL are presented in **Table 3.1-16** below.

Table 3.1-16 Lower Nyabarongo catchment (Level 1)

Catchment-level 2	**Key water bodies**	**Districts where the Rivers drain through**
Muhazi-Nyabugogo (NNYL_1)	Muhazi lake and Nyabugogo River	Gicumbi, Gatsibo, Kayonza, Rwamagana, Gasabo, Nyarugenge, Kicukiro, Rulindo
Nyabarongo (NNYL_2)	Nyabarongo River	Kamonyi, Muhanga, Gakenke, Rulindo, Nyarugenge

Source: Rwanda National Water Resources Master Plan

Nyabarongo River drains the entire western part of the catchment through a number of small and rather

steep secondary valleys. The wide valley of the Nyabarongo is extensively used for agricultural purpose. Nyabugogo River is a major tributary of the Nyabarongo River. Higher water use is registered for the lower Nyabarongo (NNYL) catchment, which is related to the water used for the CoK and irrigation development in the Nyabarongo valley.

Major aquifers in Rwanda are found under fractured and weathered Precambrian basement rocks such as granites, metasedimentary quartzites and schists. Cenozoic volcanic aquifers are found in the Western Province, and along the northern border. Quaternary alluvial aquifers generally form narrow and shallow depth along the river valleys.

In the CoK, groundwater from the alluvial aquifers along the Nyabarongo River is being used at the Nzove WTP and Kanzenze WTP. In addition, there are many handpumps installed along the river valleys, which abstracts the shallow groundwater. On the other hand, very few boreholes are drilled to abstract deep groundwater from basement rocks.

3.1.8 Water Permit System

The Rwanda Water Resources Board (RWB) is a regulatory organization pertaining to water resources. The RWB is mandated to: (1) manage the water resources effectively (2) allocate water and (3) protect the environment. Water users, including the WASAC need to obtain the water permit from the RWB. There are three types of water permits which are Authorization, Concession and Declaration.

The water permit is determined based on usage of water, impact on the environment, disaster risk, and impact on other water use. For use of the water, it requires (1) concession level water abstraction permit/water use permit, (2) EIA certificate, and (3) construction permit as well.
Table 3.1-17 shows the water permit system.

Table 3.1-17 Water Permit System

Type of scheme	Type of water permit required
Irrigation schemes of above 1 ha	Authorization
Water treatment plants for water supply	Authorization
Hydropower plants	Authorization
Industries /coffee washing stations /mining companies getting water from surface water or ground water	Authorization
Construction of dam	Authorization
Any deviation of a water body (lake, river or stream)	Authorization
Groundwater abstraction	Authorization
Fish farmers in lakes or ponds	Concession
Physical or juridical persons wishing to carry out research in water bodies or exploration of water resources	Declaration

Source: RWB

As shown in the above **Table 3.1-17**, the owners of the water treatment plants such as the WASAC need to obtain the authorization for a water permit. There are two types of water permit application forms depending on water source (surface water and groundwater abstraction). The sample application forms are attached in **Appendix-10,11**.

In addition to the application form, the following documents are also required.

- ✓ Recommendation letter from the related Ministry
- ✓ Identification of the applicant
- ✓ Site Identification (location, coordinate and map)
- ✓ EIA certificate and report
- ✓ Application fee

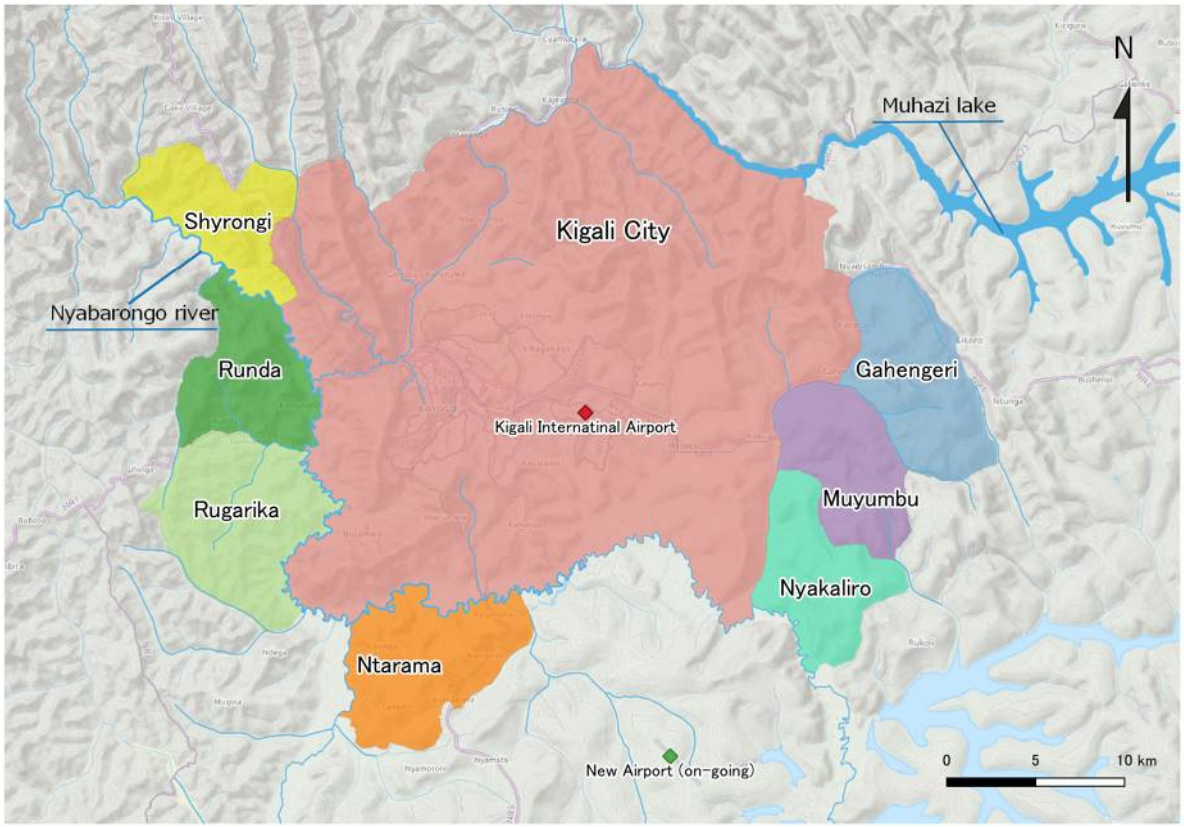
After submission of the application, the RWB conducts the assessment for approval.

3.2 ADJACENT 7 SECTORS

Study Area of the WASAC/JICA M/P includes not only the CoK but also its adjacent 7 sectors.

3.2.1 Location

The locations of the 7 sectors are shown in **Figure 3.2-1**. Shyorongi sector, Runda sector and Rugarika sector are located on the west side, Ntarama sector on the south side, and Gahengeri sector, Muyumbu sector and Nyakaliro sector on the east side from the CoK. Shyorongi belongs to Rulindo district, Runda and Rugarika belong to Kamonyi district, Ntarama belongs to Bugesera district, and Gahengeri, Muyumbu and Nyakaliro belong to Rwamagana district (**Table 3.2-1** and **Figure 3.2-2**).



Source: JST

Figure 3.2-1 Location of 7 Sectors

Table 3.2-1 List of 7 Sectors

District	Sector	Location from CoK
Rulindo	Shyorongi	West
Kamonyi	Runda, Rugarika	West
Bugesera	Ntarama	South
Rwamagana	Gahengeri, Muyumbu, Nyakaliro	East

Source: JST



Source: JST

Figure 3.2-2 Location of the Adjacent 7 Sector's Districts

3.2.2 Administrative Units

The number of Sectors, Cells and Villages on each District of the adjacent 7 sectors are shown in **Table 3.2-2**. The number of cells and villages under each sector need to be studied as it is not available at the moment.

Table 3.2-2 Number of Administrative Units under the District

Province	District	Sector	Number of Cell	Number of Villages
Northern	Rulindo	17	71	494
		Shyorongi	n/a	n/a
Southern	Kamonyi	12	59	317
		Runda	n/a	n/a
		Rugarika	n/a	n/a
Eastern	Bugesera	15	72	581
		Ntarama	n/a	n/a
	Rwamagana	14	82	474
		Gahengeri	n/a	n/a
		Muyumbu	n/a	n/a
		Nyakaliro	n/a	n/a

Source: Statistical Yearbook, 2017, NISR

3.2.3 Socio-economic Conditions

3.2.3.1 Population

Table 3.2-3 represents the Year 2012 census population which characterizes:

- Urban population rate is very low, less than 10% of the total population.
- Only Shyorongi sector (Rulindo District) and Runda sector (Kamonyl District) have urban areas.
- Most of the people live in rural areas.

Table 3.2-3 Population of Adjacent 7 Sectors

Province	District	Sector	Land Area km^2	Population (.000)				Density
				Urban	(Urban Rate)	Rural	Total	Person /km^2
Northern	Rulindo	Shyorongi	47	4.4	18.7	19.1	23.5	504
Southern	Kamonyi	Runda	51	13.0	37.7	21.8	34.8	681
		Rugarika	75	0	0	34.9	34.9	466
		Total	126	13.0	18.7	56.7	69.7	553
Eastern	Bugesera	Ntarama	64	0	0	18.0	18.0	281
	Rwamagana	Gahengeri	63	0	0	23.5	23.5	373
		Muyumbu	50	0	0	24.2	24.2	482
		Nyakaliro	50	0	0	20.2	20.2	404
		Total	163	0	0	67.9	67.9	416
Total of adjacent 7 sectors			400	17.4	9.7	161.8	179.2	448

Source: NISR

3.2.3.2 Socio-economic Features

The socio-economic features, as observed by JST in the 7 sectors are summarized in **Table 3.2-4**. However, the actual developments in the sectors are elaborated in the master scenario according to the development plan obtained from each district office.

Table 3.2-4 Socio-Economic Features

Sector	Features
Syrongi	• The National Road (NR) links with the CoK • More than 80% is categorized as rural area. • Only the neighborhood around the sector office is categorized as urban area. • Agriculture is the main industry.
Runda	• The NR links with the CoK. • The sector office is located only 10 km from the center of the CoK. • A lot of residential houses are scattered along the NR.
Rugarika	• The NR links with the CoK. • The whole area of the sector is categorized as rural area. • The sector office is located 20 km from the center of the CoK. • The roads are mostly unpaved and in bad conditions.
Ntarama	• The whole area of the sector is categorized as rural area. However, the sector is growing as a residential area for the people working in the CoK. • The location is just adjacent to Gahanga Sector of the CoK where urban development is expected. • The NR is under the expansion due to the way to the new airport in Rilima Sector.
Gahengeri	• Rice fields spread out in the flat area adjacent to the CoK along the NR. And leafy vegetables and banana are broadly cultivated in the hill areas. • The neighborhood is gathered in the hillside far from the NR. • Inner roads are unpaved and in bad conditions.
Muyumbu	• Same as Gahengeri. • However, inner roads are maintained through unpaved.

Nyakariro	• Just adjacent to Masaka Sector of the CoK. • Middle-class residential houses are scattered in the area close to Masaka Sector. • A big dairy factory is operating near the NR. • However, the road conditions are still bad.

Source: JST

3.2.3.3 Social Figure of the 7 Sectors

Due to the limitation of available information on the 7 sectors, the JST referred to the EICV studies' rural area's social figure as a representation of the area.

According to the EICV5 study, the maximum number of rural residents is living in Umudugudu (67.0%). Only one-tenth of the people are migrants from other areas (Migrated during the last five years, 9.5%). In the case of the 7 sectors, the region may already face a much higher migration, especially if the area is adjacent to a major road (National Road). S/he has access to improved drinking water (85.4%). Regardless of whether s/he has access to improved water or not, habitats in the rural area report illness (has access 32.1%, doesn't have access 35.5%).

- Living in Umudugudu (67.0%),
- Less migrant from other areas during the last five years (9.5%)
- Access to the improved drinking water (85.4%)
- Reports on illnesses over the past 4 weeks (33.9%)

Source: EICV5 Thematic Report Environment and Natural Resources

The current trends observed from the EICV5 (comparison between the EICV4 year 2014 and EICV5 year 2017) are as follows. Improvement of access to improved water has slowed down (EICV4: 83.7%, EICV5: 85.4%). Rural habitation is changing from isolated rural housing is decreasing (EICV4: 30.2% EICV5: 20.1%), and Umudugudu is increasing (EICV4: 55.8% EICV5: 67.0%). In terms of migration amongst different types of habitation, the female-headed household has significantly reduced in isolated rural housing and is increased in Umudugudu. It may be a part of Vision 2020/2050 implementation. In rural area, the poverty rate is not reduced as observed in the urban area (EICV4: 43.7%, EICV5: 41.1%).

- Improved access to improved drinking water (EICV4: 84.5%, EICV5: 95.9%)
- Migration to Umudugudu (EICV4: 55.8%, EICV5: 67.0%)
- Poverty conditions stay still (EIC: V4 43.7%, EICV5: 41.1%)

Source: EICV5 Thematic Report Environment and Natural Resources

CHAPTER 4 GOVERNMENT AND RELATED DEVELOPMENT PLANS

Followings are the notable governing superior plans and/or related policies relevant to this Study..

- Rwanda Vision 2020 (2012)
- 7 Years Government Program: National Strategy for Transformation (NST1)- 2017-2024.
- The City of Kigali Master Plan (CoK M/P)
- National Water Supply and Sanitation Master Plans by AfDB (AfDB M/P)
- Economic Development and Poverty Reduction Strategy II (EDPRS II), 2013-2018 (2013)
- Water and Sanitation Sector Strategic Plan 2013/14 - 2017/18 (2013)
- National Water Supply Policy Implementation Strategy (NWSPIS) - December 2016
- Integrated Water Management Policy (IWMP)
- Development Plan for Special Economic Zone (SEZ)

4.1 VISION 2020 AND VISION 2050

Formulation of Vision 2020 was conducted through a national consultative process during 1998 and 1999. The vision pertains to transform Rwanda into a middle-income country by the year 2020. The Vision is coordinated by the Ministry of Finance and Economic Planning through its involvement on implementation of formulation, monitoring, and evaluation. In the year 2000, first macro-level targets (47 indicators) are addressed as original Vision 2020.

Rwanda Vision 2020 is a framework for Rwanda's development toward 2020 that was launched by the President, presenting the key priorities and providing Rwandans with a guiding tool for the future. It supports a clear Rwandan identity while showing ambition and imagination in overcoming poverty and division. This vision identified six priority pillars:

- Good Governance and a Capable State
- Human Resource Development and a Knowledge-based Economy
- Private Sector-led Development
- Infrastructure Development
- Productive high value and market-oriented agriculture
- Regional and International Integration

Besides the above mentioned six pillars, there are three cross-cutting areas which comprise of gender, natural resources & environment and culture, science & technology. In 2012, the Ministry of Finance and Economic Planning (MINECOFIN), who is in charge of implementation and monitoring and evaluation of the Vision published a revised version of the Vision 2020. According to the revised version, Indicator No. 29 that indicates population ratio to access to clean water is indicated as 52% in 2000, 74.2% at 2012 and 100% by 2020. Currently, Vision 2050 is being prepared and according to the presentation material

presented by the MINECOFIN in 2016[1], Vision 2050 is about ensuring high standards of living for all Rwandans, including achieving "Universal, sustainable and reliable access to in-house water and sanitation".

Alongside the macro-level target of Vision 2020, Rwanda institutes the principle of precaution to mitigate the negative effects caused to the environment by the socio-economic development, and preventive measures to ensure that the environment is safeguarded from abuse. The Vision further requires that Environmental Impact Assessment (EIA) should be carried out for development activities which are likely to induce a negative impact on the environment.

Vision 2050 and the associated year 2035 targets are prepared for guidance to the Rwandan's post Vision 2020 era. Targets of Vision 2050 were set on reaching an upper-middle-income country (GDP per capita in US$ 4,035) by 2035 and a high-income country by 2050 (GDP per capita in US$ 12,476). It is an extension of Vision 2020 and the first four years of Vision 2050 is compiled as the National Strategy for Transformation (NST1).

Under Vision 2050, the specific priorities and strategies are identified as five (5) pillars, as shown below.

- High Quality and Standards of Life:
- Developing Modern Infrastructure and Livelihoods
- Transformation for Prosperity
- Values for Vision 2050
- International cooperation and positioning

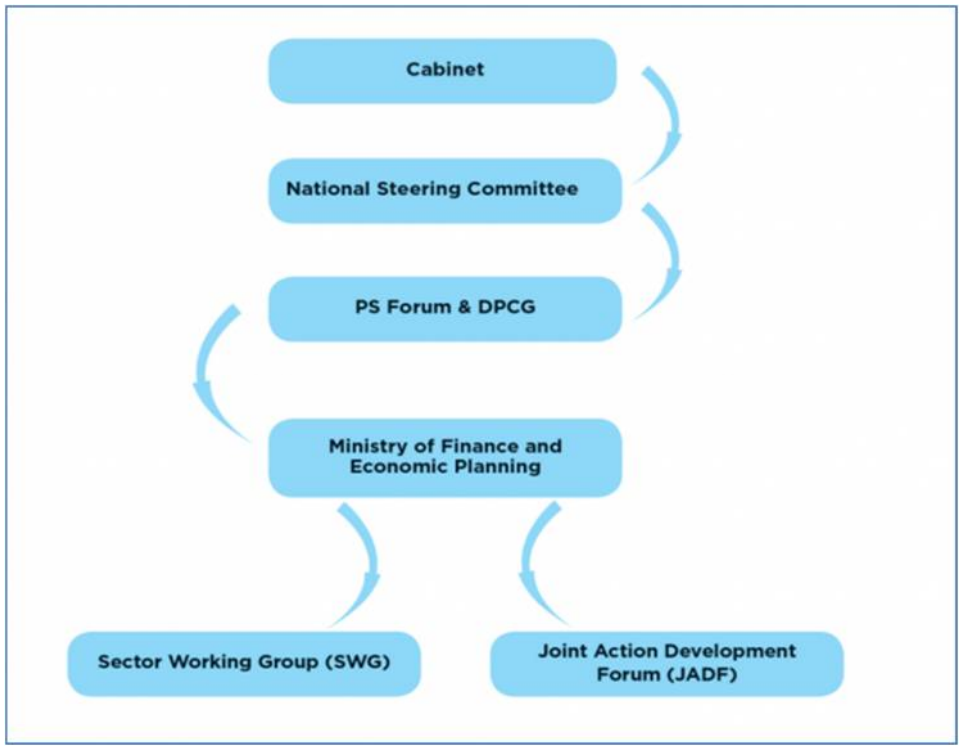
In this regard, as a part of ensuring high quality and standards of life pillar, water supply sector target is set as a universal, sustainable and reliable access to water (in houses) and sanitation. In addition, the Vision 2050, recalls following emerging political agenda and action plans;

- The Sustainable Development Goals (SDGs) consisting of 17 Goals with associated targets and indicators, across a range of economic, social and environmental aspects;
- The African Union Agenda 2063 and its First 10-Year Implementation Plan 2014-2023 which is dedicated to the building of an integrated, prosperous and peaceful Africa, driven by its citizens and representing a dynamic force in the international arena;
- The East African Community (EAC) Vision 2050 which focuses on initiatives for job creation and employment by prioritizing development enablers which are integral to long-term transformation, value addition and acceleration of sustained growth;
- The COP 21 Paris Agreement on Climate Change and other agreements.

[1] THE RWANDA WE WANT: TOWARDS 'VISION 2050, Claver GATETE, Minister of Finance and Economic Planning, Rwanda, National Dialogue Presentation, 16 December 2016

4.1.1 The Institutional Framework of Vision 2020

The policy-making body of the Vision 2020 is the Cabinet and the National Steering Committee (Ministers and Governors). The Permanent Secretaries (PS) forum and the Development Partners Coordination Group (DPCG) oversee and guide the implementation of the Vision and ensure that consensus building around the Vision 2020 implementation is realized. The Ministry in charge of Finance and Economic Planning coordinates the implementation, monitoring and evaluation of the Vision. It also ensures that the Vision 2020 targets are considered in Sector Strategies as well as under the District Development Plans.



Source: Rwanda Vision 2020

Figure 4.1-1 Institutional framework for the implementation of Vision 2020

The vision seeks to transform Rwanda into a middle-class income country by 2020. To achieve this, the vision challenges the following major economic targets:

1. Macroeconomic stability and wealth creation to reduce aid-grant dependency
    1) To reduce the budget deficit (see **Table 4.1-1** below)
    2) To improve the external balance of payments
2. Structural economic transformation
    1) To reduce the dependency on the agriculture sector
    2) To promote investments in industries and services
3. Creating a productive middle class and fostering entrepreneurship
    1) To foster private sector development
    2) To develop industrial parks and export processing zones

3) To develop the financial sector for necessary capital provision

Reference: Budget of GOR

Table 4.1-1 presents the budget of the GOR over the 5 financial years. It is characterized that:

- The current and capital expenditures cannot be covered with their own current revenues such as taxes.
- The budget varies depending on the grants to balance the deficit of taxes
- Nevertheless, the final budget balance results in negative every year.
- The final negative balance is covered up with external financing from foreign and domestic financial institutions.

Table 4.1-1 Budget of GOR (RWF in billion)

Budget Account			2015/16	2016/17	2017/18	2018/19	2019/20
			Actual	Actual	Projected	Projected	Projected
Revenues	Current	Tax revenue	1,000.3	1,104.1	1,252.9	1,396.9	1,613.7
		Non-tax revenue	165.9	181.4	208.6	238.9	222.0
		Total	1,166.2	1,285.5	1,461.5	1,635.8	1,835.7
	Grants	Budget support	204.8	184.2	358.9	425.4	416.7
		Project support	168.9	146.0			
		Total	373.7	330.2	358.9	425.4	416.7
	Total		1,539.9	1,615.7	1,820.4	2,061.2	2,252.4
Expenditures	Current	General	870.1	997.4	1,085.7	1,198.2	1,314.7
	Capital	-	720.9	759.5	850.2	1,027.6	1,068.5
	Loan	Amortization	88.4	113.8	160.0	190.0	213.1
		Interest	56.7	72.2	91.6	103.1	125.0
		Total	145.1	186.0	251.6	293.1	338.1
	Total		1,736.1	1,942.9	2,187.5	2,518.8	2,721.3
Net			-196.2	-327.2	-367.1	-457.6	-468.9
External Financing (from domestic/foreign)			223.7	347.2	392.2	484.9	499.5

Source: Updated Macro-framework as of 15th November 2018, MINECOFIN

4.1.2 Major Indicators of Vision 2050

Vision 2050 charts a big picture of Rwandan society with steady and strong economic growth.
Some major indicators of Vison 2050 are stated in the **Table 4.1-2**.

Table 4.1-2 Major Indicators of Vision 2050

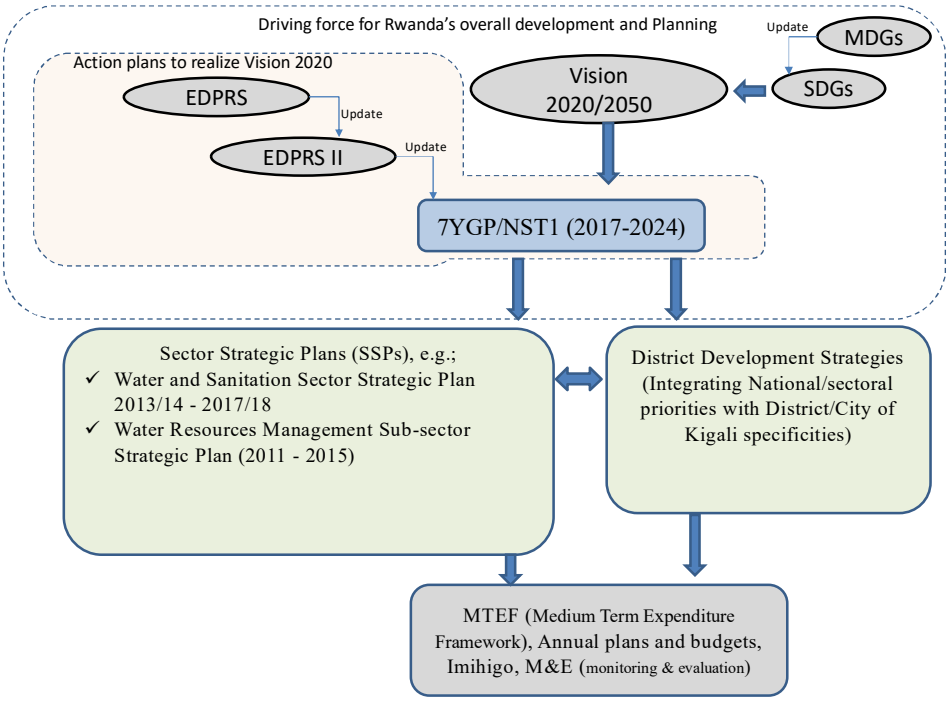
Indicator	Baseline	Target 2035	Target 2050
GDP per Capita (US $)	837	4,036	12,476
Unemployment	15%	7%	5%
Population accessing social security	9%	30%	50%
Population living in urban areas	19%	53%	70%
Population conveying with public transportation	17%	24%	40%
Access to electricity	56%	100%	100%
Energy Consumption per capita	50Kwh	1,026Kwh	3,080Kwh
Population using internet	22%	60%	88%

Source: Vision 2050 by MINECOFIN

4.2 NATIONAL STRATEGY FOR TRANSFORMATION AND SEVEN YEARS GOVERNMENT PROGRAM

The National Strategy for Transformation and the Seven (7) Years Government Program (Abbreviated by

NST1) are the strategies and its associated Sector and District's development strategies where transiting from Vision 2020 to 2050. It starts from 2017 to 2024 and guides National development during these seven years.



Source: JST (Based on 7 Years Government Program: National Strategy for Transformation (NST 1) 2017 – 2024

Figure 4.2-1 Development Planning Framework for Vision 2050 and NST1

Under NST1, 3 (three) pillars, namely Economic transformation Pillar, Social Transformation Pillar, and Transformational Governance Pillar along with its cross-cutting areas are identified. For each pillar and cross-cutting area, priority area and interventions are addressed. Water supply sector is mentioned in the pillars of "Economic Transformation" and "Social Transformation" as shown in **Table 4.2-1**.

Table 4.2-1 Strategies and Interventions Mentioned in NST1

Pillars	Priority area	Intervention
Economic Transformation	Promote Sustainable Management of the Environment and Natural Resources to transition Rwanda towards a Green Economy	Develop a project to manage water flows from the volcano region and other rivers to mitigate related disasters and improve water resource management
Social Transformation	Moving towards a modern Rwandan household. This will be achieved through universal access to basic infrastructures such as electricity, water, sanitation and broadband	Access to water in the target was to set from 85 % (Estimates 2017) to 100% by 2024 through investments

Source: Prepared by JST

4.3 THE CITY OF KIGALI MASTER PLAN (COK M/P)

In response to the city's emerging growth and development, the Cok M/P is updated from the previous version prepared in 2013. At the time of preparation of the IT/R of the Study as of December 2019, the

CoK M/P side has prepared 'Master Plan Report (2019 Edition)' that can be regarded as the final version of the city's master plan.

The specific objectives of the CoK M/P (2019 Edition) are as below:

- Collect, integrate and incorporate all new data, plans, projects and regulations elaborated after 2013 Master Plan adoption, including green growth strategies, transport studies elaborated and planned and upcoming developments for Rwanda.
- Integrate baseline studies with primary data collection and update Project Programming with refined forecasts on population, income, employment, services and transport demand.
- Review 2013 Master Plan Implementation Status, assessing the progress of the capital improvement plan and catalytic projects, highlight delays and issues in the implementation, paving the way to the updated Implementation Report
- Integrate a new transportation analysis and modeling into the planning process to further reinforce the Transport Oriented Design approach in 2013 Master Plan
- Involve key stakeholder groups and re-shape the plan to address most critical issues, but without losing track of the overarching Vision. Effectively communicate the project to the community, ensuring ownership of and compliance to the Update Plan.
- Update the Nyarugenge CBD Urban Design Plan, incorporating all recent projects and aligning it with market trends.
- Involve the CoK technical team in all stages of the project, requesting them to actively contribute to the preparation of draft deliverables (e.g., Interim Master Plan Update)
- Update the entire Master Plan GIS database and coordinate with the ESRI for its publication on the new web portal.
- Update the Implementation Plan with a revised Capital Improvement

The proposed Cok M/P will be implemented under five phases and each phase has been aligned with the specific development activities which are expected to generate at least 1.7 million jobs over the next 30 years.

4.4 NATIONAL WATER SUPPLY AND SANITATION MASTER PLANS (AFDB M/P)

Among the major works done, the GOR has prepared two Water Supply Master Plans (Master Plan for the Eastern Sub-Basin (with 9,269 km^2) and Master Plan for the Upper Nyabarongo Catchment (3,348 km^2) and three Sanitation Master Plans (Huye, Muhanga and Rwamagana Districts that cover 1,229.2 km^2). Unfortunately, the National Water Resources Master Plan carried out in 2015 (NWRMP) did not integrate sanitation service with water supply. For this reason, the GOR called for the development of the integrated National Water Supply and Sanitation Master Plans (AfDB M/P). The specific study to be carried out for the M/P is expected to play a vital role in enhancing the water supply and sanitation coverage of Rwanda in the shortest time possible.

The main objective of the AfDB M/P is to provide the Government of Rwanda long-term (at the year 2050) National Master Plans and 10 years Investment Plan for Water Supply and Sanitation, which will allow the identification gaps in the sectors and lead to implementation of effective Water Supply & Sanitation Projects. The second objective is the Capacity building for stakeholders in Water Supply and Sanitation Projects and Operation & Maintenance for achieving Water Supply and Sanitation targets.
The Study is carried out by means of three Components, namely:

- Component 1 deals with the Development of the National Water Supply and Sanitation investment plans for a 10-year horizon, and the preparation of feasibility and detailed designs for small selected prioritized projects.
- Component 2 focuses on capacity building activities for main stakeholders, WASAC, district staff and private sector staff on previously identified topics.
- Component 3 comprises project management, stakeholder consultation and community participation and also includes the establishment of a Project Implementation Unit (PIU) within WASAC to coordinate project implementation.

Under the AfDB M/P study, Baseline Data Report was prepared in March 2019. After then, the progress of the AfDB M/P was suspended since the contract of the consultant was terminated in October 2019. The work resumed in November 2020 after the re-procurement process of the consultant, taking over the Baseline Data Report. According to the AfDB's portal website[2], the planned completion date of the AfDB M/P study is scheduled to be June 2023[3].

Originally, integration of the 10-year investment plan of the AfDB M/P and the 15-Year Investment Plan (15-YIP) of WASAC/JICA M/P had been supposed to be done under this Study according to the ToR of the Study between JICA and the JST. However, due to the delay of the AfDB M/P, its 10-year investment plan would probably not be available by the beginning of September 2021 at which the field work of the Study is scheduled to complete. Accordingly, the 10-Year Investment Plan of the WASAC/JICA M/P is separately complied under the Study, taking out the first 10-year portion of the 15-YIP so that it can be added to the investment plan under the AfDB M/P. The 10-Year Investment Plan is summarized in **Appendix-12**.

4.5 OTHER RELEVANT PLANS/POLICIES

4.5.1 Economic Development and Poverty Reduction Strategy II, 2013-2018 (2013)

The structure and objectives of the second Economic Development and Poverty Reduction Strategy (EDPRS II), that extends from 2013 to 2017 are closely coordinated with the government's thematic areas and priorities (after the evaluation of the implementation of the EDPRS I, which covered the period of 2008-2012). As the country's medium-term economic development plan, EDPRS II establishes the

[2] https://projectsportal.afdb.org/dataportal/VProject/show/P-RW-EA0-013
[3] June/2023 is the updated expiry of AfDB's loan (loan period has been extended due to re-procurement of the consultant and impact of Covid-19). The master scenario has been drafted in Aug/2021, the master plan including 10-year investment plan are supposed to be available by Dec/2021, and the feasibility study and the detailed design for the priority projects are supposed to be available in Dec/2022, according to the information obtained through WASAC's in charge of the AfDB M/P at the validation meeting for the master scenario on 12/Aug/2021.

framework within which the Government had to change the structure of the economy and move towards achieving or surpassing the long-term targets of the Vision 2020 and the MDGs.

The EDPRS II is aimed at increasing the pace of economic growth and further reducing the incidence of poverty and lays the foundation for sustainable growth in the future. The overarching goal of EDPRS II is to accelerate progress towards a middle-income status and to ensure a better quality of life for all Rwandans through a sustained growth of 11.5% and accelerated poverty reduction.

This policy document emphasizes that Rwanda's economy is heavily dependent on its environment and natural resources, and the livelihoods of rural (and increasingly urban) communities depend on the access, use and management of such resources. Without sound planning instruments such as the AfDB M/P, development activities in key sectors such as agriculture, industry, infrastructure, commerce, and energy can lead to significant environmental degradation that can undermine economic growth.

4.5.2 Water and Sanitation Sector Strategic Plan 2013/14 - 2017/18 (2013)

The revised Water and Sanitation Sector Strategic Plan was prepared based on the existing sector strategic plan 2010-2015. The sector strategic plan 2010-2015 was implemented for a period of one and a half years before the same was revised / updated to ensure conformity with the EDPRSII targets for ensuring 100% coverage for the sector. The Vision 2020 also served as a strong long-term planning tool that guided the preparation of the revised sector strategic plan. It is important to understand at this point that the Vision 2020 targets for water and sanitation sector had been brought forward by the EDPRSII in order to achieve 100% coverage by 2017, as it was not achieved till then. The revised sector strategic plan is also the aspiration of the seven years Government program to accelerate the achievement of the water and sanitation sector targets to 100% by 2024

4.5.3 National Water Supply Policy Implementation Strategy (NWSPIS) - December 2016

This policy implementation strategy was meant to guide the achievement of the key development goals as set out in the EDPRS II, the Vision 2020 and the SDGs. Therefore, it was spanned to the 2020 horizon. The targets set out under this document were referred to the EICV4 Main indicators report. The main indicators for water supply were as follows (according to EICV4):
47.3 % of households in rural areas were accessing drinking water source within 500 m while 60.5 % of households in urban areas were accessing drinking water source within 200 m. Based on the above-mentioned figures, the NWSPIS document set out the following targets:

- The target percentage of rural households accessing the improved water source within 500 m is 100 % in 2020 and
- For the urban areas, the percentage of urban households accessing the improved water source within 200 m is 100 % in 2020.

Based on the reports from the EICV5- 2016/2017, it can be inferred that the target is quite far from being

achieved as the figures were raised from 47.3% (EICV4) to 54 % (EICV5) in rural areas and from 60.5% (EICV4) to 63% (EICV5) in urban areas. The indicators show that the GOR is still to make a tremendous effort to reach the targets.

4.5.4 Integrated Water Management Policy (IWMP)

The Integrated Water Management Policy aims for ensuring sustainable management of water resources of Rwanda. This policy is highly relevant to works related to the activities such as water supply networks, construction of intakes and sanitation facilities, landfills, etc. The policy also highlights the management of water on both demand and supply side and also integrates the other policies on forests, wetland, agriculture and land.

4.5.5 Rwanda National Water Resources Master Plan (2015)

The general objective of the Rwanda National Water Resources Master Plan is to ensure sustainable water resources development, utilization and management in the country.

By dividing into two major basins (Nile and Congo basins) and further dividing into nine catchment areas (Lake Kivu, Rusizi, Upper Nyabarongo, Mukukngwa, Lower Nyabarongo, Akayaru, Upper Akagera, Lower Akagera, and Muyumba) this Master Plan provides the following evaluations for current status and projections for the period up to 2040:

- Quantify available water resources (surface and groundwater, in time and space)
- Quantify water resources demand by sector and catchment
- Identify surplus and deficit areas both in time and space
- Propose a management plan for optimal and rational utilization of available quantity of water resources
- Qualify all available water resources in the study area

4.5.6 Development Plan for the Special Economic Zone (SEZ)

4.5.6.1 Law

The SEZ law of Rwanda was enacted in 2011, which specifies the guidelines for the SEZs to operate, their structures and the roles of their key players that are the regulators, the developers and the operators. The Special Economic Zones Authority of Rwanda (SEZAR), founded under the Rwanda Development Board (RDB) is the regulator for the SEZ.

4.5.6.2 Kigali SEZ (KSEZ)

The KSEZ is located in the District of Gasabo with the developed area of 276 ha. The phase 1 (98 ha) was completed in 2013. Phase 2 (178 ha) is still under construction. The KSEZ is managed as a mixed-use zone and designed to accommodate the following types of investors.

- Heavy and light manufacturing industries
- Commercial wholesalers
- Chemical industries including pharmaceutical and plastics
- Warehousing

Table 4.5-1 presents the actual water consumption of customers operating in the KSEZ.

Table 4.5-1 Water Consumption at KSEZ

Items		Unit	Qty
Number of Customers		Entities	103
Consumption	Overall	m^3/month	15,600
		m^3/day	520
	per customer	m^3/month	150
		m^3/day	5

Source: Actual consumption data from July 2018 to March 2019, WASAC

4.5.6.3 Development Program

The GOR has set out the SEZ expansion program in 10 districts. The development programs in the CoK and its adjacent districts are shown in **Table 4.5-2**.

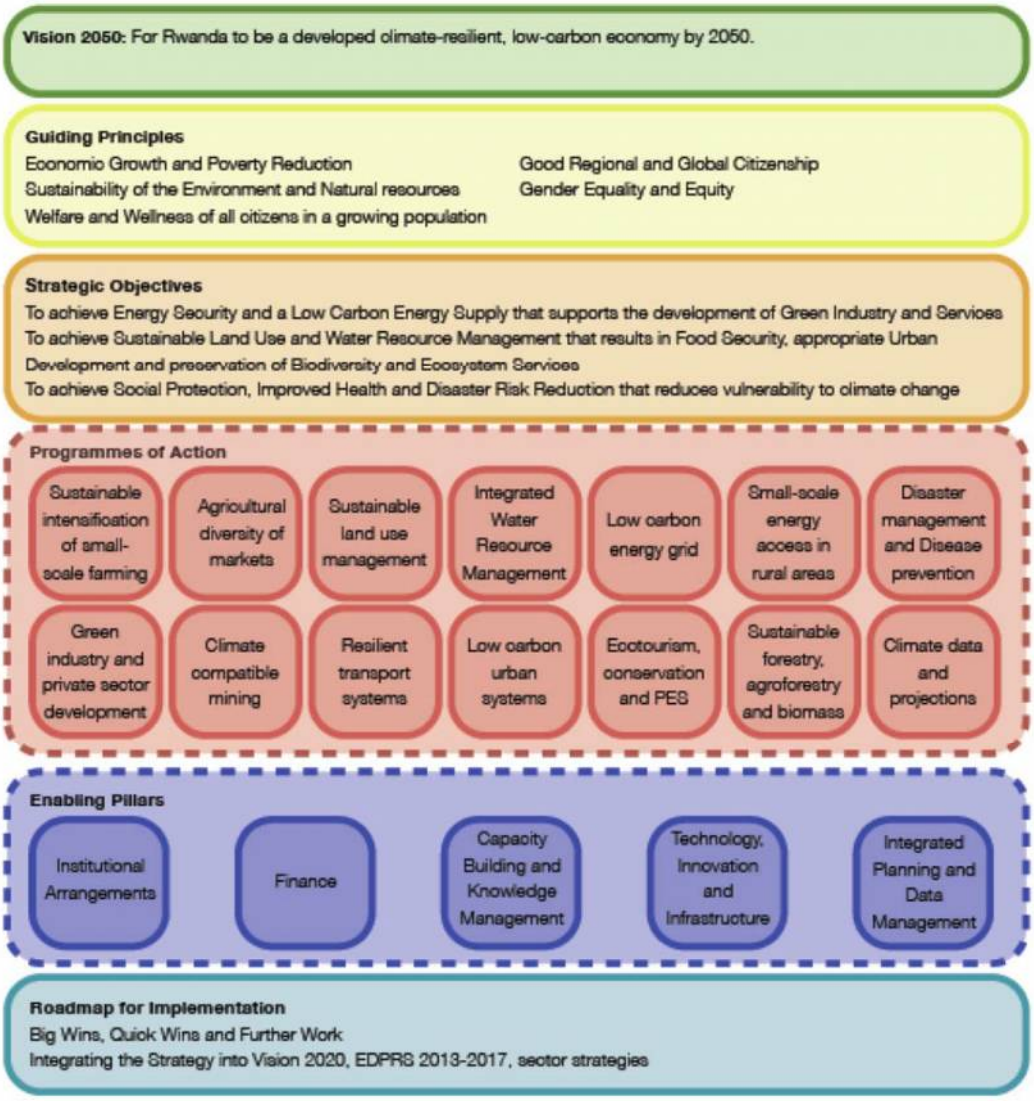
Table 4.5-2 SEZ Development Programs in Project Area

Location	Area (ha)	Status
1. Bugesera	330	A prime program due to its proximity to the CoK and new international airport under the construction
2. Kicukiro SME Parks	43.2	● The GOR provided the basic infrastructure on district industrial land, but not expropriated. ● Close to full occupancy.
3. Rwamagana	80	● Feasibility study and detailed engineering study completed ● 50 ha currently expropriated near Rwamagana City ● Two numbers of industries currently operate.

Source: Revised SEZ Policy, 2018, Ministry of Trade and Industry

4.5.7 Climate Change Adaptation

Rwanda has started implementing climate change adaptation measures since 2006 (The Rwanda National Adaptation of Action: NAPA, Republic of Rwanda 2006). The National Strategy for Climate Change and Low Carbon Development (Republic of Rwanda, 2011) set out the Vision for Rwanda to be a developed climate-resilient, low-carbon economy by 2050. This strategy guides a strategic development framework which includes a vision for 2050, guiding principles, strategic objectives, programs of action, enabling pillars and a roadmap for implementation and is presented under **Figure 4.5-1**.



Source: Rwanda Technical Report 2015 Future Climate for Africa, GCAP, UK Met Office and Atkins

Figure 4.5-1 Strategic Development Framework for Climate Resilient and Low-Carbon Economy

For mainstreaming climate adaptation, the REMA (Rwanda Environmental Management Authority) has provided guidelines for such activity. At present, the WASAC is following the guidelines for climate change adaptation.

4.5.7.1 Guidelines to Mainstream Climate Change Adaptation and Mitigation in the Energy and Infrastructure Sector

This Guideline was prepared in 2011 by the REMA and meant to mainstream the adaptation and mitigation of the foreseen climate change impacts. The guideline covers public sector infrastructure such as housing, transportation, energy, and water supply and sanitation. The facility for water supply is mentioned as a part of the water supply and sanitation sector.

The risks that are identified for the water supply facility are related to water quality degradation and increase

of water consumption duly impacted by global warming. Adaptation measures recognized at that moment were the expansion of water supply services to meet the growing demand and provision of quality water.

4.5.7.2 The City of Kigali Master Plan (CoK M/P)

In the City of Kigali Master Plan (CoK M/P), adaptation to climate change is mentioned in the aspect of protection from disaster damage to infrastructure such as floods, landslides, and erosion. In this regard, infrastructure development is now required to be sustainable and resilient to hazards

4.6 SUMMARY OF THE ABOVE PLANS

Summary of the above-mentioned plans for administrative and organizational subjects is shown in **Table 4.6-1.**

Table 4.6-1 Summary of the Above Plans

Plan/Policy	Key Contents (Target Year/Population)	Water Sector
Rwanda Vision 2020 (2012) (including Vision 2050 currently being revised)	• Original vision: prepared in 1998-1999 • Revised vision: prepared in 2012 • Target year: 2020 • 48 indicators (original 47 indicators)	Access to clean water (of the population) • 52% in 2010 • 74.2% in 2012 (current status) • 100% in 2020
National Strategy for transformation and seven (7) Years Government Program: (NST1)-2017-2024.	• Target year: 2024	7 Years Government Program: National Strategy for transformation (NST1)-2017-2024.
CoK M/P (2013)	• Target year: 2040 • Population projection: Low scenarios: 3.5 million Medium scenarios: 4.2 million High scenarios: 5.0 million • GDP projection: 12.29-21.28 trillion RWF	• Water demand unit rate: 120 lpcd (urban area) 80 lpcd (rural area) • Non-revenue water (NRW): 30% (2025) 15% (2040) • Projected water demand: 369,000 m^3/d (2025) 622,000 m^3/d (2040)
CoK M/P (update 2019)	• Target year: 2050 • Population projection: Low scenarios: 3.2 million Medium scenarios: 3.5 million High scenarios: 3.8 million • GDP projection: 12.3-29.8 trillion RWF	• Water demand unit rate: 120 lpcd (urban area) 80 lpcd (rural area) • Non-revenue water (NRW): Not given • Projected water demand: 573,000 m^3/d (2050, high population growth scenarios are applied and NRW is not included), of which 443,000 m^3/d for domestic (77%) and 130,000 m^3/d for no-domestic (23%).
National Water Supply and Sanitation Master Plans by AfDB (AfDB M/P)	• Target year: 2050 • Population projection: 3.8 million (basically, same as high scenarios of CoK M/P)	• Water demand unit rate: 120 lpcd • Non-revenue water (NRW): 15% • Projected water demand (only for domestic): 443,000 m^3/d (NRW is not included) 509,000 m^3/d (NRW is included) • Projected wastewater generation (only for domestic): 420,000 m^3/d (95% of domestic water consumption)

Plan/Policy	Key Contents (Target Year/Population)	Water Sector
Economic Development and Poverty Reduction Strategy II (EDPRS II), 2013-2018 (2013)	• Target year: 2018 • Average GDP growth: 11.5 % by 2018 • GDP per capita: $1,240 by 2020 • Poverty rate: 30% (2018), 20% (2020)	• Urban households within 200m of an improved water source 86.4% in 2012 (baseline) 100% by 2018
Water and Sanitation Sector Strategic Plan 2013/14 - 2017/18 (2013)	• Target year: 2018 • Develop fully and implement to 100% of the sector's institutional and capacity building framework by 2017/18. • Total budget: RWF 382.3 billion	• Raise rural water supply coverage to 100% by 2017/2018, and implementing public-private partnership (PPP) arrangements • Ensure 100% safe, reliable and affordable urban water supply services by 2017/18
National Water Supply Policy Implementation Strategy (NWSPIS) - December 2016	• Target year: 2020 • Total budget: RWF 337 billion	• % of rural households within 500m of an improved water source: 47.3% in 2015 (baseline, EICV 4) 100% by 2020 • % of urban households within 200m of an improved water source: 60.5% in 2015 (baseline, EICV 4) 100% by 2020 • % non-revenue water (NRW): 35% in 2015 (baseline) 20% by 2020
Integrated Water Management Policy (IWMP)	• Sustainable management of water resources of Rwanda	• Management of water on both demand and supply side and also integrates the other policies on forests, wetland, agriculture and land
Rwanda National Water Resources Master Plan	• Target Year: 2040 • Coverage: Nation-wide	• Water demand unit rate: For Urban: 60/70/80/100 lpcd for 2012/2020/2030/2040 For Rural: 40/60/80/100 for 2012/2020/2030/2040
Development Plan for Special Economic Zone (SEZ)	• Enacted in 2011 which specifies the guidelines for SEZs to operate, the structures and their roles of key players that are regulator, developer and operator.	
Climate Change Adaptation	• Following Vision 2020 target	• Impact recognized by climate change were Increase of demand for water supply increase of water temperature (water quality deterioration by algal bloom)

EICV: Integrated Household Living Conditions Survey
Source: JST

4.7 ACTIVITIES OF OTHER DEVELOPMENT PARTNERS AND THEIR PLANS

4.7.1 AfDB

The African Development Bank (AfDB)[4] has operated eleven projects pertaining to water and sanitation sector since 1977 with the total commitment amount of approximately USD 333 million and as listed in **Appendix-13**. Amongst them, four projects that are in operation as of Jun/2019 are itemized below:

- Sustainable Water Supply and Sanitation Program – Additional Financing
- Sustainable Water Supply and Sanitation Program
- Kigali Bulk Water Supply Project
- National water supply and sanitation master plans

4.7.2 USAID

The United States Agency for International Development (USAID)[5] supports an integrated program that improves the sustainable management of water in Rwanda. The program builds local capacity to monitor and manage water resources and helps develop water and sanitation services to the public, with a focus on the rural poor. Its aid related to water supply and sanitation in Rwanda as published on its official website is summarized in **Appendix-14**.

4.7.3 WB

Since 1970, the World Bank (WB)[6] has been operating 145 projects for a total equivalent amount of 4,940.40 million USD. Amongst them, four projects were related to the water supply sector and all the projects were closed / completed as on Jun 2019. Detailed contents of the WB's aid related to water supply project in Rwanda and as available in its official website and it is summarized in **Appendix-15**.

4.7.4 UNICEF

The UNICEF[7] began its development work in Rwanda in 1986. The new 2018-2023 Country Program will continue to support the realization of the rights of every child, especially the most disadvantaged. Guided by the SDG principle 'leaving no one behind', the program will contribute to five priorities under the social transformation pillar of the Government's National Strategy for Transformation 2017-2024: (i) ensuring access to quality health for all; (ii) reducing malnutrition; (iii) increasing access to and improving the quality of education; (iv) moving towards a modern Rwandan household; and (v) enhancing graduation from poverty and promoting resilience. The UNICEF's country program for Rwanda has seven main components, namely, (i) Child Health, (ii) Nutrition, (iii) Early Childhood Development, (iv) Education, (v) Child Protection, (vi) Water, Sanitation and Hygiene (WASH), and (vii) Social Policy. The WASH Program aims

[4] https://projectsportal.AfDB.org/dataportal/VTopCountry/show/RW?query=&hi5Id=&offset=105&max=15&sort=actualStartDate&order=desc
[5] https://www.usaid.gov/rwanda/water, https://explorer.usaid.gov/query
[6] http://projects.worldbank.org/search?lang=en&searchTerm=&countrycode_exact=RW
[7] UNICEF Rwanda, Country Profile 2018

to ensure that more Rwandan households and communities, particularly in rural areas, have access to safe and sustainable WASH services, and children and their families practice key hygiene behaviors. The focus is on:

- Monitoring to improve evidence-based decision making is strengthened.
- Developing sustainable financing for WASH.
- Ensuring more families use basic sanitation services and practice handwashing with soap.
- Ensuring more families access and use safe, sustainable and reliable water supply services.
- Improve WASH in schools, including menstrual hygiene management.

4.7.5 DFID

Projects that include a component of water supply and aided by the Department for International Development (DFID) in Rwanda are summarized below[8] :

- Rwanda Growth and Poverty Reduction Grant (GPRG):
  - Project description: To enhance the GOR's ability to reduce poverty and inequality, provide better essential services to poor Rwandans (especially education, health, water and sanitation, social protection) and increase equitable, pro-poor economic growth through increased investment in infrastructure, energy and agriculture.
  - Duration: From Aug. 2012 to Dec. 2015
  - Project budget: £8,000,000
- General Budget Support to the Rwanda-Second Three Year Phase:
  - Project description: To improve the effectiveness of the government budget in achieving the economic, social and governance targets of the Economic Development and Poverty Reduction Strategy.
  - Duration: From Aug 2009 to May 2013
  - Project Budget: £105,849,999

4.7.6 KfW

Projects related to water supply and aided by the KfW (German state-owned development bank) in Rwanda are summarized below.

- Water Supply for 8 rural Communities / Kigali, Phase I & II
  - Project Description: During the program (totaling about 925 km²), 40 gravitational and three pump-assisted drinking water systems were built in the rural area around Kigali, and 14 more rehabilitated, altogether installing 468 water supply points for approximately 524,000 inhabitants (83 enclosed wells and 385 standpipes). Complementary measures included the preparation of

[8] https://devtracker.dfid.gov.uk/

users for assuming operational responsibility for the facilities and setting up or strengthening financially self-sustaining, local self-governance capacities (user committees).

- Project Budget: EUR 8.1 million
- Timing of post-evaluation: 2011

- Water Supply Bugesera South
  - The objective of the project was to ensure the rural population living in the municipality of Ngenda in the Bugesera-South region to meet their basic needs through a provision of hygienically safe drinking water via taps from a central water supply facility. Indicators were the coverage index, continuous water supply, per capita consumption, water quality, changes in water use practices and proper tap operation. The project was intended to contribute to improving the health of the rural populace by reducing the related hazards (overall objective).
  - Project Budget: EUR 15.3 million
  - From 1990 (for the 96-month duration)

4.7.7 Dutch Government's Aid

4.7.7.1 SusWAS Project

The SusWAS Project[9] is a PPP-based project that is jointly invested by the Dutch government for 60% and the remaining by the private sector for 40%. It is a project for the Kanombe and the Remera branch in the CoK, focusing on measures against NRW, the establishment of Management Information System, training on PPP contract style, preparation of maintenance manual, and construction of small-scale water treatment plants.

The Project is carried out by the Vitens Evides International from the Netherlands. The activities of this project are divided into six phases as follows:

- Phase 1: Establishment of 5 pilot DMAs in the Kanombe branch area
- Phase 2: Sectorization of entire the Remera branch area
- Phase 3: Establishment of 2 pilot DMAs in the Remera branch area
- Phase 4: Sectorization and DMA establishment over the entire Kanombe branch area
- Phase 5: DMA establishment over the entire Remera Branch area
- Phase 6: Preparation of a roll-out plan for other branches and regional cities

The official completion date of the project is at the end of June 2017.

Under the SusWAS project, two branches are converted to DMA in order to monitor flow and pressure as part of the NRW reduction measure. Electromagnetic flow meters and water pressure gauges are installed at the DMA boundary under the Project. The Project has built up a mechanism that accumulates and manages the measurement results on the Internet with a server (supplied by the Itron Company from France).

[9] Basic Data Collection Study on Urban Water Supply Systems in the Republic of Rwanda, February 2017, JICA

The results can also be browsed on the Internet.

4.7.7.2 SCALE Project

Scaling universal access to safe and climate-resilient water services in Rwanda, with a focus on small towns (SCALE), which is an on-going project[10] based on the partnership agreement amongst the WASAC (with financed by the AfDB), the Vitens Evides International and the WaterAid. A partnership agreement was signed among all the three project partners in which they had indicated their commitment to the successful implementation of the Project. The agreement sets out the roles, tasks and responsibilities of the partners for execution of the Project in accordance with the grant decision within the agreed time schedule and budget. Under the agreement, the partners undertake to act in good faith with respect to each other's rights and to adopt all reasonable measures to ensure the realization of the Project's goals. The key information of the Project is:

- Project title:
  Scaling universal access to safe and climate-resilient water services in Rwanda, with a focus on small towns (SCALE)
- Start and end: 1/Jan/2019 to 31/Mar/2024
- Location: The Nyagatare and the Rwamagana Branches of the WASAC - Rwanda
- Project budget: €4,900,632. - out of which a subsidy of €2,940,379
- Lead partner and its project contribution:
  The Vitens Evides International B.V – (NL - Private: 310,253.00 EUR in cash/250,000 EUR in-kind)
- Formal partners and their project contributions:
  - ✓ The WASAC (RW – 1,200,000 EUR cash and 150,000 EU in-kind),
  - ✓ The WaterAid (RW – NGO 50,000 EUR in-kind),
  - ✓ The Ministry of Infrastructure (RW – Public 0 EUR)

The overall objective of the SCALE is to accelerate the provision of climate-resilient and social inclusive water services to the residents of the Nyagatare and the Rwamagana branches of the WASAC. The project will document, evaluate and mainstream (where applicable) the demonstration pilot projects into the existing structures of the WASAC with the objective to accelerate results on the remaining 12 branches of the WASAC outside the CoK.

The Project's principal goals are:

- providing access to clean drinking water services to at least 100,000 people in the Nyagatare and the Rwamagana branches of the WASAC;
- providing supplementary water access to children in schools of the Nyagatare and the Rwamagana branches through climate-resilient technologies such as rainwater harvesting;
- promoting and realizing safe, reliable and financially sustainable water service operations in the

[10] Inception Report of 'Scaling universal access to safe and climate resilient water services in Rwanda, with a focus on small towns (SCALE)', October 2019 shared by WASAC

Nyagatare and the Rwamagana branches through the implementation of Water Safety Plans, Non-Revenue Water Reduction Program;
- document and validate demonstration projects and assess their viability to guarantee its continued implementation of suitable practices upon completion of the project;
- enhancing the exchange of existing knowledge pertaining to the best practices in order to accelerate progress across all branches.

4.7.8 Hungarian Government's Aid

The Government of Hungary is one of the key countries that contribute development of Eastern African countries including Rwanda[11] as well as Uganda[12], through bilateral aid scheme.

The Government of Hungary, through its Ministry of Foreign Affairs and Trade, shows its positive interest on contributing to rehabilitation/expansion of Karenge WTP that is itemized as one of the priority projects listed in the 15-Year Investment Plan under the Study. The Hungarian government, with EXIM Bank Hungary that is a potential funding source for the above project, has initiated discussion with WASAC regarding this matter since 2020, and the discussion is still carrying on as of July/2021. The EXIM Bank Hungary[13] increases its presence as one of the key potential funding sources for the Hungarian government to raise its finance for ODA projects.

Following is the key information including condition and scale of the Hungarian government's loan to Rwanda, according to the interview with the Hungarian side.

- Loan amount:
  - USD 50 million in total (still flexible and negotiable)
  - No additional/ further grant portion
- Grace period:
  - 2 to 5 years in general, or 10 years may be granted depending on situation and/or nature of a project.
  - For the case of the loan to the rehabilitation/ expansion of Karenge WTP, grace period could be extendable until, at least, the timing of its inauguration.
- Repayment period: 10 years or more (flexible and negotiable)
- Interest rate: virtually zero (0) percent
- Condition of loan: tied-loan, which must contain fifty (50) percent or more of Hungarian goods and/or technical service.

[11] https://dailynewshungary.com/hungary-and-rwanda-sign-strategic-development-agreement/
[12] https://nefe.kormany.hu/overview-of-hungary-s-international-development-programme-in-the-republic-of-uganda
[13] https://bankwatch.org/wp-content/uploads/2019/06/Hungary.pdf

CHAPTER 5 CONDITION OF EXISTING WATER SUPPLY SYSTEMS

5.1 WATER SUPPLY COVERAGE AND SUPPLY AREA

Water supply coverage in the City of Kigali and its adjacent 7 sectors are summarized in **Table 5.1-1**. The water supply coverage in the City of Kigali, including for both piped and non-piped water supply is 85%, as provided in the NST1. Meanwhile, the WASAC's coverage is estimated to be 645,000 populations which are around 41%[1] to 49%[2] of the City's total population; the remaining population may be covered by natural springs, shared tap from neighbors or private wells. Note that the population as in 2018 is the projected value by the NISR or the CoK since the official census was conducted in 2012. The estimated coverage is low compared to the previous data as per the EICV5, in which the access to piped water in the CoK was shown as 77.7% and 33.5% in the adjacent 7 sectors. This gap between the EICV5 and the estimate may be due to the population having shared piped water supply with the neighbors or the lag of increasing served population due to a rapid population increase in the target area.

Table 5.1-1 Water Supply Coverage in the CoK and Adjacent Sectors

	NISR Projection*4	CoK Projection	Population served
Population in CoK in 2018	1,305,286	1,582,659	-
Population in adjacent 7 sectors*5		217,522	-
Total Target Population	**1,522,808**	**1,800,181**	-
Covered by on-plot piped water supply*1, 2	29%	25%[3]	388,100[4]
CHAPTER 5 Covered by Public Stand-pipe*1,3	**CHAPTER 6** 20%	**CHAPTER 7** 16%[5]	**CHAPTER 8** 256,900[6]
Coverage by WASAC	**49%**	**41%**	645,000
Shared water use or non-WASAC	36%	44%	-
Total Coverage*6	85%	85%	-

Note:
*1 Based on the WASAC's billing record in March 2019 (105,580 nos. in which 97,022 for residential, 734 for public tap, and the balance is for non-residential connections).
*2 4.0 population/household (EICV5, 2016/2017)
*3 350 customers/public tap
*4 Based on NISR population increase rate, estimated by AfDB M/P
*5 Estimated in this study based on the population projection from each district office
*6 Provision by 7 Years Government Programme: National Strategy for Transformation (NST1)

The water supply areas catered by the existing WTPs are presented in **Figure 5.1-2**. The three major water production facilities (the Nzove, the Kimisagara, and the Karenge) cover most of the CoK and its adjacent seven sectors. The Karenge WTP covers the eastern areas including the Muyumbu Nyakaliro in the Rwamagana district, and the Rusororo, the Masaka, the Ndera, and the Nyarugunga sectors in the city. The Kimisagara WTP covers the city center (the Muhima), the Kimisagara, the Nyarugunga and a part of the

[1] Percentage of CoK projection
[2] Percentage of NISR projection
[3] 97,022 x 4.0 / 1,582,659 (based on EICV5)
[4] 97,022 x 4.0 (based on EICV5)
[5] 734 x 350 / 1,582,659 (based on WASAC's Std)
[6] 734 public taps x 350 pop/tap (based on WASAC's Std)

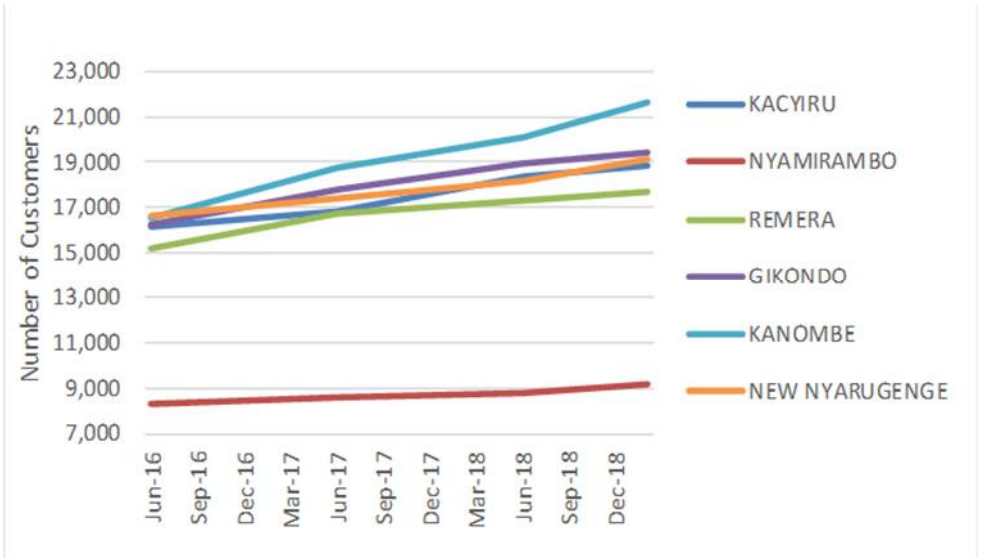
Kimihurura, the Gikondo, and the Kacyiru. Note that the distributed water from reservoirs under the Kimisagara WTP service area is a mixture of the water from the Kimisagara (13,000 m^3/day) with the transmitted water from the Nzove WTP (approx. 3,000 m^3/day, June 2019). The Nzove WTP supplies water to the remaining areas which extend from the western Runda and the Rugarika in the Kamonyi district to the southern Mageregere and the Gahanga sectors, the northern Kinyinya and the Bumbogo sectors, and the eastern Ndera sector.

Water supply in the CoK is currently being managed by six branches, namely; the Gikondo, the Kacyiru, the Kanombe, the Nyamirambo, the New Nyarugenge, and the Remera. The total number of connections is 105,850 as of March 2019. The largest number of customers (21,000 connections, 20% of the total number of connections) and the most growing branch is the south-eastern Kanombe branch. Most of the water in the Kanombe branch is currently supplied from the Karenge WTP and is presently suffering from water shortage (**Table 5.1-2** and **Figure 5.1-1**). Note that the New Nyarugenge Branch started its operations from March 2019 by combining the Muhima and the old Nyarugenge branch. The supply areas from the major production facilities are not consistent with the supply area from the branches. The Karenge WTP covers most of the Kanombe branches while some areas in the Ndera (the Buhoro and the Kigarama reservoirs) and the Kanombe sectors (the Kicukiro, the Nyanza and the Rwandatel reservoirs) use the water from the Nzove. The Kimisagara WTP supplies water to the Nyamirambo and a part of the New Nyarugenge branch area, duly supported by the water from the Nzove especially through the reservoirs of the Ntora and the Mont-Kigali.

Table 5.1-2 Daily Average Consumption by Branches

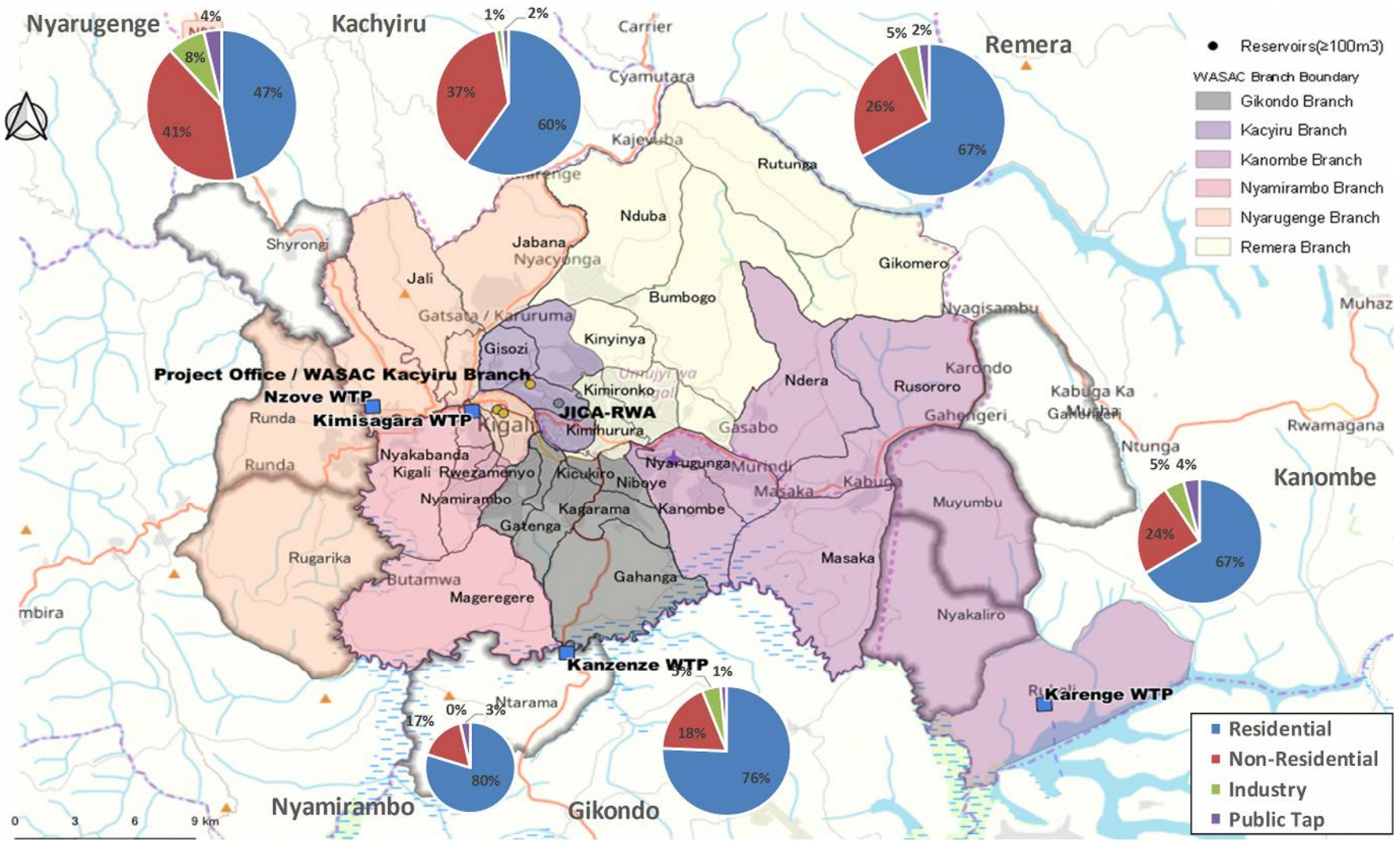
Branches	Daily Consumption, Billed Amount Basis (m^3/day) *1	Percentage to total
Kacyiru	10,643	21%
Kanombe	8,001	16%
Gikondo	7,892	16%
Nyamirambo	3,404	7%
Nyarugenge	10,518	21%
Remera	9,637	19%
Total	50,096	100%

Source: this study
Note *1: Based on the bill in March 2019



Source: JST

Figure 5.1-1 Number of Connections by Branches



Source: JST (Data from WASAC)
Note: Water consumption is based on the data in March 2019

Figure 5.1-2 Existing Service Areas and Water Consumption

5.2 MININFRA

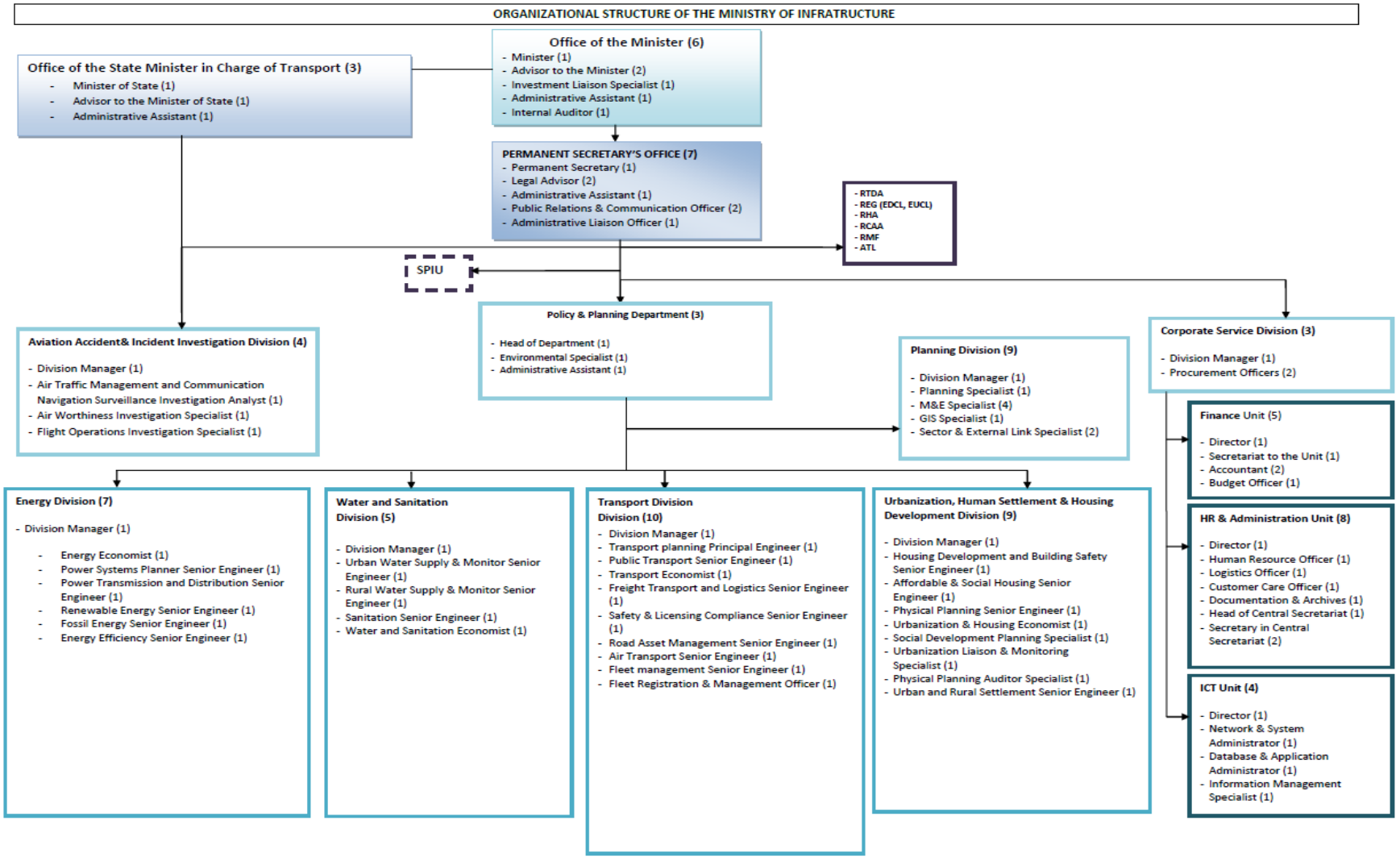
MININFRA supervises WASAC for initiating, developing, and facilitating urban development programs aimed at providing affordable shelter with due regard to adequate water and sanitation facilities for the population.

MININFRA is also in charge of initiation and development program of the following industrial sectors.

- National transport infrastructure network
- Power generation facilities
-
- Access to affordable energy, water and sanitation, and transport infrastructure and related services for the population
- National infrastructures are in line with regional integration
- Implementation of quality standards and norms, cost effectiveness, response to environmental sustainability,
- Implementation of national policies and programs on matters relating to habitat and urbanism, transport, energy, water and sanitation
- Development programs under the decentralized structures under the respective sub-sectors as per the District Development Programs in each district

MINIFRA also supervise the functioning and management of public institutions, agencies and companies under the Ministry of Infrastructure including existing agencies such as Road Maintenance Fund (RMF), Rwanda Civil Aviation Authority (RCAA), Rwanda Energy Group (Energy Development Company Ltd and Energy Utility Company Ltd), Water and Sanitation Corporation Ltd. (WASAC), Rwanda Transport Development Agency (RTDA), Rwanda Housing Authority (RHA), Rwanda Air and other agencies to be formed under its sub-sectors;

The organization chart of the MININFRA is presented in **Figure 5.2-1**.



Source: MININFRA

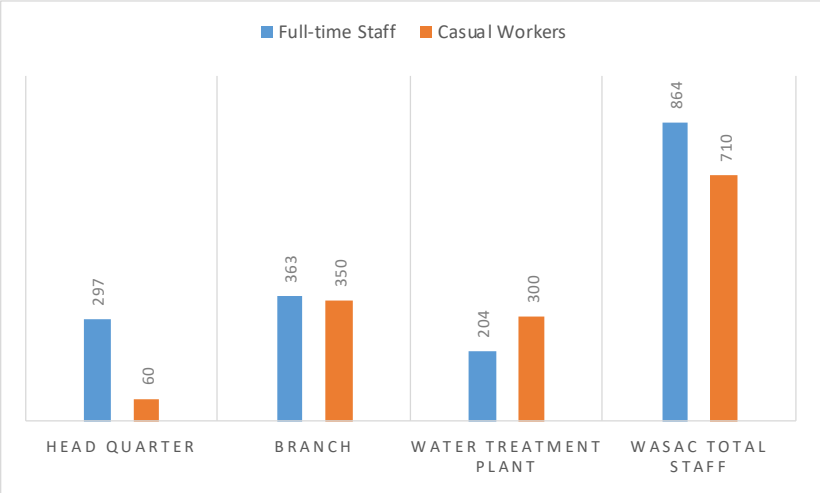
Figure 5.2-1 Organization Chart of MININFRA

5.3 WASAC

5.3.1 WASAC Organizational Structure

WASAC is the main service provider pertaining to water supply and sanitation services in Rwanda as national utility. The Energy Water and Sanitation Authority (EWSA) was responsible for the water works in the CoK up to August 2014. Since then, the water and sanitation department of EWSA became independent as WASAC, which is wholly owned by the government. WASAC is responsible for the water supply business at national level with its head office, branches, and water treatment plants (WTP).

WASAC provides water supply services by implementing water supply project planning, research, maintenance and guidance nationwide. As of 2019, it has water connections with approximately 110,000 customers and a total of 864 full-time staff. (297 at the head office, 363 at the branch, 204 at the WTP). WASAC also employs approximately 700 short-term contract workers assigned for field work at branches and WTP. **Figure 5.3-1.**shows the placement of staff, including regular and temporary staff.



Source: JST based on WASAC data

Figure 5.3-1 WASAC Staff Number and Allocation

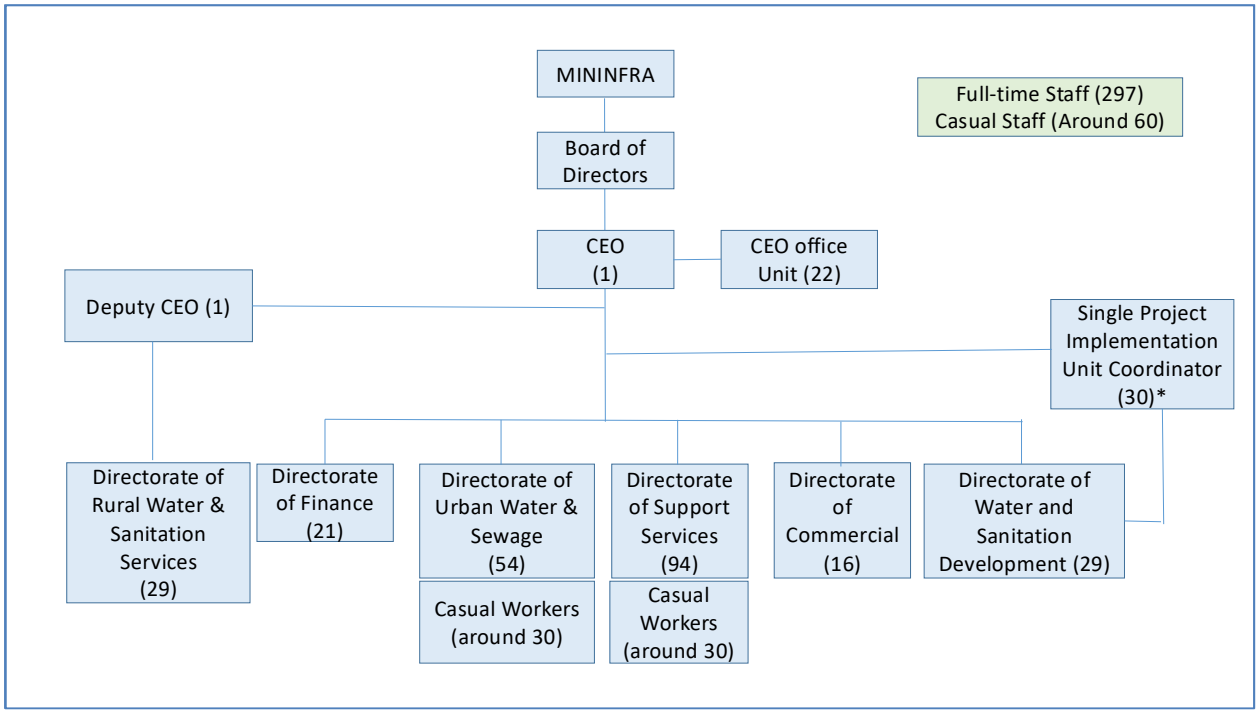
5.3.2 WASAC Head Office Structure

WASAC is administered by the MININFRA and is managed by seven board members, including the CEO in charge of overall business and the Deputy CEO in charge of the Rural Water and Sanitation Services. Its regular business decision making and activities are implemented by six directors who are responsible for its technical and general services under overall supervision of CEO and DCEO.

The current organization structure of WASAC Head Office is presented in **Figure 5.3-2** below and the detailed organizational structure is presented in **Figure 5.3-3**. Head office consists of around 300 full-time

staff within the job grade 1~5[7]. These grades are defined based on qualifications of officer and engineer such as senior engineer, manager, and directors. Main administration and engineering works are implemented by the senior managers and engineers of each Directorate with a support of around 60 casual workers.

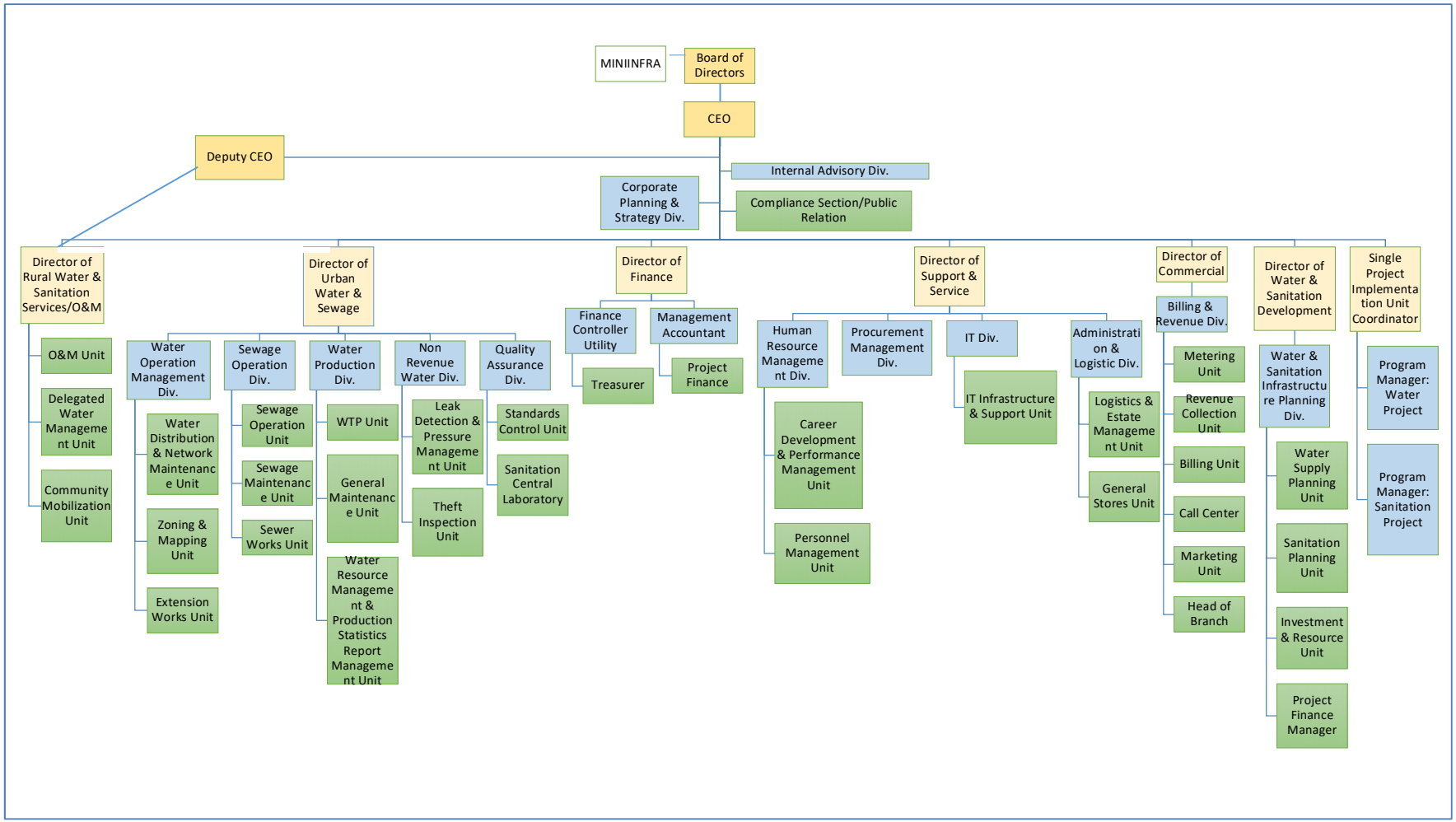
WASAC has a high demand for staff ability, as staff who do not meet the job requirement level are treated under temporary dismissal sometimes. In addition, WASAC's upper management constantly considers the optimal organizational structure with a desire to improve work.



*Number of SPIU staff is dependent on the scale of on-going projects by development partners.
Source: JST based on WASAC data

Figure 5.3-2 WASAC Head Office Organizational Structure

[7] WASAC job grade #1: CEO, DCEO, grade #2: Directors, SPIU Coordinator, grade #3: Manager, Head of Unit, grade #4: Specialist, Senior Engineer, Senior Officer, grade #5: Engineer, Officer, grade #6: Operator, grade #7: Support staff, grade #8: Technical helper



Source: JST based on WASAC data

Figure 5.3-3 Detailed WASAC's HQ Organization Chart

5.3.2.1 Core Function of Each Directorate

WASAC has a Human Resource Manual which describes the role and function of each directorate. The core function of each directorate is described in the following **Table 5.3-1.**

Table 5.3-1 WASAC Head Office Core Functional Structure

Name of Directorate	Core Functions
CEO Office	The CEO heads WASAC and is responsible for ensuring its efficient functioning. The CEO reports to the Board of directors. The following divisions and units are managed by the CEO; • Company Secretary • Legal functions • Internal Audit • Public Relations and Communication Units • Legal Advisory Services • Corporate Planning and Strategy Division
Deputy CEO Office	The Deputy CEO is in charge of rural water and sanitation services, also acts on behalf of the CEO in his/her absence.
Rural Water and Sewage Service	Under the Deputy CEO management, it operates and manages all aspects of production, quality control and distribution of water and sanitation service and collection of revenue, planning and installing new water and sanitation infrastructure in the rural areas of the country. Includes the following units; • Community Mobilization Services Unit • Resource Mobilization Services Unit • Rural Operations Unit • Rural Water Services Management Units
Single Project Implementation Unit (SPIU)	The SPIU Coordinator is responsible for all aspects of the project implementation and directly reports to the CEO.
Finance	Responsible for budgeting and accounting, collection and disbursements, financial reporting and coordinating the annual audit process. Develops and advises on appropriate fiscal management systems and procedures. Includes the following units; • Management accountants • Financial controller
Urban Water and Sewage Services	Operates and manages all aspects of production, quality control and distribution of water and sewerage services and collection of revenue, planning and installing new water and sewerage connection in the urban areas of the country. It includes the following units; • Water Operation Services • Sewerage Operation Services • Non-revenue Water Control Services • Quality Assurance Services • Water Production Services
Support Services	Responsible for the following divisions; • Human Resource Management • Information and Communication Technology • Procurement Management Services • Administration and Logistic Services
Commercial Services	Operates and manages all aspects related to customer services, which include billing, revenue collection and marketing of WASAC products and services. It includes the following units; • Marketing and Customer Care Services • Billing and Revenue Management Services
Water and Sanitation Development Service	Responsible for planning and implementation of water and sanitation projects development. Includes the following units; • Infrastructure planning unit • Water Project Implementation Unit • Investment Unit • Sanitation Project Implementation Unit

Source: JST based on WASAC HR Policy & Procedure Manual (2018)

5.3.2.2 Classification of Staff

The grades of managers, officers, and staff of the WASAC are classified into 8 nos. of grades as presented in **Table 5.3-2** below.

Table 5.3-2 Staff Classification of the WASAC

Grade	Categories
1	CEO Deputy CEO
2	Directors SPIU Coordinator
3	Managers Head of Unit
4	Specialist, Senior Engineers Senior Officers
5	Officers, Engineers
6	Operators
7	Support Staff (Drivers)
8	Technical helpers (Laboratory helpers, watchman, other helpers)

Source: WASAC HR Policy & Procedure Manual (2018)

5.3.2.3 WASAC Mission

The WASAC Mission Statement, Vision Statement and Core Value are aligned for the formation of the corporate culture as shown in **Table 5.3-3.**

Table 5.3-3 WASAC Statements, Values and Motto

Mission Statement:
"Providing quality, reliable and affordable water and sewerage services through continuous innovation and detailed care to our customer's needs."

Vision Statement;
"To be the most sustainable Water and Sanitation Utility in Africa, exceeding stakeholder's expectations."

Core Values;
1. Customer oriented
2. Efficiency
3. Integrity
4. Innovation
5. Professionalism

Motto;
WASAC: DIGNIFYING LIFE

Source: WASAC HR Policy & Procedure Manual (2018)

5.3.2.4 Human Resource Development

WASAC has an organized human resource (HR) plan that acknowledges the capacity development of staff is a key factor for business growth and development.

Following this HR policy, several training modules are held and planned for the management, managers, engineers and officers.

Most of training modules are focusing on data management, utilization, and an improvement of ICT skills to enhance labor productivity. The training plan for 2020 is shown in the **Table 5.3-4**. below and its intentions.

WASAC management acknowledged that GIS data utilization is a key factor to enhance O&M of water supply and customer data,

- A training for enhancing NRW reduction is specially focused as an important issue to improve water sales revenue and WASAC financial performance.
- Waste management module is started in recent year as an important O&M issue

Table 5.3-4 WASAC Training Plan during the year 2020

Training Modules	Categories	Training Purpose	N^0 of staff (Trainees)	Training Schedule
Surveying Techniques, Instruments and GIS	Operators and Engineers	GIS utilization for O&M	59	January 2020
International Water Quality Standards	Operators & Engineers	Water quality improvement	59	February 2020
Computer Essentials, Spreadsheet, Word Processing	Management	Documents processing by computer	20	February & March 2020
	Officers and Technicians		10	
	Secretaries		9	
Wastewater Management and Sludge Management Systems	Operators & Engineers	O&M for waste management	59	March 2020
Computer Essentials, Spreadsheet, Word Processing	Officers and Technicians	Documents processing by computer	18	March 2020
	Secretaries		25	
Online Essentials, Presentation, Online Collaboration	Management	ICT processing improvement	20	March 2020
	Officers and Technicians		10	
	Secretaries		9	
Online Essentials, Presentation, Online Collaboration	Officers and Technicians	ICT processing improvement	18	April 2020
	Secretaries		25	
Online Collaboration, IT Security	Management	ICT processing improvement	20	May 2020
	Officers and Technicians		10	
	Secretaries		9	
Online Collaboration, IT Security	Officers and Technicians	ICT processing improvement	18	May 2020
	Secretaries		25	
Business Analysis	Management	Strategy building	3	June 2020
NRW Reduction	Management	Strategy, O&M for NRW reduction	20	Late 2020
	Officers and Technicians		20	
Total			203	January to June

Source: WASAC

5.3.3 WASAC Branches

5.3.3.1 WASAC Branches' Structure

There are six WASAC branches in charge of the CoK (Nyarugenge, Nyamirambo, Gikond, Remera, Kacyiru and Kanombe branch). Each branch manages around 20,000 connections (**Table 5.3-5)**. One branch has approximately 40～50 staffs, of which around 20~25 are full-time in charge of office work

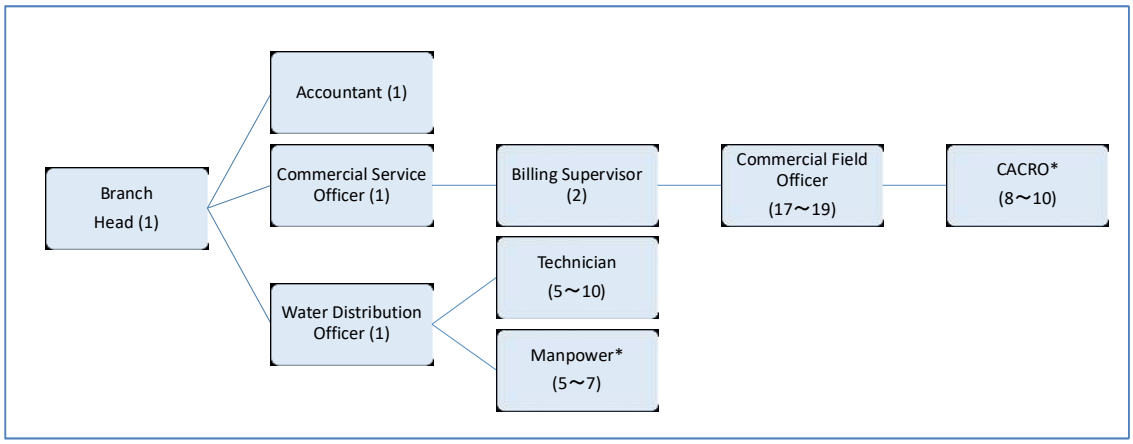
pertaining to the customer connections/support and around 20~30 are casual workers.

Table 5.3-5 Number of connections managed by the six branches (Dec. 2019)

Branch	Nyarugenge	Kachiru	Remera	Kanombe	Gikondo	Nyamirambo
Number of connections	21,824	19,718	20,165	23,647	20,580	10,013

Source: JST based on WASAC data

The standard branch structure is shown in **Figure 5.3-4** below. It has reporting lines to the Branch Head from the Commercial Service Officer, the Water Distribution Officer and the Accounting Officer.



*CACRO and Manpower are short term employment staffs.
Source: JST based on WASAC data.

Figure 5.3-4 WASAC Branches' Structure

Meter maintenance and reading are handled by the Commercial Field Officer and the CACRO by short-term staffs. Meter-readers visit their customers with their own transport to read the meter-index and report the index to the concerned officer without going back to the branch. Average number of the index being read by one reader in one month is for 1,000 connections. Technicians and manpower are utilized for carrying out various field works such as setting/repairing pipes, digging of ground.

5.3.3.2 Function of the Branches

Main functions of the branches pertain to the following activities.

- General customer support for the existing connection, such as service complaint, water leakage
- Marketing activity for new connection
- O&M of the connection, such as repairing pipes and setting up new pipes
- Meter reading, including setting and maintenance of meter device
- Billing analysis and issuing an invoice based on the meter reading result.

5.3.3.3 Collection of Water Bill

Apart from issuing an invoice, collection of water charge bill is not a function of the branch. All payments are made by the customer directly through WASAC-bank account or mobile money; no money is physically paid to branch staff.

Water supply is stopped if payment is not received within 15 days after issuing the invoice and is resumed only after payment is confirmed.

5.3.3.4 Meter Device

The installation of Automatic Meter Reading Devices is planned for upgrading the current meters on which index are being read manually by the meter readers. These new devices would enable the meter readers to read the index through mobile devices over a short distance.

WASAC plans to install 200,000 devices by 2023. Around 2,000 connections per month are expected to be read after installation of the devises. The same number of meters is expected to be read in branch even after the increase of connection due to the improved efficiency of meter reading.



Source: WASAC

Figure 5.3-5 Example of Automatic Meter Reading Device

5.3.3.5 The WASAC's Scope of Services

Three major scopes of services by the WASAC are stated in the following **Table 5.3-6.**

Table 5.3-6 Business Scope-Definition of Areas

Business Stream	Type of business	Area	Type of connections	Nbr. of connections
Urban Water Supply	Based on existing systems and branches Centralized production units	Largest cities Minimum population of 25,000	Individual Shared between households	Minimum 1,400 connections
Rural Water Supply	Small production units, e.g., spring, catchment, single wells	Small cities and villages under 25,000 people	Under 1,400 connections per system	Standpipes
Urban Sanitation	Centralized and semi-centralized sewerage systems	Largest cities Minimum population of 25,000	Individual connections	To be defined

Source: WASAC 5-year business plan (2016)

5.3.3.6 Urban Water Supply

The urban water supply business corresponds to the core activities of the WASAC and relates to the production and distribution of potable water. This also includes the management and supervision of bulk water production under the PPP operation. The details of activities are stated in **Table 5.3-7**.

Table 5.3-7 Urban Water Supply Business Stream Activities

Activities	Definition
Water production operations	Operation and management of the abstraction of raw water, water treatment and transmission facilities, including water quality control
Water distribution operations	Operation and management of the water supply distribution network in the urban areas supplied from a water treatment plant. Repairment of networks
Bulk water provider management and supervision	Coordination and supervision of the activities of the bulk water supply provider as well as the integration of their supply into the water supply network

Source: WASAC 5-year business plan (2016)

5.3.3.7 Urban Sanitation

Urban sanitation business became the main scope of business during recent years. The details of activities are stated in **Table 5.3-8**.

Table 5.3-8 Urban Sanitation Business Activities

Urban Sanitation Activities		Definition
Sewer collection	Collective	Centralized sewerage systems covering un-urban areas connected to a wastewater treatment plant
	Semi collective	Sewerage system collecting the effluent of a residence, compound of several houses, and connected to some small wastewater treatment facilities
	Sludge	Septic tanks and latrine pits emptying waste collected by sewerage trucks
Treatment	Collective	Wastewater treatment plants and ponds able to treat centralized sewerage system effluents and liquid waste
	Semi collective	Wastewater treatment plants and ponds able to treat the effluents from semi collective sewerage systems
	Liquid waste	The point in a wastewater treatment plant treating collective sewerage effluent where liquid waste collected by sewerage trucks can be discharged and treated.

Source: WASAC 5-year business plan (2016)

5.3.3.8 Rural Water Supply

The WASAC has the mandate to ensure accessibility to rural water supplies.

Table 5.3-9 lists up the major rural water activities.

Rural water supply has become the responsibility and authority of the county of the local government due to decentralization, and the county basically owns the water supply facility. Most of the water supply businesses are outsourced to private operators (POs), and in most cases POs supply rural areas with natural water sources that do not require large capital investment. The PO pays royalties to the county according to sales volume and is positioned as a business partner incorporated into the local water supply operation. WASAC is responsible for providing technical assistance to POs, planning and implementing facility construction, managing contracts between groups and POs, and supporting community organizations for the proper use and maintenance of water sources.

Table 5.3-9 Rural Water Supply Activities Definition

Activities	Definitions
Coordination of existing initiatives	Coordination and monitoring of the existing rural water supply outside WASAC operations that are initiated/operated by private operators
Operations of existing schemes	Existing water supply schemes operated by WASAC Natural spring source is operated by PO with support of WASAC for preservation
Support	Technical and management support for rural water schemes to PO outside WASAC operations

Source: JST

5.3.3.9 Solid Waste Management

WASAC started the treatment and management of solid waste in Kigali at the request of CoK. This commitment comes with two major improvements of introducing new contractor for the daily management of Nduba dumpsites as well as the Feasibility Study for construction of modern Solid Waste Management System including Detailed Design for the Construction of a Sanitary Landfill at Nduba.

Business plan for waste management is focused by Corporate Planning & Strategy Dept. and O&M is handle by Water & Sanitation Development Dept. Management acknowledges the importance of managing solid waste management as a government utility, at the same time making business strategy as profitable business.

5.3.3.10 Business Performance

The recent WASAC business performance results based on the sector benchmarking and target are shown in **Table 5.3-10**.

Table 5.3-10 Sector Benchmarking and Target of the WASAC

No	Service Indicator	Status 2015/2016	Status 2016/2017	Sector Benchmark at year 2017
1	Water Coverage	90% (urban)	100% (urban)	80% Low Density Area 90% High Density Area
2	NRW	35.5%	38.3%	25% after 5 years
3	Metering Ratio	100%	100%	
4	Billing for services	98%	99%	100% monthly
5	Collection Rate	N.A.	102% including arrears, 77% for 2017 invoice	90%-100%
6	Staff Productivity No of staff/1000 connection	4.2	4.2	
7	Staff Turn Over	1%	0.1%	<3%
8	Average hours of supply	15hours	15hours	20~24hours
9	Water Quality compliance	100%	100%	90> for residual chlorine 100 for bacteriological quality
10	Compliance with the rationing program	90%	92%	95% to comply with the rationing program*

* The rationing program is set to allocate water to the demand of branch offices in each region since the water supply in Kigali is insufficient for the total demand.

Source: WASAC annual report 2016/2017

5.4 CURRENT WATER SOURCES

Rivers, lakes and groundwater (river bed water) that are currently being used as water sources by the WASAC WTPs are shown in **Table 5.4-1**.

Table 5.4-1 Water Sources Used by WASAC (for WTP)

WTP	Water Source	Quantity	Quality	Problems/challenges
Nzove 1WTP	 Groundwater (river bed water)	Thirty-one boreholes drilled in 2006. At the moment, 9 boreholes do not work. Current capacity for 22 boreholes is around 25,000 m^3/d.	It is relatively low turbidity compared to the Nyabarongo River. Sometimes high concentrations of ammonia, iron (Fe) and manganese (Mn) are detected.	Maintenance of boreholes
Nzove 2 and New Nzove 1 WTPs	 River (Nyabarongo)	Nyabarongo river can secure a considerable amount of water.	Sometimes the maximum turbidity of the Nyabarongo River was over 10,000 NTU which results in intake stop.	Water Treatment cost is high because of high turbidity. .
Kimisagara WTP	 River (Yanze)	Yanze is a small river and cannot produce much water compared to the Nyabarongo river.	It has better quality than the Nyabarongo River since the environment around the river has been protected.	Presence of sand, mud, stones and gravels at Yanze intake leads to the clogging of raw water transmission pipelines.
Karenge WTP	 Lake (Mugesera)	No specific issues in terms of quantity	Water quality varies depending on the time, but turbidity increases in the rainy season. Eutrophic conditions due to high level of total-nitrogen, total-phosphorus, and pH.	The lake is located in the eastern part of the CoK and is quite far from the town. The Karenge WTP is built near the lake. Algae is always the problem during treatment.
Kanzenze WTP		Analysis of 12 pumping test data on Nyabarongo flood plain shows that it is possible to withdraw 1,200 - 1,400 m^3/day per borehole.	Turbidity is lower than that of rivers (<100 NTU), iron, manganese and ammonia are as high as river water. From the pumping test results, the turbidity tends to rise as the pumping time increases.	Although turbidity is lower than that of rivers, water quality is not good compared to deep groundwater because it is river bed water. In the floodplain of the Nyabarongo River there are places where the clay layer is thickly deposited, and there is not a good aquifer.

Source:JST

In addition to the WTPs, there are some pumping stations that use independent water sources such as springs and wells. The water from such sources is connected to water tanks of the pumping station and undergo chemical treatment before use at the site.

Table 5.4-2 Water Sources Used by WASAC (Non-WTP)

Water source	Quantity	Quality	Problems
Springs (14 sources used)	One spring can produce around 50-70m^3/day	Water quality is relatively good but difficult to protect the area due to urbanization.	Quality can be deteriorated easily.
Wells (3 sources used)	It cannot be estimated since water from wells are mixed with treated water from Kimisagara WTP.	Water quality is relatively good but difficult to protect the area due to urbanization.	Depth is shallow (around 13m) and can be contaminated easily.

Source: JST

The water quality of major water sources analyzed by WASAC in 2018 is summarized in **Table 5.4-3**. As shown in **Table 5.4-3**, the main problem related to the water quality of the Nyabarongo River at the Nzove is turbidity, color, organic matter, ammonia, iron, chromium and cyanide. However, for the groundwater at the Nzove, it is turbidity, iron and manganese. Comparing water quality with the Nyabarongo River, there is no big problem for the Yanze River. The annual average of turbidity in Mugesera Lake is at a low level (21 NTU). However, the eutrophication of the lake cannot be ignored.

It should be noted that the average concentration of chromium (2.7 mg/L) and cyanide (1.93 mg/L) in the waters of the Nyabarongo River exceed Rwanda's standards and WHO guidelines (0.05 and 0.01 mg/L) for drinking water quality by 54 and 193 times, respectively. These values are considered to be abnormal for general surface water. The possible reasons to be considered are:

1) Analysis method: The HACH analysis methods (not standard methods) are used at the laboratory of each WTP. Comparing with standard methods, the HACH methods have poor accuracy.
2) Interferences of high turbidity and color, and
3) Insufficient quality control (QC): During daily analysis, QC activities (such as duplicate test, standard solution method, standard additions methods etc.) are not conducted at the laboratory of each WTP.
4) There are big differences with the results analyzed by the WASAC's central laboratory and JST.

Table 5.4-3 Water Quality of Major Water Sources (2018 by WASAC)

Item	Unit	Nyabarongo River at Nzove	Groundwater at Nzove	Yanze River	Mugesera Lake	RDWQS
Source for	-	Nzove 2 and New Nzove 1 WTP	Nzove 1 WTP	Kimisagara WTP	Karenge WTP	
pH	-	7.0-7.6 7.1	7.0-7.0 7.0	7.0-7.0 7.0	7.3-8.2 8.0	6.5-8.5
Turbidity	NTU	370-6,040 1,994	17-43 28	44-1,183 368	11.6-123 21.2	5
Color	TCU	1,023-28,150 9,297	41-940 334	-	209-1,865 371	15
Coliform	MPN/ 100ml	4.9×10^2-2.6×10^5 6.4×10^4	6-9.5$\times10^3$ 2.3×10^3	1.5×10^2-3.1×10^5 5.7×10^4	5.8-11$\times10^3$ 7.4×10^3	Nil
Alkalinity	mg/l	9-120 36	13-61 29	6-42 22	62-101 80	-
Hardness	mg/l	16-514	15-70	2.3-42	148-246	300

Item	Unit	Nyabarongo River at Nzove	Groundwater at Nzove	Yanze River	Mugesera Lake	RDWQS
Source for	**-**	**Nzove 2 and New Nzove 1 WTP**	**Nzove 1 WTP**	**Kimisagara WTP**	**Karenge WTP**	
		136	44	32	196	
Dissolved oxygen	mg/l	-	-	-	8.1-16.7 14.3	-
Organic matter	mg/l	4.2-22 9.1	2.2-9.0 4.9	1.4-5.6 2.4	3.1-12.5 8.5	0.003
NH_3-N	mg/l	0.7-7.2 2.7	0.1-2.0 1.3	0.00-0.35 0.08	0.09-0.35 0.22	0.5
T-N	mg/l	-	-	-	0.85-9.21 5.96	-
T-P	mg/l	-	-	-	0.59-1.70 0.99	-
Fluoride (F^-)	mg/l	0.35-18 4.67	0.29-10.5 4.03	0.00-1.61 0.30	1.2-5.2 3.4	1.0
Iron (Fe)	mg/l	3.8-43 17.2	9.0-38 15	0.03-2.90 1.15	0.5-1.9 1.0	0.3
Manganese (Mn)	mg/l	0.4-3.5 1.8	1.4-4.1 2.7	0.01-0.33 0.13	0.28-0.84 0.47	0.1
Cyanide (CN^-)	mg/l	0.055-8.0 1.93	0.030-0.120 0.061	0.002-0.119 0.022	0.07-0.52 0.27	0.01
Arsenic (As)	mg/l	-	-	-	-	0.01
Cadmium (Cd)	mg/l	-	-	-	-	0.003
Chromium (Cr)	mg/l	0.54-8.2 2.7	0.10-5.1 1.4	0.00-0.23 0.09	0.08-0.83 0.24	0.05
Copper (Cu)	mg/l	1.5-17 2.7	0.8-2.5 1.6	0.01-3.58 0.62	0.02-0.42 0.25	1.0
Lead (Pb)	mg/l	-	-	-	-	0.01
Mercury (Hg)	mg/l	-	-	-	-	0.001

Source: 2018 Monthly Report of WASAC
Up figures: min.-max. values / Low figures: average values
RDWQS: Rwanda Drinking Water Standard

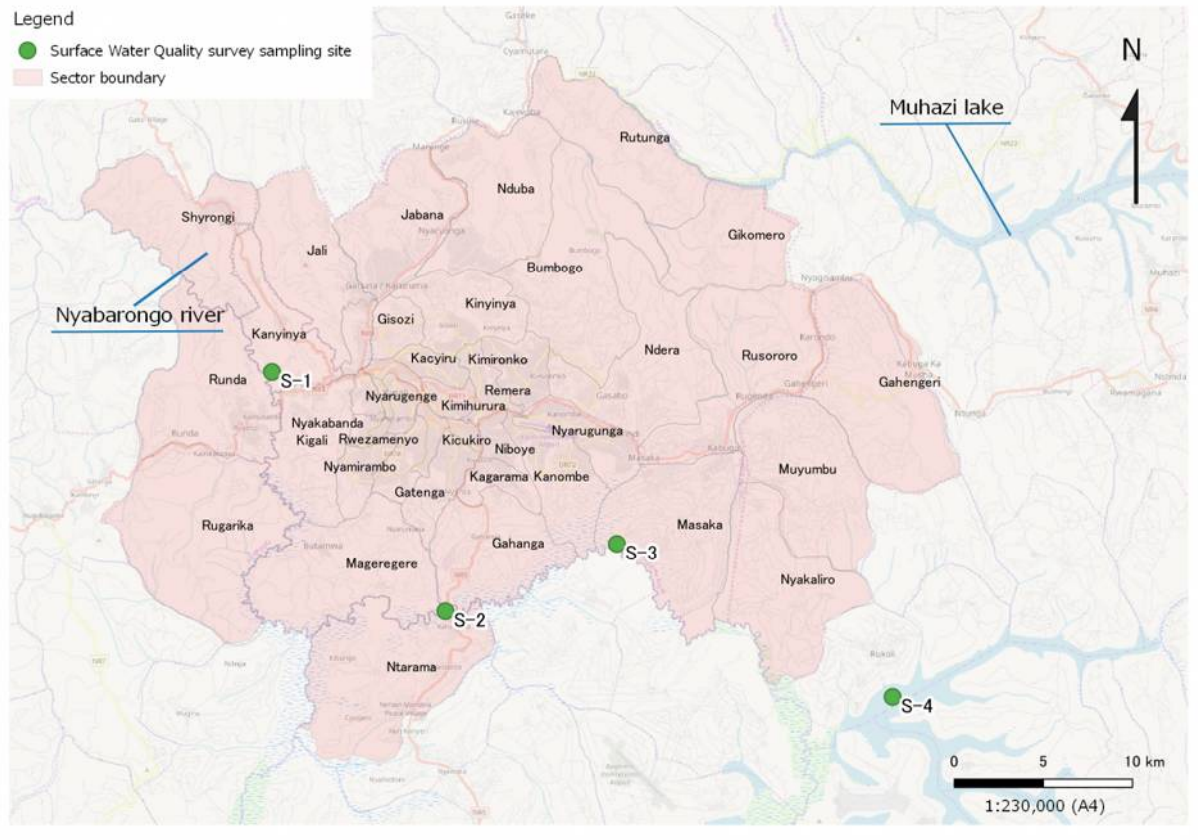
Table 5.4-4 presents the water quality of the Nyabarongo River and groundwater at the Nzove in 2017 and the water quality of the Nyabarongo River analyzed by the WASAC's central laboratory in which the QC activities were conducted. As shown in **Table 5.4-4**, the results analyzed by the WASAC's central laboratory indicate that chromium (0.035 mg/L) of the Nyabarongo River is lower than that of Rwanda standard (0.05 mg/L) for drinking water quality and cyanide (0.023 mg/L) slightly exceeds the standard (0.01 mg/L). In addition, as shown in **Table 5.4-5** and **Table 5.4-6**, the results of surface water quality survey conducted by JST also indicate that chromium and cyanide are lower than that of Rwanda standard. Therefore, it is recommended for the laboratory at each WTP to improve their capacity for quality control by applying duplicate tests or standard solution methods or even standard addition methods.

Table 5.4-4 Water Quality of Nyabarongo River and Groundwater at Nzove WTP (By WASAC)

Item	Unit	2017		2018-7-30	RDWQS
		Nyabarongo River at Nzove	Groundwater at Nzove	Nyabarongo River at Nzove	
Source for	-	Nzove 2 and New Nzove 1 WTP	Nzove 1 WTP	(By WASAC Central Lab)	
pH	-	7.0-7.3 7.1	7.0-7.0 7.0	7.0	6.5-8.5
Turbidity	NTU	233-10,500 1,559	6.5-77 19	275	5
Color	TCU	1,260-87,600 11,102	49-480 141	1,198	15
Coliform	MPN/100ml	0-3×10^4 3.3×10^3	0-2×10^2 2×10	>2.1×10^3	Nil
Alkalinity	mg/l	8-280 74	12-190 80	120	-
Hardness	mg/l	44-180 72	65-172 99	70	300
Dissolved oxygen	mg/l	-	-	-	-
Organic matter	mg/l	3.0-33 10.3	2.0-6.3 3.4	2.5	0.003
NH_3-N	mg/l	0.10-2.11 0.89	0.81-2.41 1.38	0.16	0.5
T-N	mg/l	-	-	-	-
T-P	mg/l	-	-	-	-
Fluoride (F^-)	mg/l	0.40-6.80 2.79	0.50-5.7 1.84	<0.02	1.0
Iron (Fe)	mg/l	1.6-11 6.5	8.2-15 11.6	3.48	0.3
Manganese (Mn)	mg/l	0.20-1.90 1.01	1.06-3.97 2.31	0.418	0.1
Cyanide (CN^-)	mg/l	0.100-0.620 0.266	0.020-0.080 0.044	0.023*	0.01
Arsenic (As)	mg/l	-	-	-	0.01
Cadmium (Cd)	mg/l	-	-	-	0.003
Chromium (Cr)	mg/l	0.20-1.90 1.19	0.08-0.52 0.26	0.035	0.05
Copper (Cu)	mg/l	1.61-6.10 3.96	0.20-0.80 0.37	0.72	1.0
Lead (Pb)	mg/l	-	-	-	0.01
Mercury (Hg)	mg/l	-	-	-	0.001

Source: 2017 Monthly Report of WASAC
Up figures: min.-max. values / Low figures: average values
*: The results of 2019-01-07

In order to confirm the suitability as a drinking water source, water quality survey on surface water and groundwater have been conducted by JST both during the wet season and dry season. Sampling locations of the survey are shown in **Figure 5.4-1**. The results of the survey are summarized in **Table 5.4-5** to **Table 5.4-8**.



Source: JST

Note: The locations of S-1, S-2 and S-3 are the same as the locations of groundwater quality survey sampling points (G-1, G-2, G-3).

Figure 5.4-1 Sampling Locations of Water Quality Survey

Table 5.4-5 Results of Water Quality Survey on Surface Water (Dry Season)

No.	Sampling Location / Sampling Date	Unit	S-1 (Up-stream) 2019-09-12	S-2 (Middle-stream) 2019-09-12	S-3 (Down-stream) 2019-09-12	S-4 (Mugesera Lake) 2019-09-12	RDWQS [1]	WHO Guideline (2017)
1	pH	-	7.55	7.35	7.09	8.93	6.5-8.5	-
2	Turbidity	NTU	477	474	512	10.5	5	5
3	BOD_5	mg/L	9.0	8.7	10.8	12.0	-	-
4	Ammonia nitrogen (NH_4-N)	mg/L	0.19	0.17	0.23	0.05	0.5	-
5	Nitrate nitrogen (NO_3^--N)	mg/L	0.42	0.20	0.16	<0.01	10	11.3
6	Nitrite nitrogen (NO_2^--N)	mg/L	<0.002	<0.002	<0.002	0.016	0.001	0.9
7	Fluoride (F^-)	mg/L	0.41	0.59	0.32	0.49	1.5	1.5
8	Manganese (Mn)	mg/L	0.100	0.023	0.015	0.254	0.1	0.4
9	Iron (Fe)	mg/L	0.13	0.18	0.16	0.41	0.3	0.3
10	Zinc (Zn)	mg/L	0.43	0.43	0.18	0.21	5	-
11	Calcium (Ca)	mg/L	8.0	8.4	5.6	17.8	150	-
12	Magnesium (Mg)	mg/L	9.0	6.3	8.3	13.3	100	-
13	Standard plate count bacteria	cfu/ml	5×10^4	8×10^4	5×10^4	1×10^4	1×10^2	-
14	E. coli	cfu/100 ml	5×10^1	9×10^1	4×10^1	1×10^1	Nil	Nil
15	Cyanide (CN^-) [3]	mg/L	<0.001	<0.001	<0.001	<0.001	0.01	0.5
16	Chromium (Cr^{6+}) [3]	mg/L	<0.005	<0.005	<0.005	<0.005	0.05	0.05
17	Cadmium (Cd) [3]	mg/L	<0.0003	<0.0003	<0.0003	<0.0003	0.003	0.003
18	Lead (Pb) [3]	mg/L	0.007	0.007	0.007	<0.001	0.01	0.01
19	Mercury (Hg) [3]	mg/L	<0.00005	<0.00005	<0.00005	<0.00005	0.001	0.006

Source: JST

1) RDWQS: Rwanda Drinking Water Quality Standard
2) 8.93 means the value exceeding Rwanda Drinking Water Quality Standard
3) Items which are analyzed in Japan.

Table 5.4-6 Results of Water Quality Survey on Surface Water (Rainy Season)

No.	Sampling Location	Unit	S-1 (Up-stream)	S-2 (Middle-stream)	S-3 (Down-stream)	S-4 (Mugesera Lake)	RDWQS [1]	WHO Guideline (2017)
	Sampling Date		2021-02-17	2021-02-17	2021-02-19	2021-02-19		
1	pH	-	6.76	6.80	7.17	7.54	6.5-8.5	-
2	Turbidity	NTU	6,850	2740	1,650	5.75	5	5
3	BOD_5	mg/L	10.15	12.41	16.65	9.30	-	-
4	Ammonia nitrogen (NH_4-N)	mg/L	1.007	0.31	0.502	0.805	0.5	-
5	Nitrate nitrogen (NO_3^--N)	mg/L	1.491	1.126	1.244	0.837	10	11.3
6	Nitrite nitrogen (NO_2^--N)	mg/L	0.070	0.076	0.054	0.008	0.001	0.9
7	Fluoride (F^-)	mg/L	0.11	0.17	0.13	0.41	1.5	1.5
8	Manganese (Mn)	mg/L	0.075	0.208	0.150	0.368	0.1	0.4
9	Iron (Fe)	mg/L	1.52	1.98	1.91	0.11	0.3	0.3
10	Zinc (Zn)	mg/L	0.18	0.63	0.24	0.13	5	-
11	Calcium (Ca)	mg/L	6.14	6.98	9.74	17.42	150	-
12	Magnesium (Mg)	mg/L	2.61	3.84	9.21	13.49	100	-
13	Standard plate count bacteria	cfu/ml	1.5×10^6	8.6×10^6	1.4×10^6	1.7×10^5	1×10^2	-
14	E. coli	cfu/100 ml	4.8×10^3	2.6×10^4	1×10^5	4.7×10^3	Nil	Nil
15	Cyanide (CN^-) [3]	mg/L	<0.001	<0.001	<0.001	<0.001	0.01	0.5
16	Chromium (Cr^{6+}) [3]	mg/L	0.053 [4]	0.036 [4]	0.014 [4]	<0.002	0.05	0.05
17	Dissolved Chromium	mg/L	0.005 [4]	0.005 [4]	0.002 [4]	<0.002 [4]	-	-
18	Cadmium (Cd) [3]	mg/L	0.0004	<0.0003	<0.0003	<0.0003	0.003	0.003
19	Lead (Pb) [3]	mg/L	0.065	0.045	0.018	<0.001	0.01	0.01
20	Dissolved Lead [3]	mg/L	0.005	0.004	0.002	<0.001	-	-
21	Lead in supernatant after Jar Test for coagulation [3]	mg/L	<0.001	<0.001	<0.001	-	-	-s
22	Mercury (Hg) [3]	mg/L	0.00043	0.00024	0.00008	<0.00005	0.001	0.006

Source: JST

1) RDWQS: Rwanda Drinking Water Quality Standard
2) 6,850 means the value exceeding Rwanda Drinking Water Quality Standard
3) Items which are analyzed in Japan.
4) Total Chromium

Table 5.4-7 Results of Water Quality Survey on Ground Water (Dry Season)

No.	Sampling Location	Unit	G-1 (Nyabarongo at Nzove)	G-2 (Nyabarongo at Kanzeze)	G-3 (Nyabarongo at Masaka)	RDWQS [1]	WHO Guideline (2017)
	Sampling Date		2020-11-10	2020-11-10	2020-11-10		
1	pH	-	7.00	7.17	7.51	6.5-8.5	-
2	Turbidity	NTU	302	90	21	5	5
3	Electrical Conductivity	µS/cm	244	227	292	1,500	-
4	Ammonia nitrogen (NH_4-N)	mg/L	0.03	0.00	0.73	0.5	-
5	Nitrate nitrogen (NO_3^--N)	mg/L	0.35	0.50	1.03	10	11.3
6	Nitrite nitrogen (NO_2^--N)	mg/L	0.06	0.10	0.07	0.001	0.9
7	Fluoride (F^-)	mg/L	0.50	0.09	0.49	1.5	1.5
8	Manganese (Mn)	mg/L	1.30	1.01	3.12	0.1	0.4
9	Iron (Fe)	mg/L	1.46	1.54	2.91	0.3	0.3
10	Calcium (Ca)	mg/L	14.57	12.18	15.62	150	-
11	Magnesium (Mg)	mg/L	11.77	6.34	11.46	100	-
12	Chloride (Cl^-)	mg/L	17.6	16.1	22.2	250	-
13	Standard plate count bacteria	cfu/ml	1×10^5	3.6×10^5	8.5×10^4	1×10^2	-
14	E. coli	cfu/100 ml	1.4×10^1	8.9×10^1	1.9×10^1	Nil	Nil
15	Arsenic (As) [3]	mg/L	0.004	0.005	0.003	0.01	0.01

Source: JST

1) RDWQS: Rwanda Drinking Water Quality Standard
2) 302 means the value exceeding Rwanda Drinking Water Quality Standard
3) Items which are analyzed in Japan.

Table 5.4-8 Results of Water Quality Survey on Ground Water (Rainy Season)

No.	Sampling Location	Unit	G-1 (Nyabarongo at Nzove)	G-2 (Nyabarongo at Kanzeze)	G-3 (Nyabarongo at Masaka)	RDWQS [1]	WHO Guideline (2017)
	Sampling Date		2021-02-17	2021-02-17	2021-02-19		
1	pH	-	6.57	6.61	6.61	6.5-8.5	-
2	Turbidity	NTU	50	92	18	5	5
3	Electrical Conductivity	µS/cm	224	312	257	1,500	-
4	Ammonia nitrogen (NH_4-N)	mg/L	0.234	0.311	0.279	0.5	-
5	Nitrate nitrogen (NO_3^--N)	mg/L	2.07	2.00	1.425	10	11.3
6	Nitrite nitrogen (NO_2^--N)	mg/L	0.011	0.004	0.013	0.001	0.9
7	Fluoride (F^-)	mg/L	0.87	0.81	0.80	1.5	1.5
8	Manganese (Mn)	mg/L	2.022	1.654	3.037	0.1	0.4
9	Iron (Fe)	mg/L	2.40	1.83	6.70	0.3	0.3
10	Calcium (Ca)	mg/L	15.39	16.29	18.10	150	-
11	Magnesium (Mg)	mg/L	10.16	13.66	14.13	100	-
12	Chloride (Cl^-)	mg/L	13.5	13.9	14.2	250	-
13	Standard plate count bacteria	cfu/ml	4.3×10^4	9.3×10^5	3.2×10^5	1×10^2	-
14	E. coli	cfu/100 ml	$< 1 \times 10^0$	1.8×10^4	8×10^3	Nil	Nil
15	Arsenic (As) [3]	mg/L	0.002	0.004	0.006	0.01	0.01
16	Lead (Pb) [3]	mg/L	<0.001	<0.001	0.002	0.01	0.01

Source: JST

1) RDWQS: Rwanda Drinking Water Quality Standard
2) 50 means the value exceeding Rwanda Drinking Water Quality Standard
3) Items which are analyzed in Japan.

Based on the results of surface water quality survey conducted, it was observed that there were no major differences regarding water quality between upstream, midstream and downstream of the Nyabarongo/Akagera River, and the main areas of concern related to the water quality were turbidity, organic matter and bacteria. As for the Mugesera Lake, except for the characteristics of low-turbidity and high-pH which may imply a higher level of eutrophication, other water quality items were not much different from that observed along the Nyabarongo River water (such as the concentration of BOD5, bacteria and heavy metals in Mugesera Lake were at same level as that of the Nyabarongo River water. The concentrations of ammonia nitrogen, iron and manganese in Mugesera Lake were treatable by conventional treatment process to meet the Rwandan standard and WHO guideline values).

In addition, as shown in **Table 5.4-6**, it is found that the concentrations of lead at upstream (S-1), midstream (S-2) and down-stream (S-3) of the Nyabarongo/Akagera River had exceeded the Rwanda Drinking Water Quality Standard and WHO guideline (0.01 mg/L). To confirm the lead level in the water sources and its treatment performance in the existing WTPs, an additional water quality survey on lead was conducted and the results are shown in **Table 5.4-9**.

Table 5.4-9 Results of Additional Water Quality Survey on Lead

Sampling Location	Unit	Lead Concentration (May 2021)	Lead Concentration (August 2021)
1. Nyabarongo River Water (Intake of Nzove 2 WTP)	mg/L	0.006	0.037
2. Settled Water (after Sedimentation Tank in Nzove 2 WTP)	mg/L	<0.001	<0.001
3. Filtered Water (after Pressure Filter of Nzove 2 WTP)	mg/L	<0.001	<0.001
4. Groundwater for Nzove 1 WTP (at Contact Oxidation Tank)	mg/L	<0.001	<0.001
5. Filtered Water (after Filtration of Nzove 1 WTP)	mg/L	<0.001	<0.001
6. Nyabarongo River Water at Masaka	mg/L	0.005	0.074
7. Groundwater at Masaka Well	mg/L	0.005	<0.001
Rwanda Standard and WHO Guideline	mg/L	0.01	0.01

Source: JST (analyzed in Japan)

As shown in **Table 5.4-9**, even though the concentrations of lead in some samples of Nyabarongo/Akagera River had exceeded the Rwanda Drinking Water Quality Standard and WHO guideline, the concentrations of lead in all samples of treated water were not detected.

Regarding groundwater quality, turbidity in all locations shows a lower level comparing with Nyabarongo/Akagera River. However, concentrations of iron (Fe) and manganese (Mn) are higher than those of rivers.

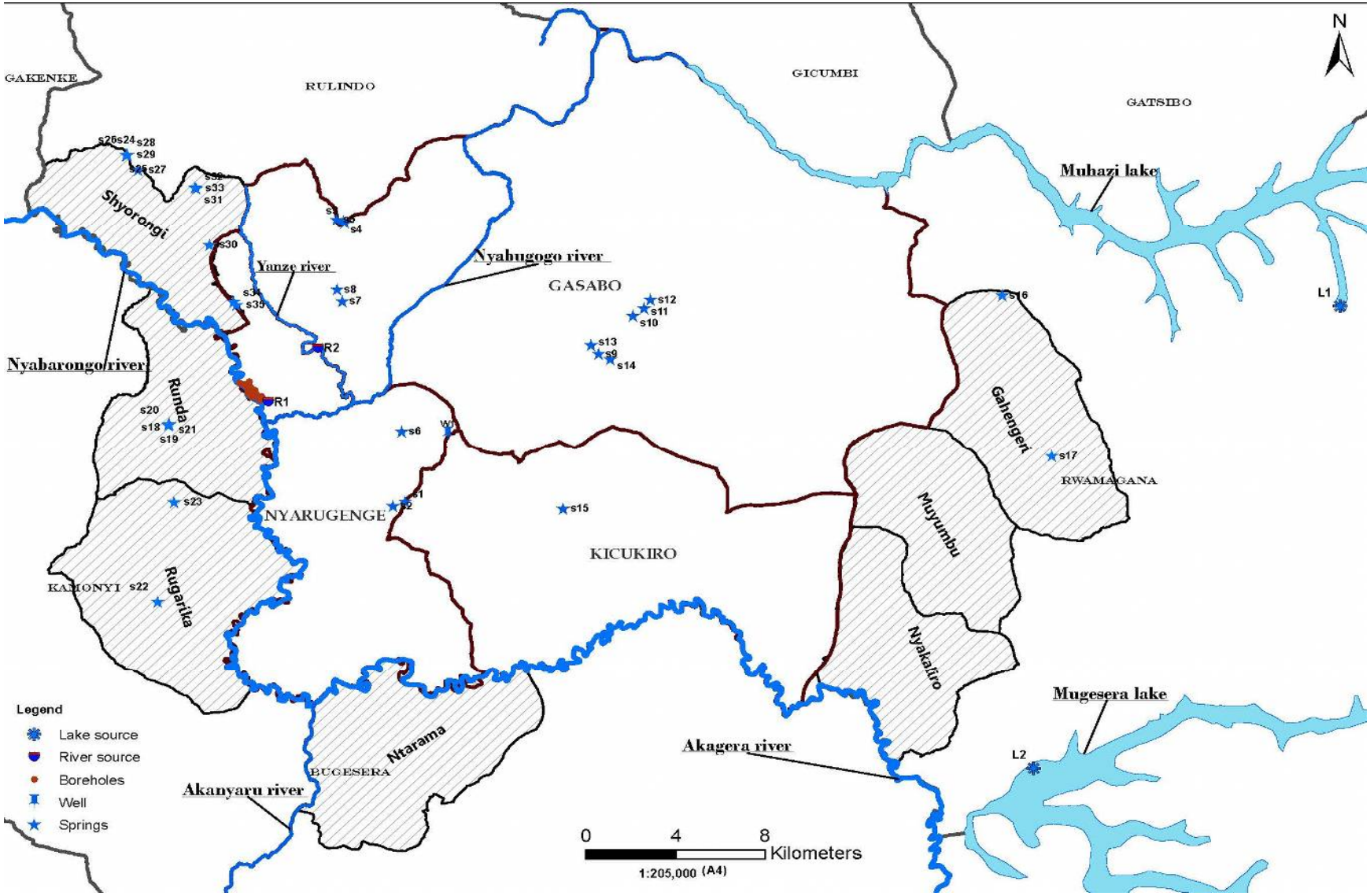
Basically, it is considered that the surface water is treatable with conventional treatment processes and ground water is treatable with biological contact oxidation and rapid filtration to achieve the Rwandan standard and WHO guideline values pertaining to drinking water supply.

Present problems of water sources are summarized in **Table 5.4-10**.and location of water sources are shown in **Figure 5.4-2.**

Table 5.4-10 Problems of Water Sources

Water Source	Development Potential	Problems
River water	High	Poor water quality, cost of treatment is high
Groundwater	Moderate to Low	Need O&M of borehole and monitoring of water level regularly. Extra maintenance cost for borehole rehabilitation.
Springwater	Low	Difficult to protect around spring area due to urbanization
Lake water	High	Difficult to estimate sustainable amount to use and need the permission to use from RWFA

Source: JST



Source: JST

Figure 5.4-2 WASAC Existing Water Sources

5.5 WATER SUPPLY FACILITIES

5.5.1 Water Treatment Plants in the CoK

As of June 2019, there are four existing water treatment plants (WTPs) in the CoK, namely the Nzove, the Kimisagara, the Karenge and the Kanzenze. As shown in **Table 5.5-1**, the total capacity of these WTPs at current and in future (around 2020) is 142,000 m^3/d and 207,000 m^3/d, respectively.

Table 5.5-1 Summary of the WTPs in the CoK (2019)

WTP		Capacity (m^3/d)	Current Condition	Water Source	Remarks
Nzove	Nzove 1	25,000	Existing	Well (infiltrated water of Nyabarongo River)	The capacity is also reported in some reports 30,000 or 40,000 m^3/d.
	Nzove 2	40,000	Existing	Nyabarongo River	
	New Nzove 1	40,000	Existing	Ditto	Sedimentation tanks with a capacity of 65,000 m^3/d were constructed.
		(25,000)	Future	Ditto	
Kimisagara		22,000	Existing	Yanze River (a tributary of Nyabarongo River)	
Karenge		15,000	Existing	Mugesera Lake	
Kanzenze		(40,000)	Under construction	Well (infiltrated water of Nyabarongo River)	Completed in 2020.
Current Total Capacity		**142,000**			
Future Total Capacity		**207,000**			

Source: WASAC

5.5.1.1 Nzove Water Treatment Plant (WTP)

The Nzove WTP is located in the Kanyinya Sector of the Nyarugenge District which lies in the western area of the CoK. The WTP consists of three parts, namely the Nzove 1, the Nzove 2 and the New Nzove 1. The total design capacity of the WTP is 120,000 m^3/d (120,000+25,000=145,000 m^3/d in future), while the actual capacity and produced capacity is only 105,000 m^3/d (105,000+25,000=130,000 m^3/d in future) and 58,400 m^3/d, respectively. The outline of the WTP is shown in **Table 5.5-2**.

Table 5.5-2 Outline of the Nzove WTP (as of May 2019)

WTP	Nzove 1		Nzove 2		New Nzove 1		Current Total
	Original	Expansion	Phase 1	Phase 2	Phase 1	Phase 2	
Design capacity (m^3/d)	3,500 (Pilot)	40,000	25,000	15,000	40,000	(25,000)	120,000
Actual capacity (m^3/d)	-	25,000	25,000	15,000	40,000	(25,000)	105,000
Current production (m^3/d)	-	17,000			41,400	-	58,400
Water source	Well (infiltrated water Nyabarongo River)		Nyabarongo River		Nyabarongo River		-
Construction year	2002	2009	2016	2017	2018	-	-
Contractor	ESPINA (Spain)		Culligan International (America)		Culligan International (America)		-
Construction cost (mil. $)		28[1)]	7.4[2)]		40.2[3)]		-

Source: Planning for Resilience in East Africa through Policy, Adaptation, Research, and Economic Development (Prepared), USA ID, 2014.
1) Converted from contract amount (155.6 Rwf) between Government of Rwanda and ESPINA dated 13/09/2006.
2) The cost included the construction of an intake, raw water transportation pipe, sedimentation tanks with the capacity to p roduce 40,000 m^3/d, pump station installed with pumps with a capacity 25,000 m^3/d, Culligan OFFSY filters with a capacity of 25,000 m^3/d, and fiberglass tank with a capacity of 1,000 m^3.
3) The cost included Culligan OFFSY filters with 15,000 m^3/d capacity for Nzove 2 Phase 2, and sedimentation tanks with the capacity to produce 65,000 m^3/d for New Nzove 1, Culligan OFFSY filters with the capacity of 40,000 m^3/d and other facilities, and transmission pipelines to Mountain Kigali and Rebero reservoirs.

The operation and maintenance system of the Nzove 1 WTP is summarized in **Table 5.5-3**.

Table 5.5-3 Summary of Operation and Maintenance System in Nzove WTP

Item	Content	Remarks
Total number of staff	53 (Nzove 1, Nzove 2 and New Nzove 1)	Permanent: 20 Temporary: 33 (one year contract)
OM system	2 shift/day (07:00 – 17:00: 7-8 staff/shift) (17:00 – 07:00: 7-8 staff/shift)	One shift including 1 team leader, 2 staff for process, 2 for laboratory and 2-3 E&M[1)]
Water sampling location	1: Raw water 2: After biological contact oxidation or sedimentation 3: After filtration 4: Reservoir	Raw water sampling at the biological contact oxidation tank
Sampling frequency	1 sample/hr	
Analysis parameter	➢ pH, turbidity (once/hr) ➢ Bacteria, physical and chemical items, toxic and heavy metals (once/month)	

Source: WASAC
1) E&M: electricity and machinery.

There is a laboratory in the Nzove WTP for water quality management of the whole plant and **Table 5.5-4** presents the staffing structure of the laboratory.

Table 5.5-4 Summary of Laboratory Staff in the Nzove WTP

Structure of Laboratory	Education Level	No.	Major	Remarks (years of service in WASAC etc.)
Chief	B. Sc.	1	Biochemistry	Previous laboratory technician
Technician	College and B. Sc.	4	Biochemistry and other fields	More than 5 years
Temporary staff	B. Sc.	2	Chemistry	3 years
Total number	-	7	-	

Source: WASAC

(1) Nzove 1 WTP

The Nzove 1 WTP receives its water from 31 wells (14 m depth) with a total capacity of 34,700 m^3/d along the Nyabarongo River. However, only 22 wells (with a total capacity of 28,000 m^3/d) are presently functioning. **Figure 5.5-1** shows one of the wells and collection chambers supplying water to the Nzove 1 WTP.



One of the wells for Nzove 1 WTP

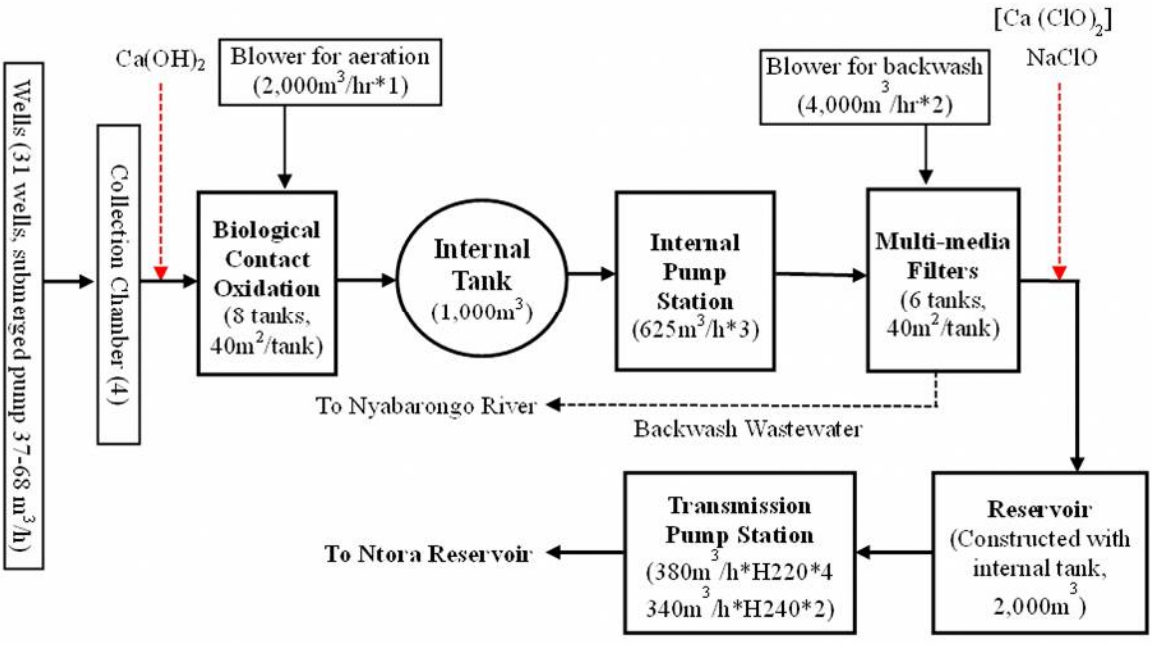


One of the collection chambers (four in total)

Source: JST

Figure 5.5-1 Raw Water Source of the Nzove 1 WTP

Figure 5.5-2 shows the treatment process of the Nzove 1 WTP and **Figure 5.5-3** shows the treatment facilities of the Nzove 1 WTP. By 2018, calcium hypochlorite [Ca(ClO)2] was used for chlorination. From 2019, it switched to sodium hypochlorite (NaClO) with completion of on-site sodium hypochlorite generation system for Nzove 2 WTP and New Nzove 1 WTP.



Source: JST

Figure 5.5-2 Treatment Flow Chart of the Nzove 1 WTP



Biological contact oxidation tank



Multi-media filter

Source: JST

Figure 5.5-3 Treatment Facilities of the Nzove 1 WTP

Design raw water quality and treated water quality are presented in **Table 5.5-5**. Although the concentration of iron and manganese in the raw water is high, the treated water can still meet the drinking water quality standard of Rwanda. However, the Nzove 1 WTP is unable to produce water at its original design capacity (40,000 m^3/d) due to the insufficient number of wells (intake capacity of 31 wells is around 34,700 m^3/d), clogging of wells (9 existing wells are out of working) and deterioration of the biological contact oxidation filters. The actual capacity of the Nzove 1 WTP is approximately 25,000 $m^{3/}$day.

Table 5.5-5 Raw Water and Treated Water Quality of the Nzove 1 WTP (in 2018)

Parameter	Unit	Design Raw Water Quality	Current Raw Water Quality [1)]	Current Raw Water Quality [2)]	Treated Water Quality		Drinking Water Quality Standards
					After Oxidation	Finish Water	
Turbidity	NTU	<10	17-43 28	7.0	2.3	1.2-3.0 2.3	5
Iron (Fe)	mg/L	10	9.0-38 15	3.48	0.16	0.08-0.31 0.19	0.3
Manganese (Mn)	mg/L	3.2	1.4-4.1 2.7	0.418	0.016	0.010-0.025 0.020	0.1
Ammonia (NH_3)	mg/L	7.9	0.1-2.0 1.3	0.16	0.05	0.01-0.10 0.06	0.5
Fluoride (F^-)	mg/L	-	0.29-10.5 4.03	<0.02	-	0.04-0.90 0.32	1.0
Cooper (Cu)	mg/L	-	0.8-2.5 1.6	0.72	-	0.01-0.06 0.03	1.0
Chromium (Cr^{+6})	mg/L	-	0.10-5.1 1.4	0.035	-	0.003-0.020 0.011	0.05
Cyanide (CN^-)	mg/L	-	0.030-0.120 0.061	0.23	-	0.001-0.012 0.004	0.01

Source: 2018 Monthly Report of WASAC
Up figures: min.-max. values / Low figures: average values
1): The results of the laboratory at Nzove WTP
2): The results of WASAC central laboratory

Chemicals and electricity consumption are summarized in **Table 5.5-6**. Unit power consumption in the Nzove 1 WTP is 1.45 kWh/m^3-water production, which is higher than that of the Nzove 2 and the New Nzove 1 WTP (1.12 kWh/m^3-water production) and the average values in Japan (0.3-0.4 kWh/m^3-water production). The main reason for this is due to high power consumption of the transmission pump station and the internal pump station.

Table 5.5-6 Summary of Chemicals and Electricity Consumption in Nzove 1 WTP

Item	Unit	2018	Remarks
Treated water volume	m^3/d	17,000	Average 12,700 m^3/d in 2019 May
Calcium hydroxide [$Ca(OH)_2$]	Kg/year	86,950	
Dosage of $Ca(OH)_2$	mg/L	5.3	Average value calculated from consumption.
Calcium hypochlorite [$Ca(ClO)_2$]	Kg/year	45	
Dosage of $Ca(ClO)_2$	mg/L	-	Not applied now.
Salt consumption	Kg/year	158,800	The figure including usage for Nzove 2 and New Nzove 1 WTP in 2018
Dosage of NaClO	mg/L	2	
Dosage of coagulant (Sudfloc)	mg/L	15	Average value of whole WTP in 2018. Dosage of coagulant in Nzove 1 WTP is not available.
Power consumption	kWh/year	3,870,000	Estimated from the data of 2019 May (7 months operation per year). Nzove 1 and Nzove 2 WTP shared pumping station to Ntora reservoir.
Unit power consumption (excluding pump station)	kWh/m^3	1.45	Average value in May 2019. For whole WTP, the value is 1.17 kWh/m^3 in 2018.
Unit operation & maintenance (OM) cost	Rwf/m^3	376 (estimated)	334 RWF/m^3 for whole WTP in 2018 (including chemicals, power for production and transmission, personnel, administration, depreciation cost and other costs). Of which, power costs account for 52%.

Source: WASAC and JST

Major challenges for operation and maintenance (O&M) are summarized in **Table 5.5-7**.

Table 5.5-7 Major Challenges for O&M in the Nzove 1 WTP

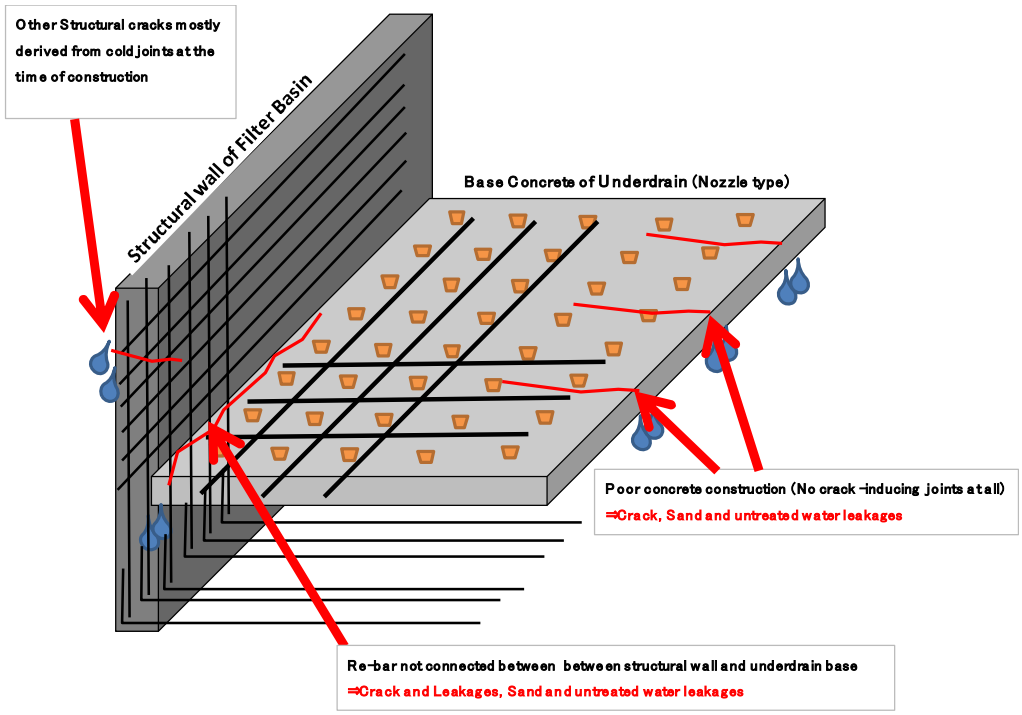
Item	Content	Remarks (Urgency)
Technical aspect	1. Shortage of raw water quantity (construction more wells)	High
	2. Rehabilitation or reconstruction of treatment facilities	High
	3. Low treatment efficiency of Fe and Mn of biological contact oxidation	Medium
	4. High turbidity of raw water	Medium
	5. No automatic control system	Medium
	6. Flow out of filter media	Low
	7. Shortage of analysis equipment in the laboratory	Low
Organizational aspect	8. Capacity development of OM staff	Medium-High
	9. Shortage of staff number	Medium
	10. Frequent personnel movement	Low
	11. QC activity in the laboratory	High
Financial aspect	12. Reduction of high OM cost	High
	13. Shortage of vehicle	Medium
	14. Shortage of budget for purchasing daily supplies (such as a fan)	Low
Others	15. Shortage of standard operation procedure (SOP)	Low
	16. Backwash wastewater discharge without proper treatment	Low
	17. Blackout (now the situation has been improved)	Low

Source: WASAC and JST

The Nzove 1 is degraded both for its capacity and structure. The decrease of the capacity (Design capacity; 40,000 m^3/day, Actual production; 17,000 m^3/day) can be due to the degradation and an insufficient number of wells, as described before, and the faulty construction. **Figure 5.5-4** illustrates the problems of the Nzove 1 structure. From an interview with a manager in charge of the WTP, it was found that the support (base) concrete slab was seriously damaged by cracks at the time of construction. The cracks at the base slab of

underdrain cause water quality degradation due to the leakages before/after filtration. It also decreases the water quantity to optimize the finished quality. Many cracks and water leakages were also observed (**Figure 5.5-5**). The cracks were caused by the cold joints at the time of construction.

In addition, Nzove 1 has an energy efficiency problem as unnecessary intermediate pumps are utilized for the final filtration process. The gravity filtration system at the Nzove 1 is designed as a gravity flow to avoid the excessive equipment and energies.



Source: JST

Figure 5.5-4 Schematic of the Nzove 1 Problems



Source: JST

Figure 5.5-5 Issues on the Nzove1: Cracks and Leakages Visible from Outside

(2) Nzove 2 WTP

The Nzove 2 WTP recieves its raw water from the Nyabarongo River. **Figure 5.5-6** shows the intake facilities for the Nzove 2 WTP.



Old intake for Nzove 2 WTP (only for emergency use now)

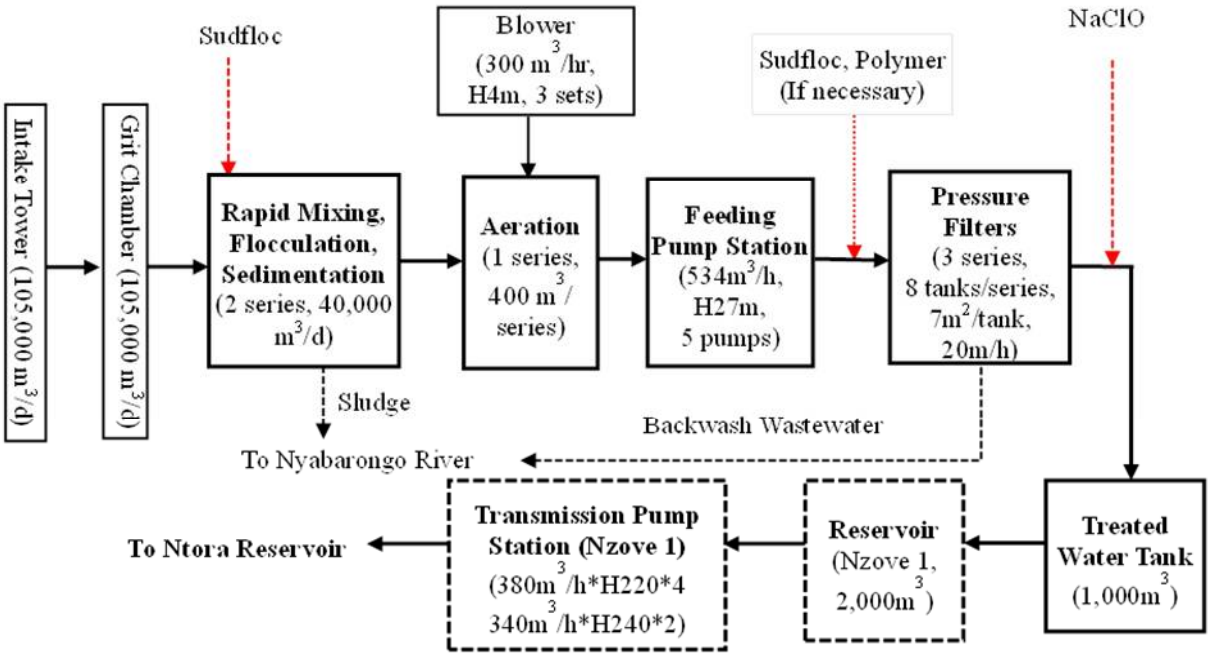


New intake with grit chamber for Nzove 2 WTP (including New Nzove 1 WTP)

Source: JST

Figure 5.5-6 Raw water Intake Facility of the Nzove 2 and the New Nzove 1 WTP

Figure 5.5-7 shows treatment process of the Nzove 2 WTP and **Figure 5.5-8** shows the treatment facilities of the Nzove 2 WTP, which was constructed under two stages for pressure filtration process (25,000 m^3/d during Phase 1 and 15,000 m^3/d during Phase 2). Sodium hypochlorite is produced on-site for chlorination and the average dosage is 2 mg/l.



Source: JST

Figure 5.5-7 Treatment Flow Chart of the Nzove 2 WTP



Mixing, flocculation, sedimentation and aeration facilities



Pressure filters (2 stages filtration)

Source: JST

Figure 5.5-8 Treatment Facilities of the Nzove 2 WTP

Raw water quality and treated water quality are presented in **Table 5.5-8**. Although the turbidity of the raw water is very high during the rainy season, the treated water can still meet the drinking water quality standard of Rwanda. However, during actual operation, when turbidity of raw water exceeds 10,000 NTU, intake stop is applied. **Table 5.5-9** presents a summary of intake stop records in 2017.

Table 5.5-8 Raw Water and Treated Water Quality of the Nzove 2 WTP (in 2018)

Parameter	Unit	Current Raw Water Quality	Treated Water Quality	Rwanda Standard
pH	-	7.0-7.6 7.1	7.2-7.7 7.4	6-9
Turbidity	NTU	370-6,040 1,994	0.35-1.40 0.93	5
Color	TCU	1,023-28,150 9,297	2-57 11	15
Iron (Fe)	mg/L	3.8-43 17.2	0.03-0.23 0.10	0.3
Manganese (Mn)	mg/L	0.4-3.5 1.8	0.003-0.055 0.032	0.1
Ammonia (NH_3)	mg/L	0.7-7.2 2.7	0.01-0.18 0.05	0.5
Coliform	CFU/100mL	4.9×10^2-2.6×10^5 6.4×10^4	Nil	Nil
Cl_2	mg/L	-	1.2-1.7	0.2-0.5

Source: 2018 Monthly Report of WASAC

Table 5.5-9 Summary of Intake Stop due to High Turbidity (in 2017)

No.	Date	Intake Stop Time (hr)	Monthly Intake Stop Time (hr/month)	Remark
1	Jan. 2	5	5	>20,000 NTU
2	Mar. 10	5	8	>15,000 NTU
3	Mar. 21	3		
4	Apr. 11	6	6	
5	Sep. 7	9	32	
6	Sep. 9	4		
7	Sep. 11	3		
8	Sep. 19	4		
9	Sep. 20	3		
10	Sep. 26	8		
11	Sep. 27	1		
12	Oct. 10	4	83	>10,000 NTU
13	Oct. 11	17		
14	Oct. 13	18		
15	Oct. 16	5		
16	Oct. 18	3		
17	Oct. 20	9		
18	Oct. 27	17		
19	Oct. 28	3		
20	Oct. 29	7		
21	Nov. 7	10	13	
22	Nov. 11	3		
23	Dec. 3	5	5	
Min.		1		
Average		6.6		
Max.		18		

Source: 2017 Monthly Report of WASAC

Chemicals and electricity consumption are summarized in **Table 5.5-10**.

Table 5.5-10 Summary of Chemicals and Electricity Consumption in the Nzove 2 WTP

Item	Unit	2018	Remarks
Treated water volume	m^3/d	37,600	Estimated from total treated water volume of whole WTP and Nzove 1 in 2018.
Salt consumption	Kg/year	158,800	Value for whole WTP in 2018
Dosage of NaClO	mg/L	2	
Power consumption	kWh/year	15,370,000 (estimated)	In 2018, Nzove 1 and Nzove 2 WTP shared pumping station to Ntora reservoir.
Unit power consumption (excluding pump station)	kWh/m^3	1.12	Estimated from total power consumption of whole WTP and Nzove 1
Unit operation & maintenance (OM) cost	Rwf/m^3	326 (Estimated)	Including chemicals, power for production and transmission, personnel, administration, Depreciation cost and other costs).

Source: WASAC and JST
Up figures: min.-max. values
Low figures: average values

Major challenges for operation and maintenance (O&M) are summarized in **Table 5.5-11**.

Table 5.5-11 Major Challenges for O&M in the Nzove 2 WTP

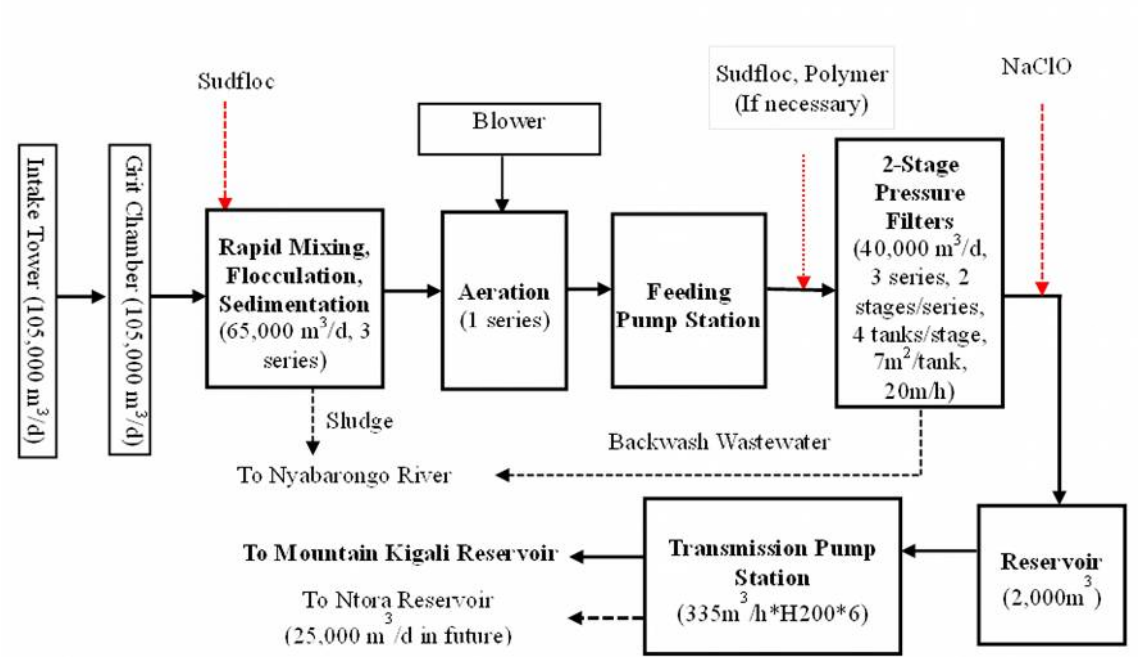
Item	Content	Remarks (Urgency)
Technical aspect	1. High turbidity of raw water during the rainy season	High
	2. Capacity shortage of transmission pipe	Medium (to be solved under JICA's grant project)
	3. Difficult for the OM of pressure filter operation	Medium-Low (handed-over in May 2019)
	4. Shortage of analysis equipment in the laboratory	Low
Organizational aspect	5. Capacity development of OM staff	High
	6. Shortage of staff number	Medium
	7. QC activity in the laboratory	High
Financial aspect	8. Reduction of high OM cost	Medium (lower than Nzove 1)
Others	9. Improvement of standard operation procedure (SOP)	Low
	10. Backwash wastewater discharge without proper treatment	Low
	11. Blackout (now the situation has been improved)	Low
	12. Intake facilities damage due to flood	High (long-term solutions are needed)

Source: WASAC and JST

(3) New Nzove 1 WTP

The New Nzove 1 WTP receives its raw water from the Nyabarongo River using new intake facilities with a capacity of 105,000 m^3/d as shown in **Figure 5.5-9**. The current capacity of the New Nzove 1 WTP is 40,000 m^3/d and the WTP is proposed to be expanded to 65,000 m^3/d in the future just by just installing 25,000 m^3/d pressure filters.

Figure 5.5-9 shows the treatment process of the New Nzove 1 WTP and **Figure 5.5-10** shows the treatment facilities of the New Nzove 1 WTP. Sodium hypochlorite is produced on-site for chlorination. It was handed over to WASAC from Culligan in the middle of 2020.



Source: WASAC and JST

Figure 5.5-9 Treatment Flow Chart of the New Nzove 1 WTP (As of June 2019)



Mixing, flocculation, sedimentation and aeration facilities



Pressure filters (2 stages filtration, open space on left will be used for installing filters of New Nzove 1 Phase 2 in future)



Transmission pump station



Supervisory Control and Data Acquisition (SCADA)

Source: JST

Figure 5.5-10 Facilities of the New Nzove 1 WTP

Raw water quality and treated water quality are presented in **Table 5.5-12**.

Table 5.5-12 Raw Water and Treated Water Quality of the New Nzove 1 WTP (May 2019)

Parameter	Unit	Current Raw Water Quality	Treated Water Quality	Rwanda Standard
pH	-	-	-	6-9
Turbidity	NTU	890-8,100 1,944	-	5
Color	TCU	-	-	15
Iron (Fe)	mg/L	-	-	0.3
Manganese (Mn)	mg/L	-	-	0.1
Ammonia (NH_3)	mg/L	-	-	0.5
Coliform	CFU/100mL	-	-	Nil
Cl_2	mg/L	-	-	0.2-0.5

Source: WASAC

Chemicals and electricity consumption are summarized in **Table 5.5-13**. Comparing with the Nzove 1 WTP, the unit electricity consumption of the New Nzove 1 WTP is at a lower level.

Table 5.5-13 Summary of Chemicals and Electricity Consumption in New Nzove 1 WTP

Item	Unit	2019	Remarks
Treated water volume	m^3/d	36,300	Average production from Jan. to Jun. 2019
Salt consumption	Kg/day	600	For whole WTP use
Dosage of NaClO	mg/L	2	
Power consumption	kWh/day	23,321	
Unit power consumption	kWh/m^3	0.64	Partial power consumption of transmission pumping stations is not included. The value is considered to be same as that of Nzove 2 WTP (1.12 kWh/m^3)
Unit operation & maintenance (OM) cost	RWF/m^3	321 (estimated)	Including chemicals, power for production and transmission, personnel, administration, Depreciation cost and other costs.

Source: WASAC and JST

Major challenges for operation and maintenance (O&M) are summarized in **Table 5.5-14**.

Table 5.5-14 Major Challenges for O&M in the New Nzove 1 WTP

Item	Content	Remarks (Urgency)
Technical aspect	1. High turbidity of raw water during the rainy season	High
	2. Capacity shortage of transmission pipe	Low (transmission pipe to Mountain Kigali is on-going)
	3. Difficult for the OM of pressure filter operation	Medium-Low (handed-over in May 2019)
Organizational aspect	4. Capacity development of OM staff	High
	5. Shortage of staff number	Medium
	6. QC activity in the laboratory	High
Financial aspect	7. Reduction of high OM cost	Medium (lower than Nzove 1)
Others	8. Improvement of standard operation procedure (SOP)	Low
	9. Backwash wastewater discharge without proper treatment	Low
	10. Blackout (now the situation has been improved)	Low
	11. Intake facilities damage due to flood	High (long-term solutions are needed)

Source: WASAC and JST

5.5.1.2 Kimisagara Water Treatment Plant (WTP)

The Kimisagara WTP is located in the Kimisagara Sector of the Nyarugenge District, about 1km from the city center. The Kimisagara WTP abstracts raw water from the Yanze River, a secondary tributary of the Nyabarongo River. The intake with the pre-sedimentation tank is located at about 6 km from the Kimisagara WTP. The clarified water is gravitated to the Kimisagara WTP through a pipe of DN600 up to a point called the Bwino, where the pipe is divided into four ND300 pipes.



Intake for Kimisagara WTP

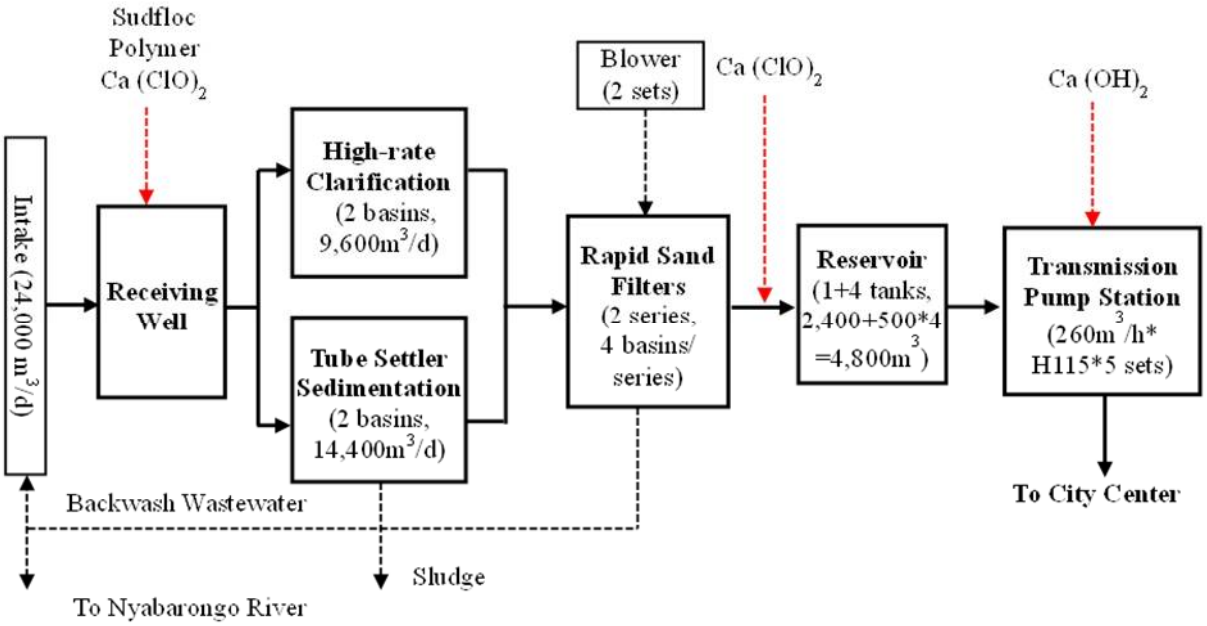


Pre-sedimentation tanks

Source: JST

Figure 5.5-11 Raw Water Intake and Pre-treatment Facilities of the Kimisagara WTP

The Kimisagara WTP was constructed in 1981 and expanded in 1988 by the SAUR (a French water company). The design capacity and current capacity is 24,000 m^3/d and 22,000 m^3/d, respectively. **Figure 5.5-12** shows the treatment process of the Kimisagara WTP and **Figure 5.5-13** shows the treatment facilities of the Kimisagara WTP. Calcium hypochlorite [$Ca(ClO)_2$] was used for chlorination and average dosage in 2018 was 1.3 mg/l. Now sodium hypochlorite (NaOCl) is applied and calcium hypochlorite is only used for special case (such as when a failure occurs with the sodium hypochlorite generation system).



Source: JST

Figure 5.5-12 Treatment Flow Chart of the Kimisagara WTP



High-rate clarification basins



Tube settler sedimentation basins (front) and rapid sand filters (back)

Source: JST

Figure 5.5-13 Treatment Facilities of the Kimisagara WTP

Raw water quality and treated water quality are presented in **Table 5.5-15**.

Table 5.5-15 Raw Water and Treated Water Quality of the Kimisagara WTP

Parameter	Unit	Current Raw Water Quality	Treated Water Quality	Rwanda Standard
pH	-	7.0-7.0 7.0	7.0-7.0 7.0	6-9
Turbidity	NTU	44-1,183 368	0.55-2.29 1.32	5
Color	TCU	-	-	15
Iron (Fe)	mg/L	0.03-2.90 1.15	0.00-0.09 0.04	0.3
Manganese (Mn)	mg/L	0.01-0.33 0.13	0.009-0.153 0.051	0.1
Ammonia (NH_3)	mg/L	0.00-0.35 0.08	0.00-0.19 0.06	0.5
Coliform	CFU/100mL	1.5×10^2-3.1×10^5 5.7×10^4	Nil	Nil
Cl_2	mg/L	-	1.0	0.2-0.5

Source: WASAC

The Operation and Maintenance system of the Kimisagara WTP is summarized in **Table 5.5-16**.

Table 5.5-16 Summary of Operation and Maintenance System in the Kimisagara WTP

Description	O/M Activities	Remarks
Total number of staff	86 (including OM on distribution network)	Permanent: 28 Temporary: 58 (one year contract)
OM system	2 shift/day (07:00 – 17:00: 6 staff/shift) (17:00 – 07:00: 6 staff/shift)	One shift including 2 staff for process and E&M[1)], 2 for laboratory, 2 workers. Totally in 4 teams.
Water sampling location	1: Raw water 2: After sedimentation 3: After filtration 4: Reservoir	Raw water sampling at receiving well.
Sampling frequency	1 sample/hr (raw water) 1 sample/2 hr (filter)	

Description	O/M Activities	Remarks
Analysis parameters	➢ pH, turbidity ➢ pH, turbidity, residual chlorine (Cl_2) ➢ Turbidity, Cl_2, coliform, *E. coli*	Raw water Filtered water and reservoir Distribution network

Source: WASAC

Chemicals and electricity consumption are summarized in **Table 5.5-17**.

Table 5.5-17 Summary of Chemicals and Electricity Consumption in the Kimisagara WTP

Item	Unit	2018	Remarks
Treated water volume	m^3/d	23,350	Average production in 2018
Dosage of Sudfloc	mg/L	5.8	Annual average dosage in 2018
Dosage of polymer	mg/L	0.046	Annual average dosage in 2018
Dosage of $Ca(ClO)_2$	mg/L	1.34	Annual average dosage in 2018
Dosage of $Ca(OH)_2$	mg/L	0.17	Annual average dosage in 2018
Power consumption	kWh/year	7,401,046	
Unit power consumption	kWh/m^3	0.87	Average 2018 (including transmission and distribution power consumption)
Unit operation & maintenance (OM) cost	Rwf/m^3	271	Chemicals, power, personnel and other costs (2018 average)

Source: WASAC

Major challenges for operation and maintenance (O&M) are summarized in **Table 5.5-18**.

Table 5.5-18 Major Challenges for O&M in the Kimisagara WTP

Item	Content	Remarks (Urgency)
Technical aspect	1. Raw water quantity during the dry season is less than the current capacity of the WTP. (Yanze River's discharge is lower than 19,000 m^3/d in the dry season.) Thus, capacity expansion may be difficult.	High (but difficult to find solutions)
	2. Heavy metals issues of raw water quality (It was reported that barium, lead and cadmium had exceeded the standard. Pollution sources should be identified.)	High
	3. Some tube settlers have fallen off due to excessive sludge. The improvement is necessary.	High
	4. High turbidity of raw water during the rainy season (even there is pre-sedimentation tank)	High-Medium
	5. Rehabilitation of flow-rate meter for raw water	Low
Organizational aspect	6. Capacity development of OM staff	Medium
	7. Shortage of staff number	Low
Financial aspect	8. Reduction of high OM cost	Medium
Others	9. Improvement of standard operation procedure (SOP)	Low
	10.Backwash wastewater discharge without proper treatment	Low
	11.Blackout (now the situation has been improved)	Low

Source: WASAC

5.5.1.3 Karenge Water Treatment Plant (WTP)

The Karenge WTP is located in the Rwamagana District, about 50 km southeast of the CoK. The Karenge WTP abstracts raw water from the Mugesera Lake. The outline of the Mugesera Lake is summarized in **Table 5.5-19**.

Table 5.5-19 Outline of the Mugesera Lake

Item	Content	Remarks
Altitude	1,360 m	CoK: 1,400-1,600 m
Surface area of the lake	21 km^2	
Average storage	253 million m^3	Estimated from the surface and mean depth.
Inflow river	5 rivers	Nyirabidibili, Rwangunda, Mwanbu, Ruvomo and Nyabarongo rivers.
Outflow river	No	Overflow to Nyabarongo River in high water level
Rainfall	951 mm	
Water level fluctuation	3-4 m	2.7m from Jan. to Jun. of 2019 (hearing information)
Pollution sources of catchment area	Non-point source	

Source: Development of National Integrated Water Supply and Sanitation Master Plans for Rwanda (Baseline Data Report) and JST

The intake pump station is located at the Lakeshore edge, about 1 km from the Karenge WTP.



Water source and intake (center of the Lake, app. 500m from the Lakeshore edge) for Karenge WTP .



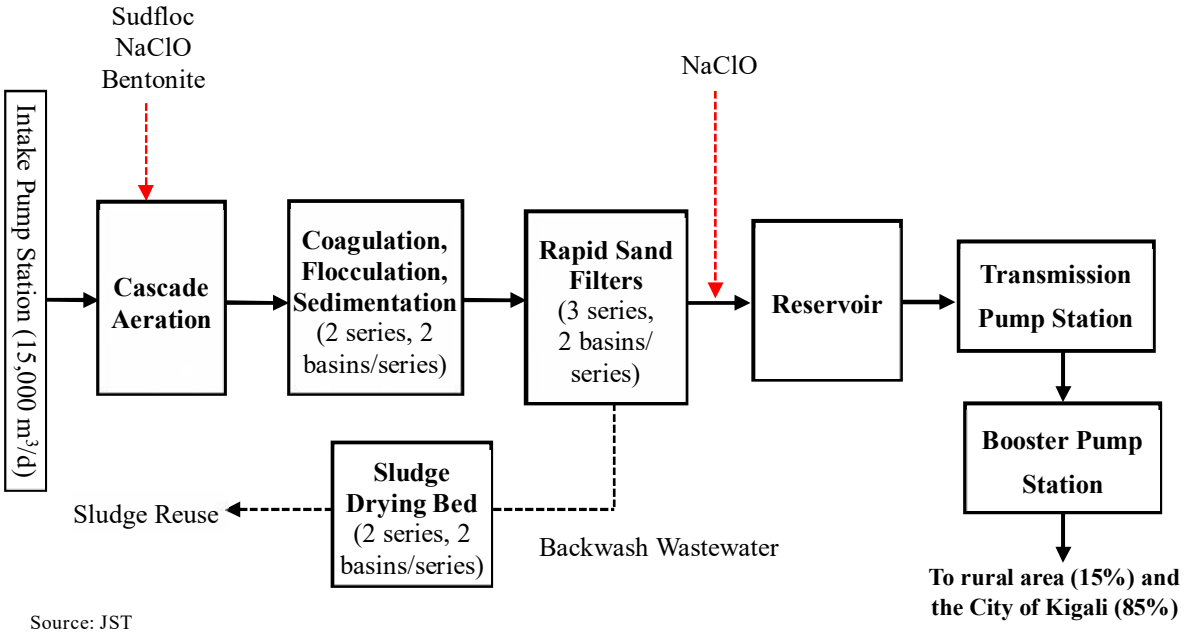
Pump station (left) of Karenge WTP, which is facing the risk of inundation during the rainy season.

Source: JST

Figure 5.5-14 Raw Water Intake Pump Station of the Karenge WTP

The Karenge WTP was constructed in 1975 by the AIDR (Association International de Development Rural) with 3,800 m^3/d capacity for rural water supply and expanded in 1985 by the SADE to 7,200 m^3/d. In 2008, another extension and rehabilitation were conducted by the SOGEA-SATOM to increase the capacity to 12,000 m^3/d for supplying water to the CoK. The current capacity of the WTP is 15,000 m^3/d, which has exceeded its original design capacity.

Figure 5.5-15 and **Figure 5.5-16** show the treatment process and treatment facilities of the Karenge WTP, respectively. To reduce the cost of production, sodium hypochlorite production is done at the WTP, and the capacity of sodium hypochlorite production is about 90 kg/d. Average dosage of sodium hypochlorite in 2018 is 3.4 mg/l.



Source: JST

Figure 5.5-15 Treatment Flow Chart of the Karenge WTP



Cascade aeration, coagulation, flocculation, sedimentation facilities (2 series, 2 basins/series)
Source: JST



Rapid sand filters (3 series, 2 basins/series)

Figure 5.5-16 Treatment Facilities of the Karenge WTP

Raw water quality and treated water quality are presented in **Table 5.5-20**. As shown in **Table 5.5-20**, the turbidity of raw water is very low, which resulted in poor coagulation and sedimentation. In addition, although color, iron, manganese, nitrogen, phosphorus and cyanide show higher levels, the treated water can still meet the drinking water quality standard of Rwanda. It should be pointed out that the Mugesera Lake is in the eutrophic state as the total nitrogen and phosphorus concentrations are 5.96 mg/L and 0.99 mg/L, respectively and have exceeded the eutrophication limit of nitrogen (0.6 to 1.5 mg/L) and phosphorus (0.03 to 0.1 mg/L).

Table 5.5-20 Raw Water and Treated Water Quality of Karenge WTP

Parameter	Unit	Current Raw Water Quality	Treated Water Quality	Rwanda Standard
pH	-	7.3-8.2 8.0	7.4-7.8 7.6	6.5-8.5
Turbidity	NTU	Dry: 19-32 Wet: 20-34	0.7-1.5 1.0	5
Color	TCU	209-1,865 371	8.3-14.2 11.2	15
DO	mg/L	8.1-16.7 14.3	-	
Organic mater	mg/L	3.1-12.5 8.5	0.9-2.0 1.2	
Iron (Fe)	mg/L	0.5-1.9 1.0	0.04-0.06 0.05	0.3
Manganese (Mn)	mg/L	0.28-0.84 0.47	0.009-0.015 0.013	0.1
Fluoride (F^-)	mg/L	1.2-5.2 3.4	0.3-0.5 0.4	1.5
Ammonia (NH_3-N)	mg/L	0.09-0.35 0.22	0.001-0.1 0.004	0.5
T-N	mg/L	0.85-9.21 5.96	-	
T-P	mg/L	0.59-1.70 0.99	-	
Cyanide (CN^-)	mg/L	0.07-0.52 0.27	0.000-0.015 0.006	0.05
Coliform	CFU/100mL	5.8×10^3-1.1×10^4	<1	Nil
Cl_2	mg/L	-	0.2-0.9 0.7	0.2-0.5

Source: WASAC
Up figures: min.-max. values
Low figures: average values

Operation and maintenance system of the Karenge WTP is summarized in **Table 5.5-21**.

Table 5.5-21 Summary of Operation and Maintenance System in the Karenge WTP

Item	Content	Remarks
Total number of staff	33 (including OM on distribution network)	Permanent: 16 Temporary: 17 (one year contract)
OM system	2 shift/day (07:00 – 17:00: 4 staff/shift) (17:00 – 07:00: 4 staff/shift)	One shift including 2 staff for process and E&M[1)], 1 for laboratory, 1 worker.
Water sampling location	1: Raw water 2: After sedimentation 3: After filtration 4: Reservoir	Raw water sampling at receiving well.
Sampling frequency	1 sample/hr (raw water) 1 sample/2 hr (filter)	
Analysis items	➢ pH, turbidity ➢ pH, turbidity, residual chlorine (Cl_2) ➢ Turbidity, Cl_2, coliform, E.coli ➢ Others (such as Fe, Mn, organic matter, NO_2, NO_3, PO_4, F^-, CN^- and heavy metals)	Raw water Filtered water and reservoir Distribution network Monthly monitoring

Source: WASAC
1) E&M: electricity and machinery.

Chemicals and electricity consumption of the Karenge WTP is summarized in **Table 5.5-22**. Unit power

consumption in the Karenge WTP is 1.74 kWh/m^3-water production and transmission, which is much higher than that of the average values in Japan (0.3-0.4 kWh/m^3-water production and transmission). Major reason for this is due to the high-power consumption of the intake pump station and transmission pump station as well as booster pump stations.

Table 5.5-22 Summary of Chemicals and Electricity Consumption in Karenge WTP

Item	Unit	2018	Remarks
Treated water volume	m^3/d	14,200	Average production in 2018
Dosage of Sudfloc	mg/L	14	Annual average dosage in 2018
Dosage of NaClO	mg/L	3.4	Annual average dosage in 2018
Power consumption	kWh/year	9,031,321	Raw pumping station, WTP and booster pumping station consume 38%, 41% and 21% of electricity, respectively.
Unit power consumption	kWh/m^3	1.74	53.8% of total OM cost.
Unit operation & maintenance (OM) cost	Rwf/m^3	481	Chemicals, power, personnel and other costs

Source: WASAC

Major challenges for operation and maintenance (O&M) are summarized in **Table 5.5-23**.

Table 5.5-23 Major Challenges for O&M in the Karenge WTP

Item	Content	Remarks (Urgency)
Technical aspect	1. Lack of stable intake in the lake	High
	2. Intake pump station exposed to inundation during the rainy season (Mar. to Jun.)	High
	3. Insufficient algae removal	High
	4. Insufficient capacity of storage reservoir for production and distribution with the risk of intermittent overflows in case of a blackout.	High-Medium
Organizational aspect	5. Capacity development of OM staff	Low
	6. Shortage of staff number	Medium
Financial aspect	7. High OM cost, especially high power consumption	High
Others	8. Improvement of standard operation procedure (SOP)	Low
	9. Limitation land for an extension.	Low

Source: JST

5.5.2 Small water production facilities

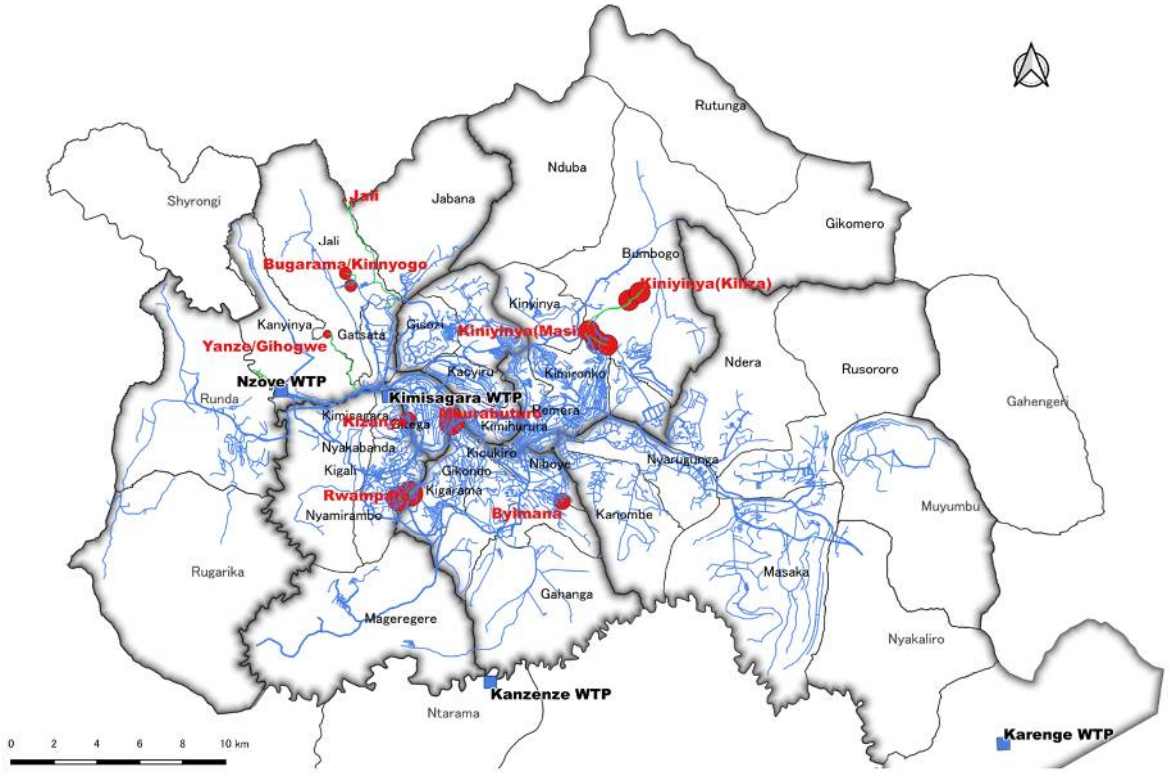
There are seven major small water production facilities in the CoK, totaling 4,950 m^3/day in capacity and 5,600 m^3/day in actual production (September 2019). These represented less than 7% of the total water production. Most of the small water production facilities are connected to the existing reservoirs and mixed with the water from the WTPs.

Note that there are some water sources that have some problems with the facility as mentioned below.

- **Rwampara**: Two out of three wells are not working due to the deficiency of the facilities. One well is not working due to its dry up. From personal communication with a WASAC operator, it was understood that the well was dried up probably due to the human activity (agriculture) near the well. Another well has a problem with pipe breaks due to the occurrence of the landslide after the rainfall.

Further study is needed to identify the facility problems of the small-scale water sources.

Location of the small water production facilities is shown in **Figure 5.5-17** and the capacity and operation of each facility are summarized in **Table 5.5-24**.



Source: JST

Figure 5.5-17 Location of the Small Water Production Facilities

Table 5.5-24 Capacity and operation of the small water production facilities

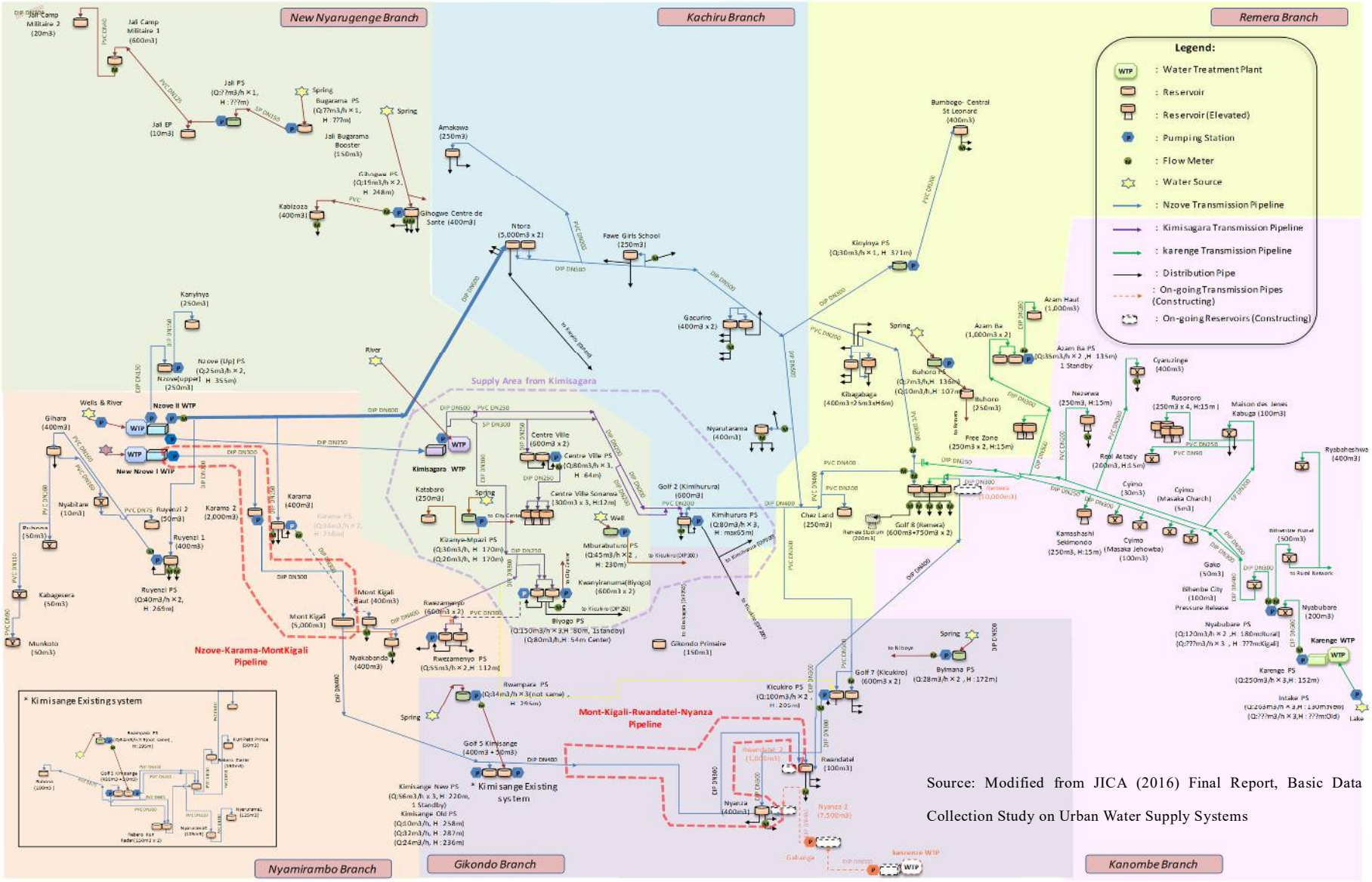
Name	Production Capacity m³/day	Production m³/day *1	Type	Current conditions (Working/Suspended)
Byimana	600/850	284	Groundwater	Working
Jali	150	170	spring	Working
Kinyinya (Masizi/Kiliza)	1,100	1,188	Groundwater	Working
Kizanye	750	1,188	spring	Working
Mburabuturo	950	1,447	spring	Working
Rwampara	1,100	806	Groundwater	Working
Yanze/Gihogwe	300	544	river	Working
Total	4,950	5,627		

Source: WASAC
Note: *1 Updated in September 2018

5.5.3 Reservoirs and Transmission Pipelines

Existing reservoirs and transmission systems are summarized in **Figure 5.5-18** and **Appendix-16(1)**. The complete list of existing reservoirs is listed in **Appendix-17**. Water is transmitted from the WTP to the reservoir and distributed by gravity in principle except for some branches on transmission pipes and some high elevation areas where water is transmitted by the help of booster pumping stations.

A major update was made during the recent expansion of the New Nzove 1 WTP with the construction of the new Karama 2 reservoir, the Nzove–Karama–Mont-Kigali pipeline and the Mont-Kigali–Rwandatel-Nyanza pipeline (**Figure 5.5-18**). The water at the Nyanza, the Rwandatel, and the Remera reservoirs are being sourced from the Nzove WTP through its expansion. Moreover, the operation at the Rwezamenyo Pumping Station was suspended by taking water from the Mont-Kigali reservoir.



Source: JST

Figure 5.5-18 Present Status of Existing Water Supply System

The total capacity of the existing reservoir is 71,512 m^3, which is equivalent to 10.4 hours of current water supply capacity (**Table 5.5-25**). The capacity of the reservoirs should be re-examined, considering the balance between the demand and the capacity at each distribution reservoir.

The "transmission pipeline" is not officially defined and recorded under the GIS system in the WASAC. The transmission pipelines, which are for the purpose of conveying the water from pumps/reservoirs to reservoirs and having diameters equal to or more than ND 100mm, are extracted and summarized in **Table 5.5-26**. The total length of the transmission pipes is 167.2km. Note that the PVC is used for transmission pipes having diameters up to ND 300mm and those having diameters equal to or more than ND 400mm are dominated by the DIP.

Table 5.5-25 Existing Reservoirs

Capacity and Category	Number of Reservoir	Capacity (m^3)	Equivalent hours to Day-Max water supply
Large (≧1000m^3)	16	47,400	-
Medium (≧100m^3)	70	22,249	-
Small (<100m^3)	35	1,223	-
Breaking Pressure	14	375	-
Kiosk, less than 10m^3	19	265	-
Capacity Unknown	4	-	-
Total for Existing Res.	158	71,512	10.4 hours

Source: WASAC

Table 5.5-26 Transmission Pipelines

Diameter (mm)	Length (km)				
	DIP	HDPE	PVC	SP	Total
100	0.7	5.6	23.8		30.1
125		0.8	4.3		5.1
150	8.0	0.4	14.5	0.7	23.5
200	12.7		9.5	2.6	24.7
250	1.5		13.2	7.2	21.9
300	20.4		11.3	12.9	44.6
400	4.2				
500	4.0				4.0
600	9.1				9.1
	60.5	6.7	76.6	23.5	167.2

Source: JST

5.5.4 Pumping Stations

There are 20 nos. of existing pumping stations apart from the pumps in the Nzove and Karenge WTPs for the water supply system in and adjacent to the CoK (**Table 5.5-27**). All pumping stations are located at reservoirs to transmit water to the other reservoirs while some small pumps in the pumping stations are allocated to distribute water directly to the customers. Operations of two pumping stations (the Karama 1 and the Rwezamenyo) are suspended operation due to the recent re-construction of the Nzove–Karama–Mont-Kigali pipeline.

Table 5.5-27 Specifications and Operation Status of the Pumping Stations

No.	Name	Specification of Pumps	Installed Year.	Operation Status (as of June 2019)
1	Kimisagara PS	P1: Q=72.2l/s; H=115m; P=132Kw, N=1480tr/min. P2: Q=260m³/h; H=115m; P=132Kw, N=1450tr/min. P3: Q=260m³/h; H=115m; P=132Kw, N=1450tr/min. P4: Q=260m³/h; H=115m; P=132Kw, N=1450tr/min. P5: Q=260m³/h; H=115m; P=132Kw, N=1450tr/min.	1983 1983 1983 1989 1989	Full Operation
2	Biyogo PS	P1: Q=80m³/h; H=54m; P=22Kw, N=1460tr/min. P2: Q=150m³/h; H=80m; P=55Kw, N=1480tr/min. P3: Q=150m³/h; H=80m; P=55Kw, N=1480tr/min.	2010 2011 2011	Operating 2 pumps every day for 19 hours/day
3	Centre-ville	P1: Q=80m³/h; H=54m; P=22Kw, N=1460tr/min. P2: Q=80m³/h; H=54m; P=22Kw, N=1460tr/min. P3: Q=80m³/h; H=54m; P=22Kw, N=1460tr/min.	2016 2016 2016	Three pumps operating 13 to 22 hours a day
4	Nyamirambo PS	P1: Q=55m³/h; H=112m; P=37Kw, N=1470tr/min. P2: Q=55m³/h; H=112m; P=37Kw, N=1470tr/min.	2008 2008	3 to 14 hours per day
5	Kizanye PS	P1: Q=20m³/h; H=170m; P=30Kw, N=2920tr/min. P2: Q=30m³/h; H=170.52m; P=30Kw, N=2945tr/min.	2010	One pump operating 10 to 21 hours a day
6	Mburabuturo PS	P1: Q=50m³/h; H=229.59m; P=55Kw, N=2976tr/min. P2: Q=50m³/h; H=229.59m; P=55Kw, N=2976tr/min.	2017 2017	Full operation
7	Rwampara PS	P1: Q=34m³/h; H298.96m; P=45Kw, N=2955tr/min. P2: Q=34m³/h; H298.96m; P=45Kw, N=2955tr/min.		One pump operating (plus one for peak demand)
8	Kimisange PS	P1: Q=56m³/h; H=220.17m; P=55Kw, N=2975tr/min. P2: Q=56m³/h; H=220.17m; P=55Kw, N=2975tr/min. P3: Q=56m³/h; H=220.17m; P=55Kw, N=2975tr/min P4: Q=10m³/h; H=258.48m; P=18Kw, N=2935tr/min. P5: Q=32m³/h; H=286.57m; P=45Kw, N=2965tr/min. P6: Q=24m³/h; H=236.44m; P=30Kw, N=2955tr/min.	2017 2017 2017 2014 2014	**No.1 to 3**: Three days a week, Two pumps for 5 to 12 hours **No.4**: suspended **No 5 and 6**: Every day. 16 hours a day
9	Byimana PS	P1: Q=28m³/h; H=171.85m; P=30Kw, N=2950tr/min. P2: Q=28m³/h; H=171.85m; P=30Kw, N=2950tr/min.	2008 2008	Every day, 4 to 10 hours a day
10	Kimihurura PS	P1: Q=80m³/h; H=65m; P=22Kw, N=1465tr/min. P2: Q=80m³/h; H=54m; P=22Kw, N=1465tr/min. P3: Q=80m³/h; H=65m; P=22Kw, N=1465tr/min.	2009 2018 2009	Two pumps operating (19 to 24 hours a day)
11	Jali Haut PS	P1: Q=32m³/h; H=179.09m; P=45Kw, N=2900tr/min.	1988	Three days a week (3 hours a day)

No.	Name	Specification of Pumps	Installed Year.	Operation Status (as of June 2019)
12	Jali Bas PS	P1: Q=32m³/h; H=225m; P=37Kw, N=2900tr/min.	1988	(No record)
13	Kicukiro PS	P1: Q=100m³/h; H=205m; P=110Kw, N=2982tr/min. P2: Q=100m³/h; H=205m; P=110Kw, N=2982tr/min.	2010 2010	Everyday operating (9 to 12 hours a day)
14	Kinyinya Bas PS	P1: Q=40m³/h; H=140m; P=30Kw, N=2970tr/min. P2: Q=40m³/h; H=140m; P=30Kw, N=2970tr/min.	2013 2013	One pump operating
15	Kinyinya Haut PS	P1: Q=20m³/h; H=100m; P=11Kw, N=2900tr/min. P2: Q=36m³/h; H=7.3m; P=5.5Kw, N=1455tr/min.	2016 2010	Two pumps operating (7 to 12 hours a day)
16	Masoro PS	P1: Q=85m³/h; H=135m; P=55Kw, N=2950tr/min. P2: Q=85m³/h; H=135m; P=55Kw, N=2950tr/min.	2014 2014	One pump, 1 hour a day
17	Gihogwe PS	P1: Q=18.50m³/h; H=246.42m; P=22Kw, N=2967tr/min. P2: Q=18.50m³/h; H=246.42m; P=22Kw, N=2967tr/min.	2015 2015	3 to 12 hours a day
18	Karama 1PS	-	-	Operation suspended
19	Karama 2 PS	-	2018	Operation recently started*1
20	Rwezamenyo PS	-	-	Operation suspended

Source: WASAC
Note: *1 Before full handover from the Contractor as of June 2019

5.5.5 Distribution Pipelines

The types, functions, and present status of the existing pipelines as a distribution system are summarized in **Table 5.5-28**. As was previously described in **Section 5.4.3**, it was difficult to distinguish the transmission and distribution pipelines from the existing data; all the transmission pipelines are classified into "the Primary distribution pipes" or sometimes classified as "the Secondary Distribution Pipes." The classification of transmission pipes as "the Secondary Distribution Pipes" occurs mostly for those pipes whose diameters are rather small (ND110 to 200).

Table 5.5-28 Classification of Transmission and Distribution Pipelines

Type of pipelines	Function	Present status	Diameter*1
Transmission Pipelines	Transmit water from pumps/reservoirs to reservoirs.	- No classification of Transmission pipes. - Pipes are sometimes branched to use for direct distribution.	DIP/**PVC**/HDPE ND100 to 600
(Primary) Distribution Mains	Main distribution pipes which only connected to secondary pipes.		
Secondary Distribution Pipes	Distribution pipes for distributing water to the supply are equally and stable, normally making the network. They connect to tertiary pipes or service connections.	- Sometimes mixed up with transmission pipes from pumps to reservoir, then used as distribution pipes. - Mixed up with tertiary pipes. - No network. Tree-like pipelines.	**PVC**/HDPE ND 32 to 300
Tertiary Distribution Pipes	Supplementary pipelines which connect secondary pipes to service connection pipes.	- Lengthy (100m to 2km) ND 63 and 90 pipes consist of secondary/tertiary pipes from	(Tertiary) PVC/**SGP**/HDPE ND 63 or 90 *2

Type of pipelines	Function	Present status	Diameter*1
Service Pipes	Service pipes for individual households from saddled branch to customer meter.	secondary (primary) mains. - ND 23 and 32 are extended repeatedly, elongated up to a few kilometers, and branched to supply water for hundreds of household.	(Service pipe)*3 ND 25 or 40

Source: JST
*1 According to Data from GIS
*2 Service pipes are called *Domestic Distribution* in proposed guidelines in WASAC
*3 Some pipes show up to ND 300 mm in GIS.

The total length of the existing pipelines, comprising of all transmission and distribution pipes is 4,592 km. 1,115km (24% of the total length of pipelines) is over 63mm and consists of primary to secondary distribution mains and transmission pipes (**Table 5.5-29**). Note that ND 90 and 110 account for 53% of the pipes over 63mm. This implies that ND 90 and 110 consists of the main portion of secondary distribution pipelines.

Table 5.5-29 Length of Existing Pipelines

Diameter	Length (km)	Percentage to all over 63mm pipes	Diameter	Length (km)	Percentage to all over 63mm pipes
25	2,134	-	140	15	1.4%
32	220	-	150	16	1.4%
40	711	-	160	73	6.6%
50	91	-	200	92	8.3%
63	321	-	225	2	0.1%
75	86	7.7%	250	52	4.6%
80	13	1.2%	300	84	7.5%
90	**330**	**29.6%**	350	0	0.0%
100	10	0.9%	400	10	0.9%
110	**266**	**23.8%**	500	10	0.9%
125	42	3.7%	600	14	1.3%
(Continued to the right column)			Total	4,592	

Source: JST

The schematic diagram of the existing reservoir and the pipeline system is presented in **Figure 5.5-19**. Typical features of the existing systems are as follows:

1. There are no networks for the primary or the secondary distribution pipes except for the city center area in the Nyarugenge. The pipeline makes a tree-like structure. Secondary distribution pipes normally start from ND110 to 300 and are reduced to ND 63 to 110 according to the area demand. The most frequently used diameters for the distribution pipes are ND 63 and 90. The length of those pipes at a branch is sometimes for a few kilometers covering several hundred households.
2. Valves are installed only at the branch of the primary to the secondary pipes, which lie at the top of the distribution tree. Lacking valves extend the water suspension time whenever there are any pipe breaks.
3. ND23 or 32 (1" and 1"1/2) pipes are sometimes used as the tertiary distribution pipes which are

branched from ND63 to 90 and extending up to a few kilometers. The lengthy ND23 or 32 may be due to the consequence of the unplanned expansion of pipes.

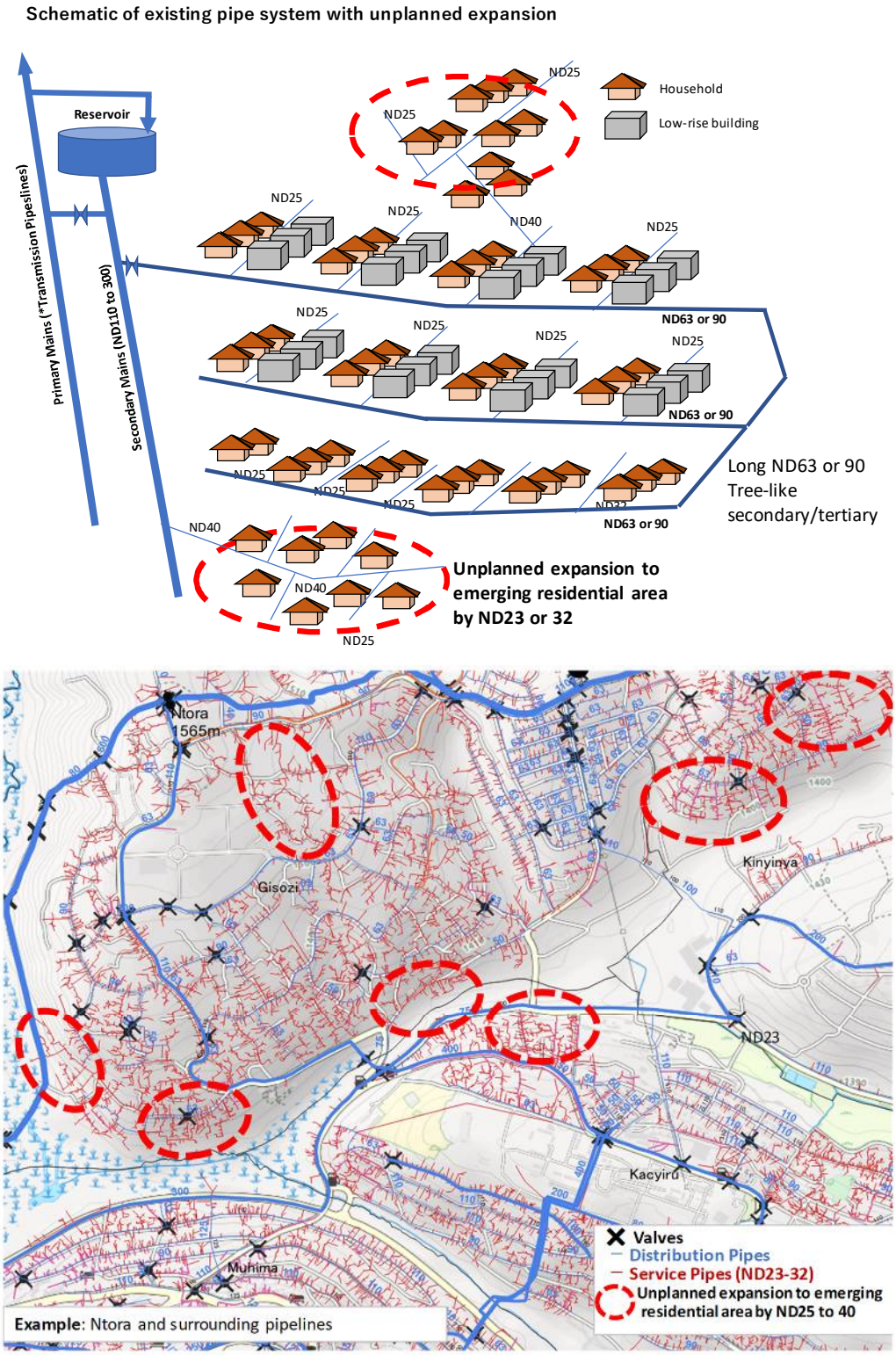
4. Primary pipes are sometimes branched and are bi-passed to distribute water directly to the supply area. The branches and the bi-passes are operated if the pressure is low during peak time, or the reservoirs do not have enough capacity to absorb hourly fluctuations of flow rate. Under this case, the reservoir is called as "unbalanced" status in the WASAC. The un-balanced reservoirs were observed to be either in overflow or in empty status during operation. In total, 42 nos. of reservoirs were found to have frequent overflow problems (**Table 5.5-30**).
5. District meters are not installed sufficiently, so it is difficult to comprehend the extent of leakages in each distribution system.
6. Pressure reducing measures, such as the installation of the Pressure Reducing Valves (PRVs) are not sufficiently conducted. The experience gained from implementing such reducing measures at the pilot areas, undertaken through the JICA's Technical Cooperation Project and carried out by the SusWAS, has not yet been disseminated to the other parts of the distribution system.

Especially for the item mentioned under No.2 above, the JST observed that there was an extensive plant shutdown at the Kimisagara WTP due to valve deficiency in March 2018. This was because of the pipe break at the branch part of the primary main located right after the WTP and the WTP was forced to stop operation to repair the pipe, solely because the branch valve was not operative. Under this sense, the valves may not be sufficiently installed at the distribution pipelines, the primary main and the yard piping.

Table 5.5-30 Reservoirs with Overflow Problems

Branch	Reservoirs with overflow (possibly in *unbalanced* status)		
Nyarugenge	Amakawa	Karama	Kizanye
	Gihogwe	Jali-bas	Katabaro
	Gihara	Jali-haut	Karama 1
	Runda	Jali-FM	Karama 2
Gikondo	Rwampara	Rwandatel	Gikondo (Ecole primaire)
	Mburabuturo	Nyanza haut	Rujugiro
	Kimisange	Gikondo - carrier	Byimana
	Rebero	Kicukiro (center)	Muyange
	Radar _ nyarurama	Murambi (brise-charge)	
	Radar (chateau metallique)	Nyanza	
Kanombe	Ayabaraya	Rusororo	Azam2
	Masaka (ikiyohova)	Kigali free trade zone	Ndera
	Kabuga	Azam1	Cyaruzinge
Kacyiru	Ntora	Gacuriro	Kimihurura
	Fawe	Nyarutarama	

Source: RTD team, WASAC



Source: WASAC (Pipe data)

Figure 5.5-19 Typical Incapable Pipeline Systems (Distribution Mains ND63-90 and Unplanned Expansions by ND 25-40)

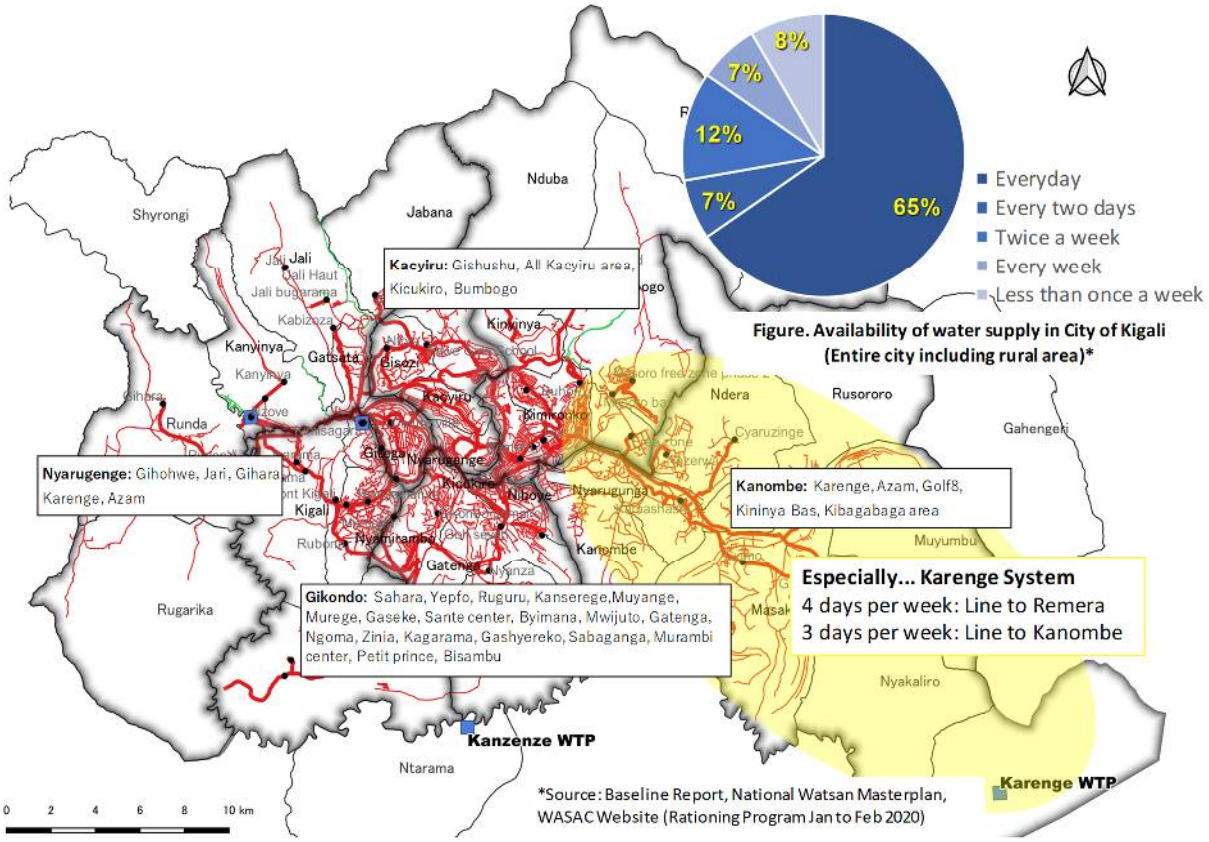
5.5.6 Current Issues on Existing Water Supply Systems

5.5.6.1 Rationing (Intermittent Water Supply)

According to AfDB M/P, one out of three CoK residents, including all WASAC and Non-WASAC population, do not have daily access to the water supply. As for the WASAC customers, most of such intermittent water supply is through "Rationing" by which the WASAC intentionally supply water for specific days in a week in order that the water allocation of limited water sources is rationalized.

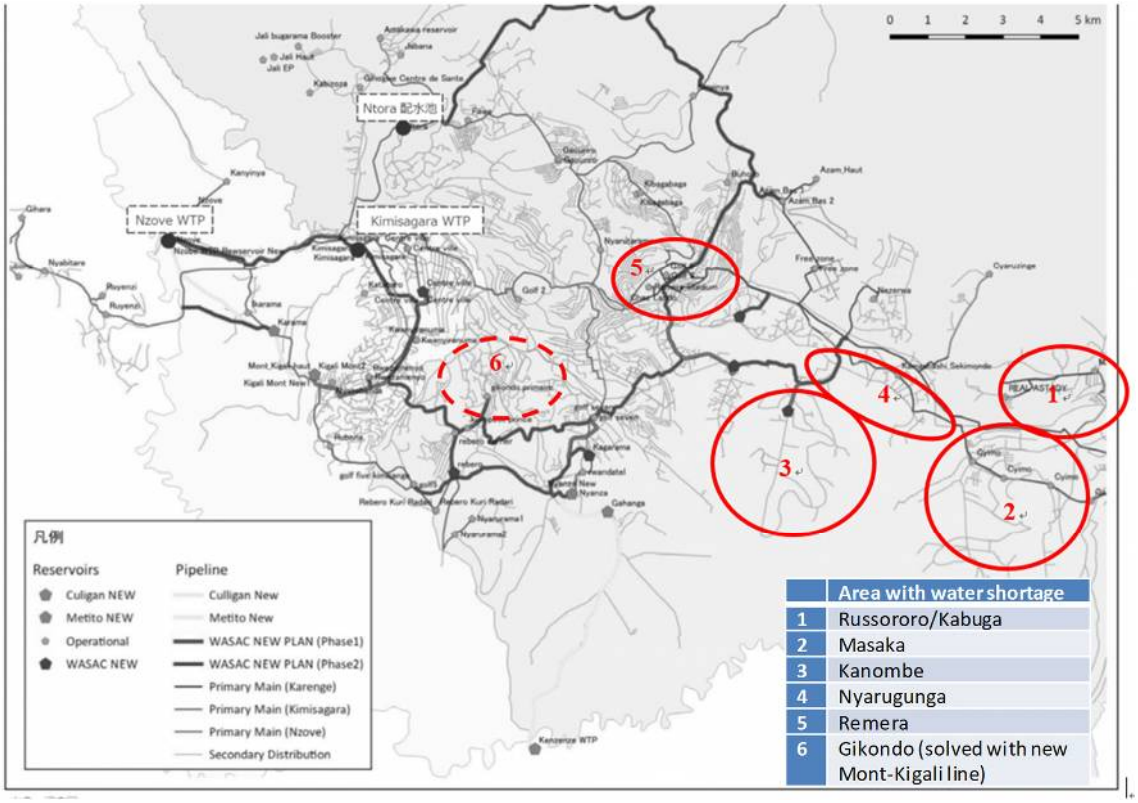
The "Rationing" programs are conducted at all branches in Kigali (**Figure 5.5-20**). Especially, the case is severe at the water supply system from the Karenge WTP. The system cannot supply 24/7 water as the absolute water supply amount is short compared to the water demand in the supply area. There are two major pipelines from the Karenge going to the Remera having diameter ND 300mm; the northern line covers the Rusororo, the Ndera and a part of the Bunbogo sector including the free trade zones, and the southern line covers the Masaka, the Nyarugunga and the Kanombe sectors. Both the lines end at the Remera reservoir pouring the remaining water supply of the demand on the way. As of April 2019, the northern line supplies four days a week while the southern line supplies three days a week. The line for water supply is switched by the valve manipulation manually.

Due to rationing, water is not available for customers at some areas. Especially, the Masaka, the Nyarugunga, and the Kanombe sectors are seriously in short of water because there are not enough reservoirs having the capacity to store water for two-to-three days to meet the demand. This understanding of the areas having water shortage is also confirmed through the qualitative observations carried out by the WASAC managers and as shown in **Figure 5.5-21**.



Source: Baseline Data Report of the Development of National Integrated Water Supply and Sanitation Master Plans (Availability of water supply) and WASAC (Karenge system)

Figure 5.5-20 Intermittent Water Supply (Rationing)



Source: WASAC

Figure 5.5-21 Areas with Water Shortages

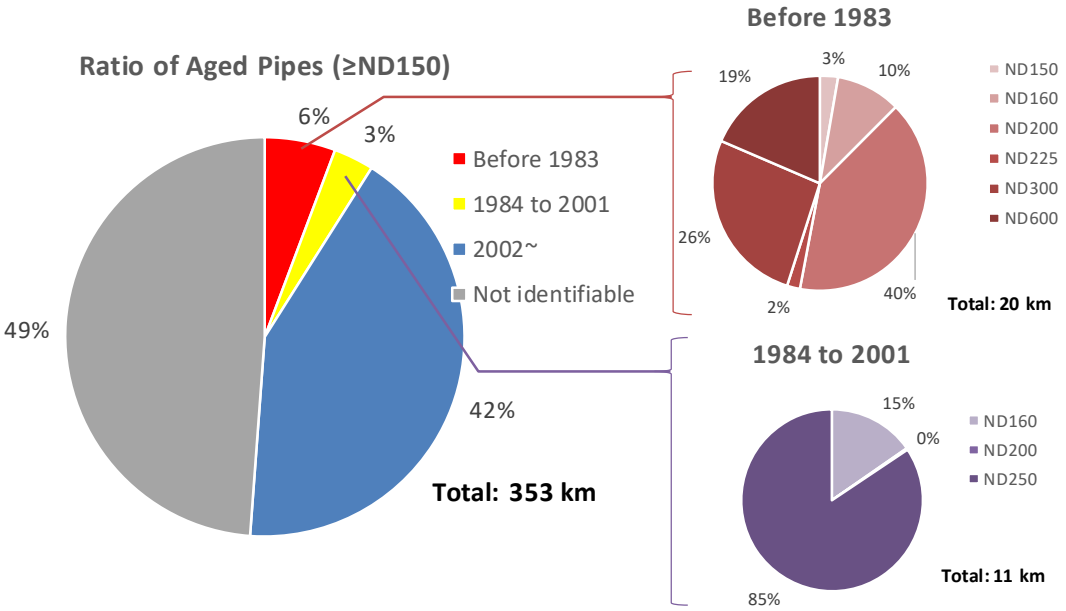
5.5.6.2 Aged Pipes

The aged pipelines cause the leakages and reduction of water supply capacity. The strength of the aged iron/steel pipes may be deteriorated due to corrosion of the pipe body, especially for the pipes buried under the corrosive soils having a high groundwater elevation. The old iron/steel pipes tend to leak from the mechanical/push-on/flanged joints as their bolts, nuts and the rubber gaskets have deteriorated. The old plastic pipes (PVC) may also have deteriorated, especially at the place where they are shallowly buried or exposed to air. Both the pipe body and their joint breakages cause serious water leakages, and such incidents would occur until they are replaced.

Figure 5.5-22 shows the ratio of the aged pipes in and adjacent to the CoK. As the city's pipe network was constructed from the early 1970s, many of the existing pipes are aged and are not being replaced. Under the GIS system, the construction year is available for 51% of the total secondary to primary distribution pipelines having diameters that are equal to or more than ND 150mm (353km). Out of the total 353km of pipelines, 6% (20km) of pipelines were constructed in or before 1983 and are thus almost more than 40 years old. Besides, another 3% (11km) of pipelines were constructed between 1984 and 2001 and these would become aged by 2050.

In general, the pipes over 40 years old tend to cause more leakages and accidents. However, the aging of

pipes are also affected by their materials, joints, and corrosive property. However, it is not yet clear as to how the pipes are aged / deteriorated and thereby causing problems in the supply network.



Source: WASAC

Figure 5.5-22 Ratio of Aged Pipes

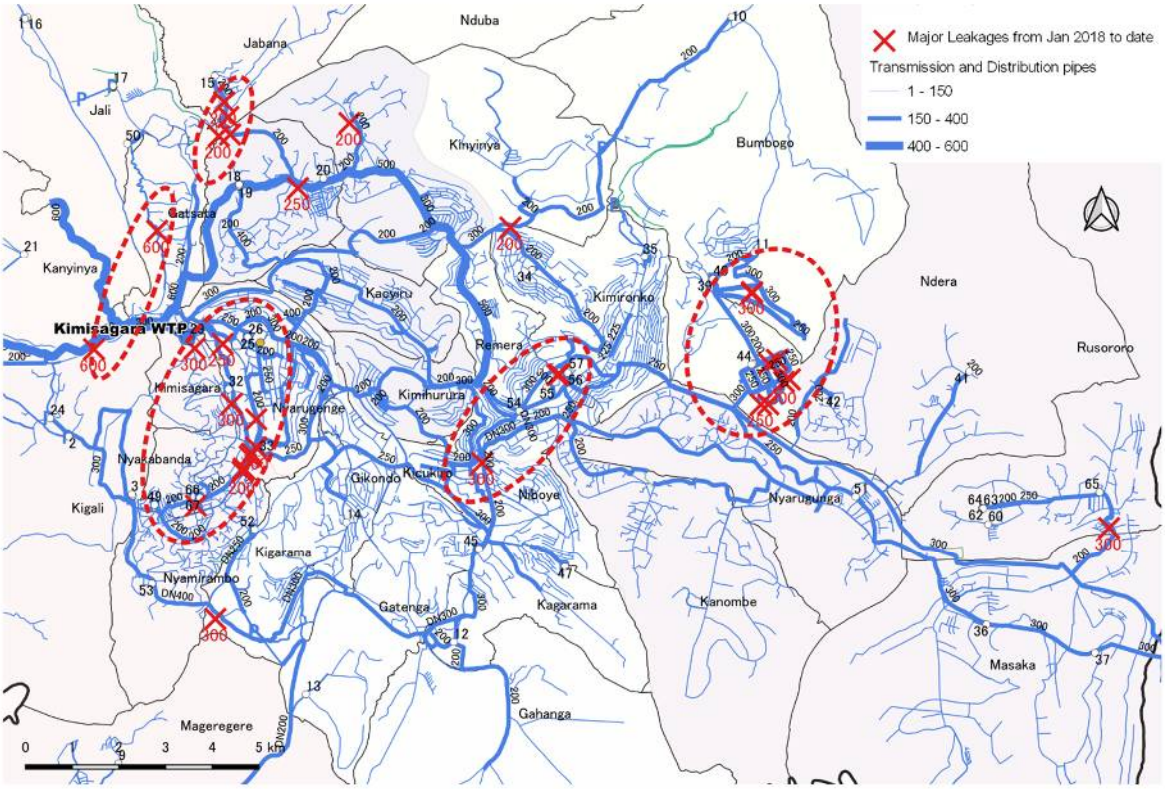
5.5.6.3 Pipe Breaks

Figure 5.5-23 shows the record and locations of recent pipe breaks having large diameters. There are also frequently leaking pipelines, information which was obtained through the qualitative analysis carried out by the WASAC managers apart from the data above. The lines include;

- The Kimisagara–Kwanyiranuma
- The Centre-ville–Kwanyiranuma
- The Karenge–Remera
- The Kwanyiranuma–Gikondo
- The Gatsata–Centre-ville

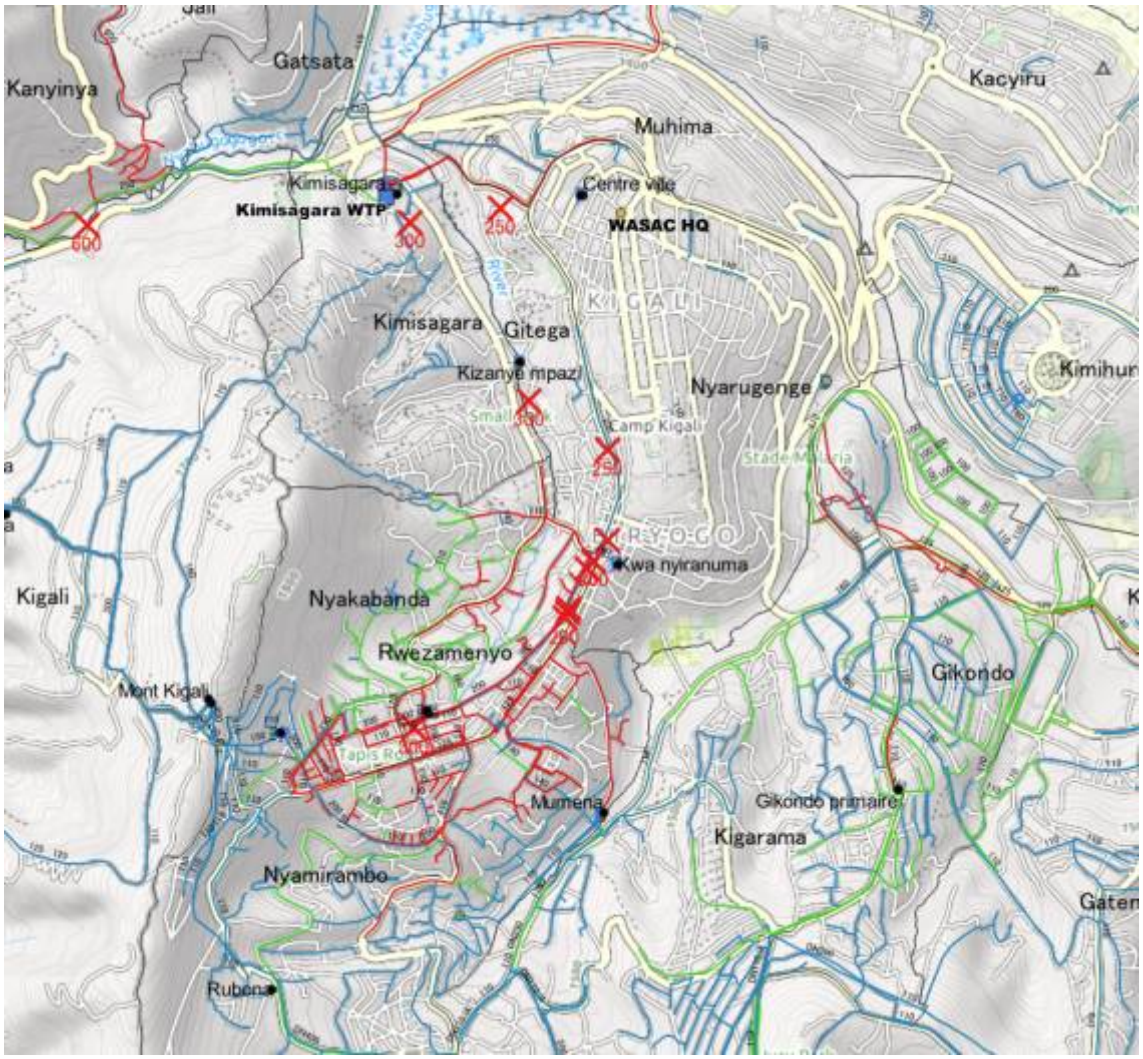
A clear relationship is observed in some pipelines between the incidents pertaining to pipe breaks and their age. Specifically, the Nyarugenge sector has many old pipes that were constructed before 1983 and as shown in **Figure 5.5-23** and **Figure 5.5-24**. The southern part of the sector, especially from the Kwanyiranuma to the Rwezamenyo has repeatedly experienced many leakage incidents at the existing aged pipes.

Note that some of the pipelines have been already replaced. However, the pipe replacement is not systematically conducted in accordance with the pipe break events, except at the target DMA of the on-going NRW reduction technical cooperation project conducted by JICA.



Source: JST

Figure 5.5-23 Location of Pipe Breaks (from January 2018 to May 2019)



Source: JST

Figure 5.5-24 Pipe Breaks and Aged Pipes at City

5.5.6.4 High Energy Cost for Distribution

High electricity cost for water transmission and distribution is destined during water supply in the CoK due to the existence of hilly geography as well as the low elevation of water sources.

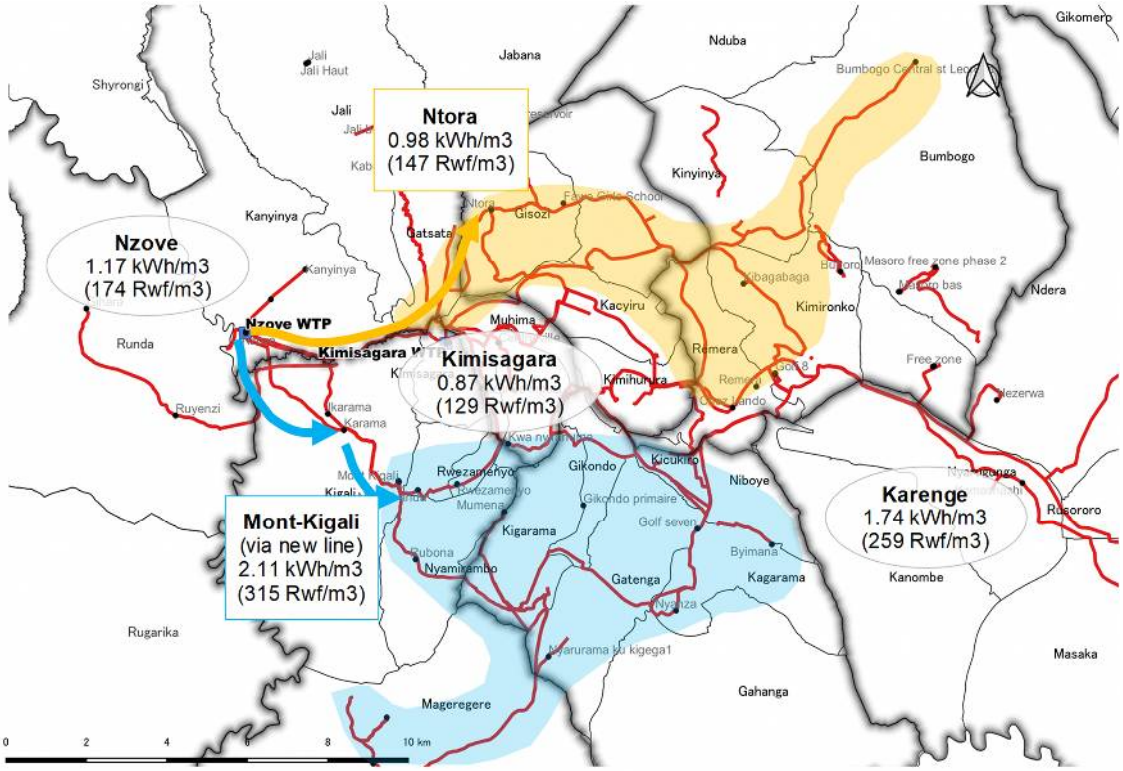
The electricity costs for three major water supply systems are, 174 RWF/m^3 for the Nzove, 129 RWF/m^3 for the Kimisagara and 259 RWF/m^3 for the Karenge which constitutes 47% to 53 % of the total production cost (The WASAC Annual Report, 2017/2018). These are equivalent to 1.17kWh/m^3 for the Nzove, 0.87kWh/m^3 for the Kimisagara, and 1.74 kWh for the Karenge as per water produced (**Figure 5.5-25**).

The efficiency of energy consumption is not optimized because the system has always been updated hastily to meet the urgent water demands. Particularly, some transmission and distribution routes consume excessive energy, which could be avoided if the distribution system is optimized. For instance, the recently expanded Nzove–Karama2–Mont-Kigali route consumes 2.11kWh/m^3, which is more than twice unit

power consumption for the Nzove–Ntora distribution. Meanwhile, this Nzove–Karama2–Mont-Kigali route largely contributes to meet the emerging water demand at the Nyakabanda, the Nyanza, the Rwandatel, and the Kicukiro. However, this could be avoided if the water is planned to be supplied from other routes such as through the Kimisagara or the lower locations. It should be noted that the Mont-Kigali reservoirs are located at +1,792 m and the highest elevation of the Kimisagara route is around +1,500 m while demands along the route are mostly located at an elevation between 1,400 m to 1,500 m. The cost impact of energy savings by changing water management may be as large as 1kWh/m^3 if one compares the Nzove–Karama2–Mont-Kigali route with the Nzove–Ntora route. In this sense, future water management must be optimized from the view of energy efficiency in the long run.

Insofar, the WASAC does not have any specific target for energy efficiency as per the performance indicators. As a reference, the unit power consumption as per distributed water is 0.31kWh/m^3 in the Yokohama City (2009) and 0.34kWh/m^3 in the Kobe city (2011) of Japan. Though it is challenging to set the benchmark to other utilities without an understanding of the geographical similarity, it is necessary to have a target for energy efficiency in order to achieve "the most efficient utility in Africa" as mentioned in the Vision.

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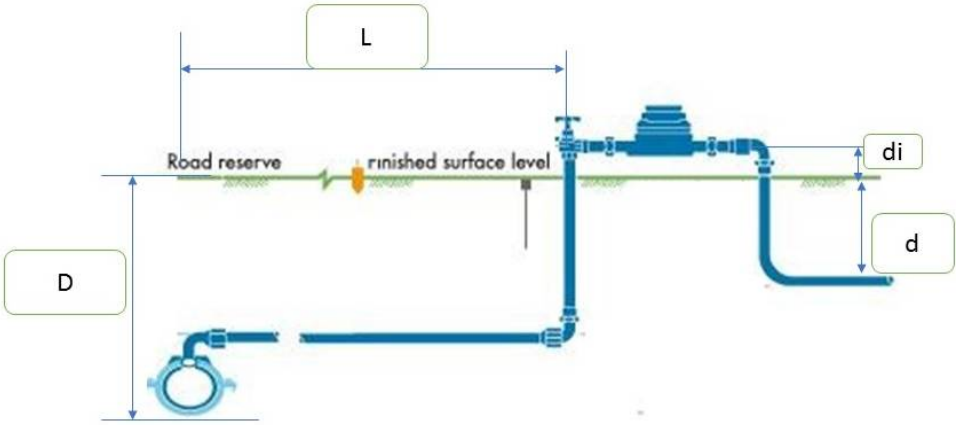
Source: JST

Figure 5.5-25 Energy Consumption by Production Facilities and Specific Pipelines

5.5.7 House Connections, Public Taps and Water Meters

Standards, specifications, and guidelines pertaining to design and construction for house connections are being identified under the JICA technical cooperation project for NRW reduction. The standard arrangement for a house connection is shown in **Figure 5.5-26**.

- Materials for the household connection except water meters are borne and owned by the customers. The customer may buy the materials either from the WASAC's store or from the private shops.
- There is no license or registration system for the shops and contractors who provide the materials and labors for house connections. Labors for house connections are mostly provided and charged by the WASAC.
- Standards for customer water meters are controlled by the Rwanda Standard Board (RSB) - RS-OIML-R 49: 2013, which is equivalent to the international standards by the OIML. There are no clear statements specifying the meter accuracy class (e.g., Class "B" or "C") which is acceptable by the WASAC.
- There are 599 nos. of exiting public kiosks (public tap) in the CoK and its adjacent sectors. Public taps are metered individually and charged monthly. Note that there are some public kiosks that are inactive and are not in current use. From the March 2019 billing information, about 20% to 40% of the counted public taps had no water consumption.



D: Upstream underground level should be at least 70 mm
L: Upper stream Distance from domestic distribution to water meter should be max. 90m in urban areas and 200m in rural areas.
d: Downstream underground distance should be Min 30 cm
di: Meter level should be minimum 20 cm
Source: Project for Strengthening Non-Revenue Water Control in Kigali City Water Network

Figure 5.5-26 Schematic of the Standard Arrangement of House Connections

5.6 NON-REVENUE WATER (NRW)

Non-Revenue Water (NRW) reduction unit of the UWSSD is responsible for its activities in co-operation with the JICA's technical cooperation project for NRW reduction. Under the cooperation scheme, the "Five years strategic plan for NRW reduction" and the "Action Plan for NRW reduction" were published in 2017. The five-year strategic plan is aimed at providing the general framework for NRW reduction activities. The

plan provides the target for NRW at 38% in the year 2017/18 and is progressively reduced to 25% by 2022/23 (**Table 5.6-1**). The target for the NRW was also mentioned under the National Water Supply Policy Implementation Strategy (2016) issued by the MININFRA. This was mentioned as 20% by the year 2019/2020. This target is outdated and was planned based on the baseline NRW of 30% in 2015–the NRW % increased after 2015 mostly due to the emerging demand growth.

Table 5.6-1 Target for Non-Revenue Water Ratio

Year	2018/19	2019/20	2020/21	2021/22	2022/23
NRW(%) Target	35%	32%	30%	28%	25%

Source: WASAC

The latest NRW ratio is 38.9% as of 2017/2018 (**Table 5.6-2**). Note that the WASAC has its own definition of NRW. NRW ratio is calculated by dividing Total Net Supplied with the water losses, which is the difference between the Total Net supplied and the Billed Amount. The Total Net Supplied includes the Service Water (the use of water for its own utility purpose) and the Network Service Water (flushing water for pipelines), which are unbilled-authorized consumption as per the IWA international standard definition. Commercial/Apparent loss (meter loss and fault at billing) is mixed up with the Physical Loss which represents the water leakages since the reliable data for meter accuracy are not available. According to the interview with the WASAC's NRW team, 1) Meter loss seems to be of less significance (intuitively 5%) based on arbitral testing of the customer meters as errors are canceled between plus and minus errors, 2) Tariff collection is nearly 100%. Therefore, the current major problem in the WASAC is the physical loss and NRW which are regarded to be equivalent to water losses.

Table 5.6-2 Non-revenue Water in the CoK (2017/2018)

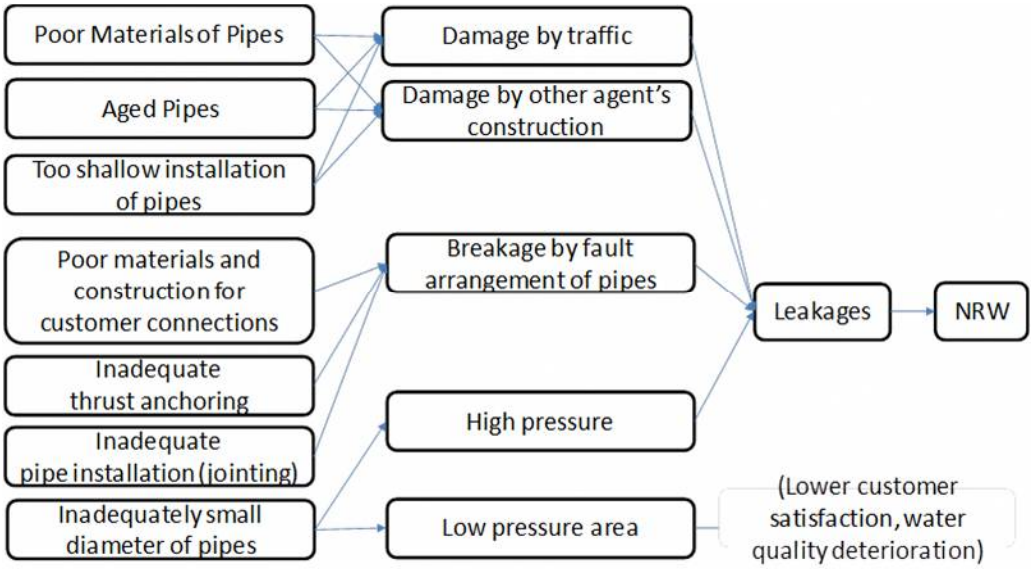
Items	2017/2018 (average m^3/day)
Production (C)	131,922
Total of Service Water (D)	6,642
Network Service Water (2% of water supplied)	2,555
Service Water	4,087
Total Net Supplied E=(C-D)	**125,280**
Total Billed	**76,604**
NRW (Water loss)	**48,676**
NRW (%)	**38.9%**

Source: WASAC

The long-term target of NRW was not planned insofar. The assumption of NRW by the AfDB M/P is 13%, which is not practical in light with the current high NRW %. As a result of the discussion with the WASAC on June 11, 2019, the long-term NRW % target was provided at 20% in 2050. The target value of 20% can also be rationalized from the previous National Water Supply Policy Implementation Strategy (2016) issued by the MININFRA, which also adopted the value of 20% for their NRW target in the final year.

NRW reduction team summarized the current status and problems as part of the KWSMP. They are presented in Box 1 and schematized as a problem tree in **Figure 5.6-1**. Note that this is the baseline schematic, which is not complete and shall be updated in line with the formation of the KWSMP.

- The central problem of the NRW reduction is the leakages at distribution pipes and customer connections.
- The cause of "High pressure" is understood in connection with "pipe diameter" while the role of metering and zonings in the distribution pipelines are not mentioned in the report. It is important to highlight the measures such as locating the reservoirs, formulating the pipeline networks and DMA or the zonings of pipelines for the master planning.
- "Inadequately small diameter pipes" imparts excessive pressure causing leakages as well as the excessively low-pressure area. The low-pressure areas are also an important issue which can be dealt with the scheme of NRW reduction though it is not directly related to the NRW.



- Factors not comprehended in the problem tree but listed up in the 5 years strategic NRW reduction plan (WASAC)
- Intermitted supply (frequent rationing)
- Time response to leak repair
- Lack of leakage survey and detection activities
- Overflow and leakages from Reservoirs
- Poor Maintenance
- Poor design (or absence) of water networks
- Old Steel Galvanized Pipes (48.6km)
- Lack of preventive maintenance
- Insufficient shut-off (line) valves
- Lacking Pressure reduction valves (PRVs)
- Unplanned flushing in pipes
- Commercial factors (Illegal connections, less inspection of customer connections, Not billed customers, zero consumption, Error in data, inactive public taps, poor implementation of meter quality assurance/replacement of meter, meter accuracy not tested)
- Budgetary constraints and Administration (Limited budget for network rehabilitation and maintenance, lack of staff and engineers, poor reporting system, Lack of standards, absence of communication with HQ)
- Customer and stakeholder problems (Vandalism, customer awareness, lack of liaison facility with other institutions, Limited capacity of local contractors, Arbitral construction on the pipelines, Unplanned settlement)

Source: JST

Figure 5.6-1 Problem Tree of NRW Summarized from the Current NRW Problems

Box 1: Current NRW Problems (Report from NRW Section)

Main Causes of Leakages

The different factors causing leakages in the water distribution network are as follows:
The accidents causing leakages in the water supply system networks are usually high and many. And at the end it requires a high budget for repairing, rebuilding and improving and upgrading of the network.

1. The Material of the Pipes

One of the effective factors in water leakage is the material of the pipes. The experience showed that pipe material has been one of the most important parameters in the causing leakage in the networks.

2. The Age of the Pipes

The age of pipes has a direct or indirect effect on the amount of leakage. So a program can be planned with a time table for the efficiency and rebuilding of the pipes with different qualities, so that the loss of water will decrease.

3. The Diameter of the Pipes

The diameter of the pipes is one the effective element in the rate of the accidents and the loss. The hydraulic pressure decreases when the diameter increases, so the loss comes down. Although, using high diameter pipes involves more cost, this investment seems to decrease the loss of leaking water in a long range program.
So, the resistance of the pipe increases against the outside or inside pressure and the destructive elements of the environment.

4. The Pressure

Another important hydraulic parameter, which determines the performance condition and the servicing of the urban water supply system network, is pressure. High pressure causes the increasing of leakage, and the loss of consuming water and the number of the accidents in the network. On the other hand, low pressure in the network causes the inability for complete supply of water or result in providing unsuitable services.
With high pressure, the probability of the accidents and the crack of the water system increases and the stability performance and suitable servicing of the network decreases. If the changing of the pressure happens according to the prescribed standards, it will be appropriate for a network user. Therefore, knowing the conditions of the changing pressure has a high importance. The loss is sometimes because of the network pressure conditions. In other words, the cracks open with the high pressure and close with the low pressure. The amount of loss in a point has a direct relation with the amount of pressure on that point so the amount of loss changes according to the changes in pressure.

5. The Movement of the Soil Around the Pipe

The movement of the soil may happen because of sliding of the ground. This movement brings a lot of pressure on the pipe and can cause cracks in the pipe, gaps in the joints or the breaking of the pipes.

6. Incorrect Installation

Installation by unprofessional workers or using incorrect and non-standardized techniques may result in incomplete sealing of the joints. In this case, there are some leaks in the joints from the beginning and this would increase over time.

7. The Depth of pipe installation

The depth of placement of pipes in the ground can have a role in leaking. But the results show that other factors such as the material and the diameter of pipe and the pressure have more importance.

8. Excessive load pressure (Load) of the Cars on the surface

Another factor of leaking is the pressure of the passing cars on road and ground where the pipeline is buried. Although, this factor is mostly not considered, the experience showed that this factor has a special importance. This parameter should be considered in the new pipeline laying.

9. The Movement of Soil

The clay soil contracts or expands according to its moisture. The resulted movement may cause loosing of the joints and local cracks on the pipelines.

10. The Damages of Pipes by the Other Utilities

The performances which are done by other service organizations such as road construction, Fiber Optics and electricity causes some leakages, unsuitable joints and non-standard piping.

11. Poor Quality Connections and Nonstandard materials and workmanship.

The loss of water is usually very much when unsuitable joints and unstandardized materials are used or incorrect piping is performed. Controlling these materials and performances of implementers can prevent loss of water and thereby decrease NRW.

5.7 SUMMARY OF TECHNICAL CHALLENGES

The current issues pertaining to the water supply facilities, the transmission and distribution pipelines, and the reservoirs are summarized as follows;

1. There is an enormous gap between water supply capacity and water demand. The demands are high, especially in the eastern to the southern part of the CoK and those areas are seriously in short of water even when compared to the existing water demand. Those areas include the Kabuga, the Rusororo, the Rebero, the Masaka, the Kanombe, the Busanza, the Rwinyana, the Remera, the Kabeza, and the Gikondo, where the capacity of pipes and water sources are lacking while developments are happening in the region.

2. Intermittent water supply is a serious issue for the inclusiveness of water supply not only in the water shortage areas but also in the fringe areas of the pipelines where the pressure is low. The low pressure is because of inappropriate pipe diameter and lacking appropriate zonings, absence of backup route by pipeline loops/networks, inappropriately small diameter of pipes, and frequent leakages from the pipes.

3. The leakage accounts for the majority of NRW, and it often cause serious water supply interruption. At least 20km of pipelines are aged more than 36 years and only 51% of pipelines have data regarding the year of its construction. Combined with the inappropriate arrangement of thrust anchoring and sub-standard pipe materials, many leakages are happening in the primary to secondary distribution mains. The situation for water supply interruption is further worsened by the existence of inappropriately few shut-off valves in the pipelines. The need for expansion cannot be an excuse for inaction of NRW reduction as "expanding water networks without addressing water losses will only lead to a cycle of waste and inefficiency"[8]. Strategic replacement of pipelines is necessary to achieve an NRW target.

4. Lack of pressure management in transmission and distribution systems accelerated the pipe breaks, leakages and wasting energies. High pressure is an intrinsic problem seeing the hilly geographical conditions of the CoK. However, it is not even understood where exactly the areas are seriously affected. Branching of the pipelines from the transmission lines also makes its management difficult as well as causes excessively high pressure at the branched pipes. Some supply areas are inefficiently supplied with water in terms of the energy; supplied water from the excessively high location as the Mont-Kigali reservoir. Therefore, there is a high potential to enhance efficiency by appropriating pressures both for the reservoirs and the distribution pipelines.

5. The existence of an independent Non-revenue water section and technical cooperation with JICA is an important opportunity to enhance efficiency. The NRW reduction has a large potential to contribute not only to water availability but also in financial sustainability. The team has acquired the knowledge and drafted standards guidelines both at the manager and at the engineer's level. Major challenges lie in the budget for implementation as well as the internal coordination of WASAC. The investment on the rehabilitation for aged system will be huge while the WASAC should also expand the water supply systems for new customers. The drafted standard for water supply pipes has not been approved or executed. The goal for the activity, 25% in 5 years, is still a long way to go – in general, the NRW will

[8] Source: Frauendorfer, R. and R. Liemberger, The issues and challenges of reducing non-revenue water. ADB, (2010)

even increase after the activity proceeds to some extent in the future. It is necessary to place the NRW reduction activity strategically and find a way to execute them more smoothly and continue it sustainably.

CHAPTER 6 FINANCIAL SITUATION OF WASAC

6.1 FINANCIAL STATEMENTS

This chapter presents the financial results of WASAC over the last 6 financial years from FY 2014/15 through FY 2019/20. This includes 1) Profit and Loss Statement, 2) Balance Sheet and 3) Cash Flow Statement.

6.1.1 Profit and Loss (P/L)

Table 6.1-1 presents the actual P/L from FY 2014/15 up to FY 2019/20 and the revenue estimate of FY 2020/21, which are characterized as below:

- The revenue of FY 2019/20 significantly increased and hit the historical high due to full contribution of tariff revision carried out in February 2019 and the gross profit (no.3) as well.
- However, the final profit for FY 2019/20 (no. 13) has recorded negative results due to the substantial depreciation amount of the fixed-assets.
- The turnover for FY 2020/21 revised budget was expected to increase by around 10% compared with that of FY 2019/20 despite of COVID negative impact. However, the Interim execution report of 10 months from June/2020 to April/2021 presents 79% of actual performance that indicates slightly lower than expected 83%.
- Other income (no. 4) was mostly from the subsidies received from the Government. This was, so-to-speak, a nominal account as the income is offset by the districts' network development expenses which are represented as other expenses (no.5).

Table 6.1-1 Profit and Loss Statement (RWF in million)

P/L Accounts		2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21 (for Ref.)	
		Audited	Audited	Audited	Audited	Audited	Non-audited	Revised Budget	Actual/June-April
1. Revenue		11,727.8	15,116.8	15,565.9	15,060.0	18,779.3	21,363.5	23,952.0	18,856.3
2. Cost of Sales		7,635.1	12,671.7	14,372.0	13,964.1	14,702.7	14,941.4	15,573.8	12,086.8
3. Gross Profit =1-2		**4,092.7**	**2,445.1**	**1,193.9**	**1,095.9**	**4,076.6**	**6,422.1**	**8,378.2**	**6,769.5**
4. Other Income		7,373.8	10,989.8	11,016.8	26,737.1	11,920.0	14,418.2		
5. Other expenses	Support to district networks	3,868.9	9,975.6	9,566.9	24,768.5	8,555.3	14,676.0		
	Administrative expenses	5,323.0	3,163.4	3,532.6	7,059.3	6,001.6	6,160.9		
	Total	9,191.9	13,139.0	13,099.5	31,827.8	14,556.9	20,836.9		
6. Operating Profit before depreciation =3+4-5		**2,274.6**	**296.0**	**-888.8**	**-3,994.8**	**1,439.7**	**3.4**	n/a	n/a
7. Depreciation/amortization		3,129.4	3,404.0	3,424.4	3,277.5	3,357.6	2,745.9		
8. Operating Profit =6-7		**-854.8**	**-3,108.0**	**-4,313.2**	**-7,272.3**	**-1,917.9**	**-2,742.5**	n/a	n/a
9. Finacial	Income	848.4	1,205.1	1,217.8	13.1	25.3	5.4		
	Expenses	1,002.7	1,205.1	1,240.9	75.1	577.7	-189.2		
	Profit	-154.3	0.0	-23.1	-62.0	-552.4	194.6		
10. Provision	Write-back	0.0	596.5	0.0	0.0	0.0	0.0		
11. Profit and Loss b/Tax =8+9+10		**-1,009.1**	**-2,511.5**	**-4,336.3**	**-7,334.3**	**-2,470.3**	**-2,547.9**	n/a	n/a
12.Tax	(-) Deffered tax liabilities	-285.9	-459.6	275.1	155.1	281.2	0.0		
13. P/L for the period =11-12		**-723.2**	**-2,051.9**	**-4,611.4**	**-7,489.4**	**-2,751.5**	**-2,547.9**	n/a	n/a

Source: Financial Statements and Budget of WASAC

6.1.2 Balance Sheet (B/S)

Table 6.1-2 presents the B/S of WASAC.

Table 6.1-2 Balance Sheet (RWF in million)

B/S Accounts			2014/15 Audited	2015/16 Audited	2016/17 Audited	2017/18 Audited	2018/19 Audited	2019/20 Non-audited
Assets	Current	Cash & banks	2,966.9	4,324.5	3,791.2	1,360.5	5,236.2	1,098.7
		Inventory	7,461.1	7,362.2	7,328.8	4,631.5	4,386.1	3,320.7
		Receivables & others	6,834.9	8,764.8	11,028.2	8,392.3	24,121.0	18,458.5
		Total	17,262.9	20,451.5	22,148.2	14,384.3	33,743.3	22,877.9
	Fixed	Property & equipment	47,152.1	50,793.6	52,226.3	52,139.9	52,152.5	49,167.1
		Developmental projects	5,002.3	17,299.5	24,421.3	13,019.9	32,669.9	0
		Intangible assets	512.5	441.3	697.6	726.5	629.3	620.0
		Concession financial assets	16,098.8	21,201.8	22,896.4	22,896.4	50,475.7	22,968.3
		Total	68,765.7	89,736.2	100,241.6	88,782.7	135,927.4	72,755.4
Total of Assets			**86,028.6**	**110,187.7**	**122,389.8**	**103,167.0**	**169,670.7**	**95,633.3**
Liabilities	Current	Payables & others	2,794.3	12,360.2	22,210.9	17,722.4	8,140.8	17,542.8
	Fixed	Deffered tax & income	6,068.5	17,288.2	21,008.1	12,123.5	37,378.4	6,039.0
		10 years' bank loan	0	0	0	0	12,204.9	11,089.7
		AfDB loan disbursement	0	0	0	0	16,924.2	0
		Concession obligation	16,098.8	21,201.8	22,896.4	22,896.4	50,403.7	22,896.4
		Others	0	0	0	545.9	332.5	545.9
		Total	22,167.3	38,490.0	43,904.5	35,565.8	117,243.7	40,571.0
	Total		**24,961.6**	**50,850.2**	**66,115.4**	**53,288.2**	**125,384.5**	**58,113.8**
Equity	Capital		50,000.0	50,000.0	51,621.7	51,621.7	51,621.7	51,621.7
	Reserves	Retainned earnings	-514.3	-2,546.1	-5,563.8	-11,461.3	-16,444.6	-23,216.7
		Re-organization reserves	11,581.3	11,883.6	10,216.5	9,718.4	9,109.1	9,114.6
		Total reserve	11,067.0	9,337.5	4,652.7	-1,742.9	-7,335.5	-14,102.1
		Total	61,067.0	59,337.5	56,274.4	49,878.8	44,286.2	37,519.6
Total of Liabilities and Equity			**86,028.6**	**110,187.7**	**122,389.8**	**103,167.0**	**169,670.7**	**95,633.4**

Source: Financial Statements of WASAC

The characteristics of the B/S are summarized as below:

- Inventory: it is noted that WASAC has been reducing the operational stock every year, particularly chemical stores. Meanwhile, it should be noted that WASAC had made a provision for obsolete stock during the past years, as a result of which an amount of 2,613 million RWF has been accumulated by the year-end of FY 2019/20.
- Receivables and others: this account derives mostly from the customers' due amount, which showed a significant increase during the FY 2018/19 despite a decrease of the previous years. The tariff was raised in February 2019 which resulted in the increase of the receivable amount. At the end of 2019/20, the account decreased but still remains high caused by the COVID-19. Meanwhile, WASAC made a provision for the bad and doubtful customers' arrears during the past years, as a result of which an amount of 3,133 million RWF has been accumulated by the year-end of FY 2019/20.
- Fixed assets:
  - ✓ Property & equipment: No significant changes during the last 5 years. Around 3 to 5 billion RWF, which is likely the same amount for annual depreciation, is disbursed every year for investment

such as new acquisition, renewal and replacement.

- ✓ Development projects: this is a nominal account for the districts' network development.
- ✓ Concession financial assets: this pertains to the government-owned properties, mostly WTPs and transmission lines. Nominally these assets are accounted here vis-à-vis "concession obligation" under the fixed liabilities.

- Long-term borrowings: this is the first drawing from the bank loan (Bank of Kigali), which was arranged in March 2019 with the Government comfort letter under the following conditions:
  Bank commitment line: 17 billion FRW, loan period: 10 years, interest rate: 15% per annum (Reference: 10-years' government-bonds coupon: around 13%)
- The current ratio (current assets / current liabilities) for 6 years' average shows 162%, beyond 100%, which indicates financially sound in the short-term. The cash and banks account soared during the FY 2018/19 due to the tariff increase implemented in February 2019 and the bank loan disbursement, despite showing a sharp decrease in the previous FY 2017/18. The account turned out for the regular level at the end of FY 2019/20.

Table 6.1-3 Current Ratio (assets / liabilities) of WASAC

2014/15	2015/16	2016/17	2017/18	2018/19	2019/20	Average
618%	165%	100%	81%	414%	130%	162%

Source: JST

- The ratio of fixed assets to long-term capital (fixed assets / (equity + fixed liabilities)) on average for the last 6 years indicates 92%. This secures the financial soundness where the appropriate long-term financing for the acquisition of fixed assets is required.

Table 6.1-4 Fixed Assets to Long-Term Capital Ratio of WASAC

2014/15	2015/16	201 6/17	2017/18	2018/19	2019/20	Average
83%	92%	100%	104%	84%	93%	92%

Source: JST

- The equity account is composed of paid-in capital and reserves. The equity ratio (equity / (equity + liabilities)) declined every financial year in line with the decrease of retained earnings caused by the negative financial results of the periods, though increased in the last year.

Table 6.1-5 Equity Ratio of WASAC

2014/15	2015/16	2016/17	2017/18	2018/19	2019/20
71%	54%	46%	48%	26%	39%

Source: JST

6.1.3 Cash Flow (C/F)

Table 6.1-6 illustrates the C/F of WASAC. The last 2 years of FY 2016/17 and FY 2017/18 resulted in negative C/F. However, the C/F for FY 2018/19 soared significantly and turned into positive due to proceeds from grants. The C/F for FY 2019/20 turned into negative again.

Table 6.1-6 Cash flow Statement (RWF in million)

Activities	C/F Accounts	2014/15	2015/16	2016/17	2017/18	2018/19	201920
		Audited	Audited	Audited	Audited	Audited	Non-audited
1. Operational	1) Net income before tax	-1,009.1	-2,511.5	-4,611.4	-7,334.3	-2,470.3	-2,547.9
	2) Adjustment:						
	Depreciation & amortization	3,129.4	3,823.3	3,424.4	3,277.5	3,357.6	2,745.9
	Re-organization adjustment	-2,586.8	-265.2	0	0	0	0
	Changes in receivables and other current assets	5,995.4	-1,234.5	-2,230.0	4,521.7	-15,483.2	-7,387.5
	Changes in payables and other current liabilities	3,081.1	7,461.7	9,850.7	1,348.8	-9,815.0	3,359.3
	Provision of write-back	0.0	-596.5	0	0	0	0
	Realized grants	-27.8	0	0	0	0	0
	Total of adjustment	9,591.3	9,188.8	11,045.1	9,148.0	-21,940.6	-1,282.3
	3) Operation Net CF = 1) - 2)	8,582.2	6,677.3	6,433.7	1,813.7	-24,410.9	-3,830.2
2. Investing	Purchase of property & equipment	-8,902.9	-14,269.3	-11,959.9	8,404.3	-50,502.3	0
3. Financial	Proceeds from grants	2,752.3	8,927.1	4,993.4	-10,590.0	78,789.3	-685.5
4. Net CF generated in the Period =1+2+3		2,431.6	1,335.1	-532.8	-372.0	3,876.1	-4,515.7

Source: Financial Statements of WASAC

6.2 WATER TARIFF

The tariff was revised first in 2015, and lately in February 2019. This is shown in **Table 6.2-1.** It is examined that the average tariff has soared by 40% to 730 RWF/m^3 by observing the consumption data of March 2019 compared with around 520 RWF/m^3 of the previous periods.

- The Rwanda Utilities Regulatory Authority (RURA) is the organization to regulate the public utilities, including tariff and charges. The RURA, during the tariff setting, considers the balancing of the interests of all water beneficiaries as well as financial sustainability and service delivery of water supply in Rwanda.
- The current water tariffs, which were effective from February 2019, significantly raised that of residential customers with a consumption range of 6–50m3. On the contrary, the tariffs for the industrial customers and the public water taps were unchanged. According to the RURA, this was done in order to attract investors and to cater to affordability issues.
- WASAC sends to the customers the monthly bills and the customers pay the due amount usually at banks or at WASAC's commercial office.

Table 6.2-1 Water Tariffs of WASAC

Customer Category	Consumption Band	Effective Date				
		Before Aug. 31, 2015	Sept. 1st, 2015		Feb. 1st, 2019	
		RWF	RWF	Rise	RWF	Rise
1.Industries	-	593	736	24%	736	Unchanged
2.Public tap	-	240	323	35%	323	Unchanged
3.Residential	0 – 5 m^3	240	323	35%	340	5%
	6 - 20	300	331	10%	720	117%
	21 - 50	400	413	3%	845	105%
	51 - 100	650	736	13%	877	19%
	>101	740	847	14%	877	4%
4.Non-residential	0 - 50	-	-	-	877	-
	>51	-	-	-	895	-

Source: WASAC

6.3 OVERALL OPERATION COSTS

The operation costs of WASAC are summarized in **Table 6.3-1**. Sector-wisely, the sum of production, distribution and commercial costs reached to 60% of the overall operation costs. The administrative sector costs followed it. By cost items, the energy costs are dominant (around 30%).

Table 6.3-1 Summary of Operation Costs (RWF in million)

Sectors	Cost Items	2015/16	2016/17	2017/18	%	2018/19	%	2019/20	%
1.Production	Chemical	712.6	1,410.30	1,742.30		1,882.3		1,799.1	
	Energy	4,703.5	5,771.3	5,769.5	23.7	6,537.3	27.2	6,986.9	29.3
	Repair & maintenance	351.5	159.5	117.9		207.1		193.5	
	Total	5,767.6	7,341.1	7,629.7	31.4	8,626.7	35.9	8,979.5	37.7
2.Distribution	Salaries	2,369.7	2,519.7	2,583.9		2,797.4		2,622.9	
	Labor Wages		998.7	1,064.5		850.3		999.6	
	Repair & maintenance	1,508.0	811.4	776.0		556.7		480.0	
	Others	386.7	672.4	566.0		557.6		596.7	
	Total	4,264.4	5,002.2	4,990.4	20.5	4,762.0	19.8	4,699.2	19.7
3.Commercial	Salaries	1,619.8	970.5	995.3		1,077.5		1,010.3	
	Rent	85.6	247.1	261.1		200.5		194.3	
	Advertisement	81.7	65.8	67.1		22.2		44.7	
	Others	852.6	745.3	20.6		13.8		13.4	
	Total	2,639.7	2,028.7	1,344.1	5.5	1,314.0	5.5	1,262.7	5.3
4.Administrative	Salaries	2,298.5	1,802.9	2,019.9		3,289.9		4,085.1	
	Others	864.9	1,719.7	*5,059.4		2,711.7		2,075.8	
	Total	3,163.4	3,522.6	7,079.3	29.1	6,001.6	24.9	6,160.9	25.8
5.Depreciation and Amortization		3,475.3	3,424.4	3,277.5	13..5	3,357.6	14.0	2,745.9	11.5
Total		**15,835.1**	**21,319.0**	**20,932.3**	**100.0**	**24,061.9**	**100.0**	**23,848.2**	**100.0**

Note: * contains provision for bad/doubtful debts (1,224.7) and obsolete stock (1,535.4)
Source: Financial Statements of WASAC

6.4 BUDGETARY SYSTEM

The budgetary system of WASAC according to the Financial Department is summarized in **Table 6.4-1**. WASAC involves every department for processing budget preparation as stated clearly in the FY 2019/20

budget report: that is, "The budget preparation was decentralized to involve both tactical and operational levels in determining their priorities and required resources. Debates and deliberations involve not only managers but also the staff in various functions." This means, so-to-speak, a bottom-up budget processing system, which obviously enhances the motivation of staff.

Table 6.4-1 Summary of the Budgetary System of WASAC

Steps	Responsible	March	April	May	June
1. Action plan preparation	Every department				
2. Budget call	CEO				
3. Budget preparation	Every department				
4. Scrutinizing and disputation	By financial dept.				
5. Approval	Board				

Source: WASAC

Some of the key assumptions as the set-up for the revised FY 2020/21 budget are as follows:

Production: 57.9 (54.6) million m^3, NRW: 41.8 (38) %, average tariff: 719 (736) RWF/m^3, electricity cost: 126 RWF/kw exclusive VAT and average energy cost: 134.8 (128.0) RWF/m^3

Note: figures in parenthesis indicate that of original budget.

6.5 EXISTING ISSUES RELEVANT TO FINANCIAL MANAGEMENT

6.5.1 Concession Agreement

WASAC was created in July 2014. The government grants WASAC the right to operate and maintain water collection, treatment and supply for 25 years according to the Concession and Implementation Agreement between WASAC and the Government. However, the agreement is yet to be signed by both parties.

1) Concession Fee

According to the agreement, WASAC has to pay the concession fee to the Government on a monthly basis. However, this is yet to be paid.

- ✓ Issues: the due amount of fee is not stated in the agreement. It hampers WASAC in making a strategic medium- and long-term financial plan.

2) Fixed Assets Owned by Government

Main facilities, e.g., the WTPs and water transmission lines, belong to the Government according to the above-mentioned agreement. These assets are not recorded under WASAC's fixed assets accordingly.

- ✓ Issues: these assets need to be clearly listed and registered under a certain form separately from WASAC's own fixed assets so as to help in a responsible and appropriate repair & maintenance work periodically and continuously.

6.5.2 Fixed Assets Owned by WASAC

The book value of WASAC's fixed assets, after depreciation, amounts to 51.9 billion RWF, which is

around 50% of the total assets

- ✓ Issues: the registration and management of the fixed assets of WASAC has not been made appropriately since its creation. However, it is emphasized that WASAC is now in the process of updating the fixed asset register, especially on the following assertions:
    1. Confirmation of ownership of the asset in the existing asset register
    2. Valuation of the assets in the register
    3. Confirmation of removals & additions as up to date
    4. Inventory check of the fixed assets in the field
    5. Rights and obligations of WASAC over those assets

6.5.3 Tariff strategy

Total unit cost of WASAC WASAC FY 2018/19 and FY 2019/20 is estimated at 780 RWF/m^3 and 806.0 RWF/m^3 respectively as presented in **Table 6.5-1** below. It is obvious that the actual water tariff of 730 RWF/ m^3 of the same period is far lower than this unit cost, which means 10% below the break-even point.

- ✓ Issues:
  1. The cost recovery policy is an essential matter for running an entity as clearly stated under WASAC's 5 Year Strategic Business Plan, January 2016. However, WASAC has no discretion for tariff revision. This hampers the financial and technical improvement of WASAC. The RURA is strongly requested to grant WASAC to some extent a right for tariff setting at its own discretion accordingly.
  2. When considering the affordability of citizens, the full cost-recovery tariff might not be permitted by the RURA. If so, the Government should commit WASAC to secure the financial gap consistently for the sustainable water supply business because WASAC is regulated heavily by the Government and is difficult to be financially independent.

Table 6.5-1 Unit Cost by Sectors

Sectors (see Table 6.3-1)	FY 2018/19			FY 2019/20		
	Expenditures	Billing	Unit cost	Expenditures	Billing	Unit cost
	RWF million	m^3 million	RWF/m^3	RWF million	m^3 million	RWF/m^3
1.Production	8,987.4	-	291.9	8,979.5	-	303.5
2.Distribution	4,993.5	-	162.2	4,669.2	-	158.8
3.Commerce	1,303.3	-	42.3	1,262.7	-	42.7
4.Administration	5,382.1	-	174.8	6,160.9	-	208.2
5.Depreciation	3,352.2	-	108.9	2,745.9	-	92.8
Total	24,019.5	30.8	780.0	23,848.2	29.6	806.0

Source: WASAC

6.5.4 Kigali Bulk Water Supply Project (Kanzenze WTP)

According to the agreement, the produced water is to be charged to WASAC at the rate of 0.75 US$/$m^3$ which is equivalent to 680 RWF/ m^3. This amount is to be due monthly from May 2020 onwards but was actually invoiced from January 2021 due to a delay of operation commencement. The charges are extremely high compared to the WASAC production cost of 313 RWF/ m^3 (see **Table 6.5-2)**.

- ✓ Issues: It is a crucial matter to simultaneously revise WASAC's water tariff as well as the budget for the year or to be financially supported by the GOR.

Table 6.5-2 Bulk Water Charges and WASAC Production Cost

Structure of charges of Kigali Bulk Water Supply		Kigali Bulk Water Charges		WASAC Production Cost*3		
Items	**Sub-items**	***1US$/m3**	**RWF/m3**	**RWF million**	**million m3**	**RWF/ m3**
1.Fixed capacity cost	Capital cost (+operational margin*2)	0.41	369	-	-	-
2.Fixed operation & maintenance charge	Recurrent cost	0.14	126	-	-	-
3.Variable operation & maintenance charge	Chemical and repair & maintenance cost			-	-	-
4. Electricity charge	Electricity	0.20	180	-		-
Total		0.75	**675**	10,152	32.4	**313**

Note: *1: US$ 1 = RWF 900,

*2: supposition by JST, *3: Actual data of Kimisagara, Karenge and Nzove in FY 2018/19

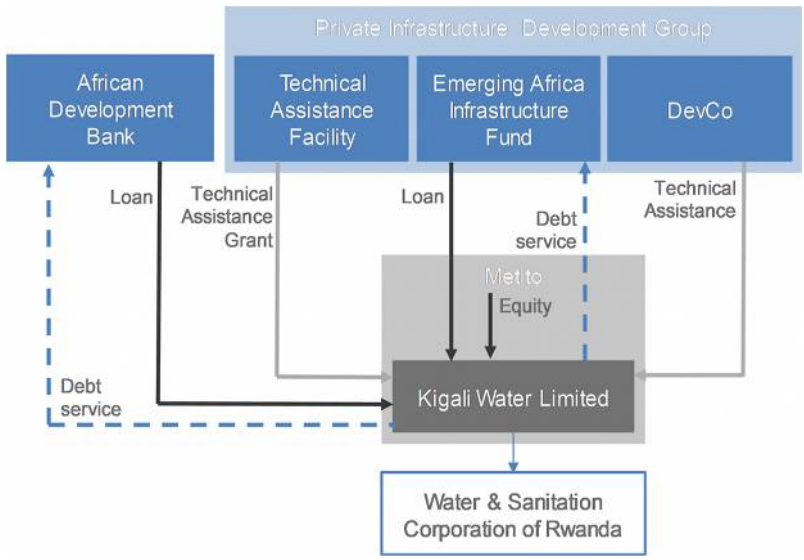
Source: WASAC

Box 1: Financing Scheme of Kigali Bulk Water Supply Project

Considering the large investment for the 2050 perspectives, Public-Private Partnerships (PPP) is one of the important schemes of the financing. The financial scheme of the Kigali Bulk Water Supply Project became a showcase of blended finance internationally. **Figure 6.5-1** represents the financial structure of the project.

The contract arrangement is as follows;

- 27 years Build-Operate-Transfer agreement (2-year grace period until construction and 25 years O&M)
- In the total 60.1 MUSD capital investment, 11 MUSD (18%) was the equity finance by a private company (Metito) and 40 MUSD was the debt financing by Emerging African Investment Fund (EAIF) and AfDB.



Total: 60.9 MUSD (Approx. 66% Debt, 18% Equity)

* Cost discrepancy is due to the currency exchange.

Unlocking Commercial Finance for SDG 6 (Annex B) (Added prices by JST)

Figure 6.5-1 Financial Structure of Kigali Bulk Water Supply Project

- The project initially had included the transmission and distribution facilities, but the component was transferred to other AfDB funded projects. The arrangement was agreed because "greater efficiency could be achieved by allocating (it) to be WASAC[1]". The project cost by PPP was reduced from 79 MUSD to 61 MUSD by this arrangement.

[1] Source: OECD (2019) Making Blended Finance Work for Water and Sanitation : Unlocking Commercial Finance for SDG 6 (Annex B)

CHAPTER 7 ON GOING PROJECT

7.1 OVERVIEW

This chapter describes the overview and the scope of works for the on-going water supply projects in the CoK. There are five on-going projects pertaining to water supply in the CoK, namely 1) The Rwanda Sustainable Water and Sanitation Program 2) The New Nzove 1 Project, 3) The Kigali Bulk Water Supply Project, 4) The Nzove-Ntora Transmission Pipeline Project and 5) The Project for Strengthening Non-Revenue Water Control in the CoK Water Network (**Table 7.1-1**). The overall schedule for these on-going projects is presented in **Table 7.1-2**. Water supply systems after the on-going projects are shown in **Appendix-16(2).**

Table 7.1-1 List of On-going Projects

No.	Name of the Project	Investor/Contractor
1	Rwanda Sustainable Water and Sanitation Program (Sub-project: the Design Rehabilitation, Upgrading and Extension of Water Supply Network in the CoK and Peri-urban areas)	AfDB/China Railway
2	New Nzove 1 Project	WASAC/Culligan
3	Kigali Bulk Water Supply Project	Metito (IFC)
4	Nzove-Ntora Transmission Pipe	JICA
5	Project for Strengthening Non-Revenue Water Control in the CoK Water Network	JICA

Source: JST

Table 7.1-2 Expected Schedule of On-going Projects (as of June 2019)

	Project	2019							2020										2021										
		6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#	1	2	3	4	5	6	7	8	9	#	#	#
1	AfDB Sustainable WatSan Program																											Until June 2023			
	(Sub-project: China Railway)	Design										Completion of Constuction																				
2	New Nzove 1 Project	<Completed but not fully delivered>																														
3	Kigali Bulk Water Supply (Kanzenze)			Service Commencement																												
4	Nzove-Ntora Pipeline																				Completion of Construction											
5	JICA Non-Revenue Water																															

Source: JST

7.2 RWANDA SUSTAINABLE WATER AND SANITATION PROGRAM

The Rwanda Sustainable Water and Sanitation Program is the loan program under the AfDB. The objective of the program is to ensure equitable provision of adequate, reliable and sustainable water and sanitation services for the targeted cities and suburban areas namely; the CoK, the Nyagatare, the Gatsibo, the Kayonza, the Ngoma, the Bugesera, the Ruhango, the Nyanza, the Muhanga, the Ngororero, the Kamonyi, the Musanze, the Nyabihu, the Rubavu, the Karongi and the Rutsiro. The total loan amount is 261.9 million Euros, including the additional loan signed during January 2019.

As for the water supply in the CoK, all the works are under a sub-project named the Design Rehabilitation,

Upgrading and Extension of the Water Supply Network in the CoK and Peri-urban Areas Project. The on-going project covers a comprehensive rehabilitation and expansion within and surrounding areas of the CoK including its four major expansion areas (**Table 7.2-1**). The project is also in line with the increase in water supply capacity by Kanzenze WTP (40,000 m^3/day).

Table 7.2-1 Overview of the On-going Project

Name of Project	Rwanda Sustainable Water and Sanitation Program
Funding	AfDB
Name of Sub-project	*the Design Rehabilitation, Upgrading and Extension of Water Supply Network in the CoK and Peri-urban Areas*
Name of Contractor	China Railway Construction Engineering Group
Scope of Work	- Design and construction (Design-Build) of water main pipelines and reservoirs for the following sections, including 64 km pipelines and eight reservoirs for Section #9.

No.	Section Name	Sector
#6	Nduba Water Network	Nduba
#7	Kanyinya Water Supply	Kanyinya
#8	Rugarika Water Supply	Rugarika
#9	Water Infrastructure for Kanzenze, Kicukiro and Bugesera	CoK and Bugesera
#10	Bweramvura	Jabana

Source: JST

The AfDB project will include 38 reservoirs with a capacity of 85,750 m^3, which is more than the existing capacity of reservoirs under the WASAC as of 2018 **(Table 7.2-2**). The total capacity of the reservoirs will be more than 159,000 m^3, which is equivalent to 19.6 hours of the water supply capacity after the completion of the Kanzenze WTP.

Table 7.2-2 Capacity of Existing Reservoirs

Capacity and Category	Number of Reservoir	Capacity (m^3)	Equivalent hours to Daily maximum water supply (Hours)
Total for Existing Res.	158	71,512	10.4
On-going Reservoirs	**38**	**85,750**	
Total Existing + On-going	196	159,125	19.6

Source: JST

Major modification on the existing system includes;

- "Northern ring" pipeline (ND500 L=10km and ND400 L=8 km) from the Ntora to the New Remera Reservoir (10,000 m^3) and the Kimironko reservoir (5,000 m^3)
- The Kanombe, the Nyarugunga, and the Masaka Area; 4 Reservoirs totaling 9,000 m^3 and pipe extension from the Kanzenze WTP
- The Gahanaga and the Gikondo; 6 Reservoirs totaling 28,000 m^3
- The CBD: A reservoir at city center (2,000 m^3)
- Expansion of reservoir capacity at the Kibagabaga (5,000 m^3), the Kacyiru (Merdien, 1,000m^3) and the

Kabuga (1,000m^3)

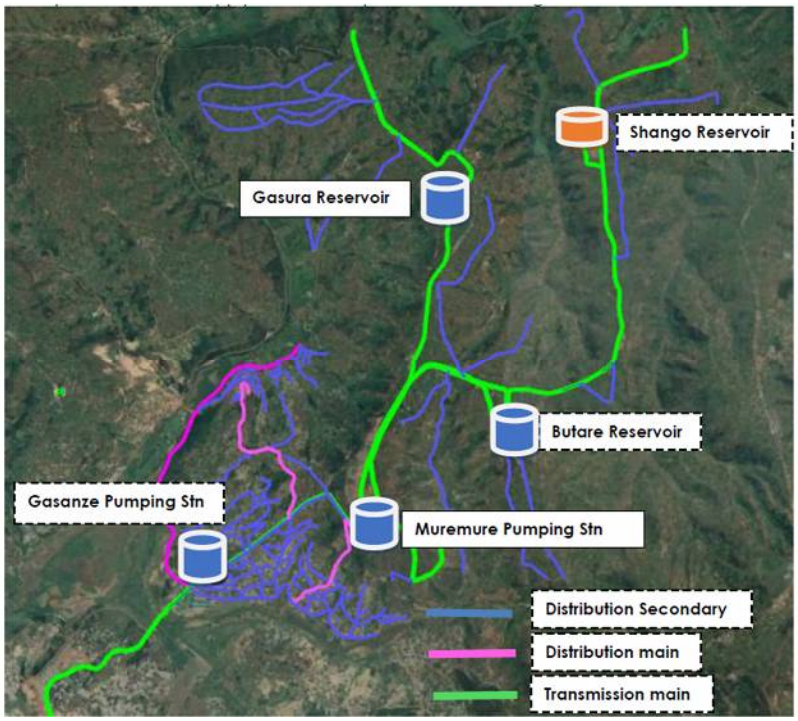
Note that the following sectors will significantly gain access as a result of the expansion.

In the CoK;

- The Jabana: New #10 Bweramvura water supply expansion for the entire Jabana sector. Water will be supplied from the new northern ring pipeline (**Figure 7.2-1)**. This line includes some booster pumping system for distribution.
- The Nduba: #6 Nduba water network for the entire Nduba sector (**Figure 7.2-1**). The water will be supplied from the Amakawa reservoir, branched from the Ntora-Fawe Girls School reservoir line.
- The Kanombe and the Gahanga: Extensive expansion from the Kanzenze WTP (**Figure 7.2-2**).
- The Kanyinya: Extension from the Kanyinya reservoir and from the Kimisagara WTP through the Nyabarongo River (left bank) to the Shyorongi sector (**Figure 7.2-3**).

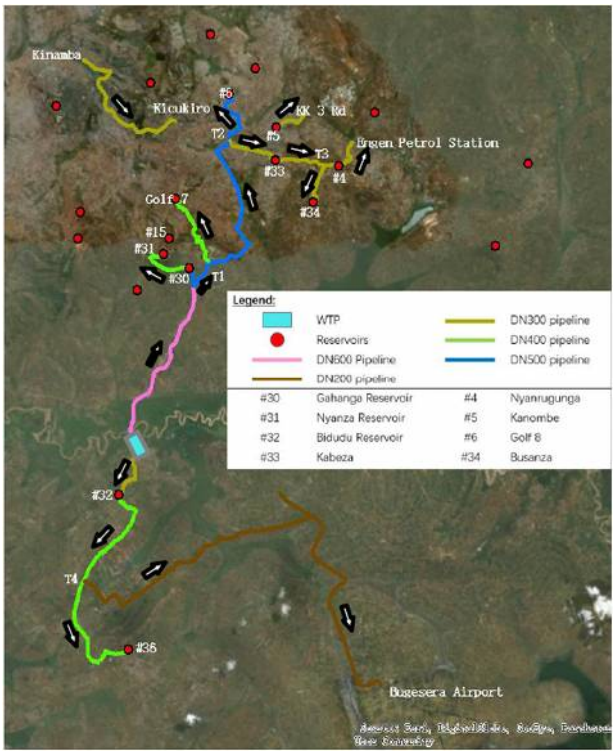
Adjacent 7 sectors;

- The Shyorongi: Southern portion of the sector near the CoK from the Kimisagara WTP through the Kanyinya (**Figure 7.2-3**).
- The Runda: Expansion of a reservoir (5,000 m^3) (**Figure 7.2-4**).
- The Rugarika: Pipes and reservoir expansion for the entire sector. Water is to be supplied from the Nzove WTP (**Figure 7.2-4**).
- The Ntarama: New Bidudu reservoir and pipeline from the Kanzenze WTP **(Figure 7.2-5**).
- The Nyakaliro: New reservoir at the Bihembe-Nyakaliro (5,000 m^3) (**Figure 7.2-6**).
- (The Gahengeri and the Muyumbu: No expansion)



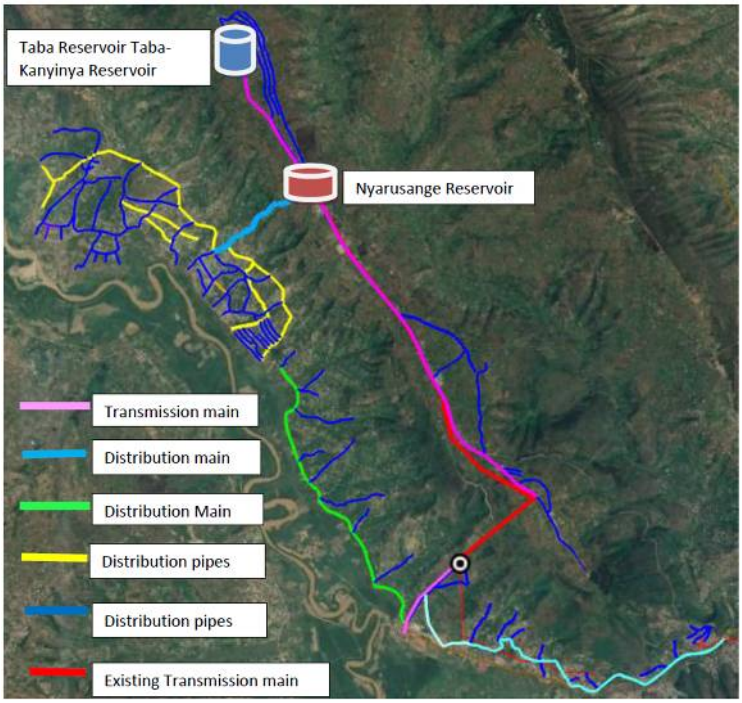
Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-1 On-going Expansion at Jabana and Nduba Sectors



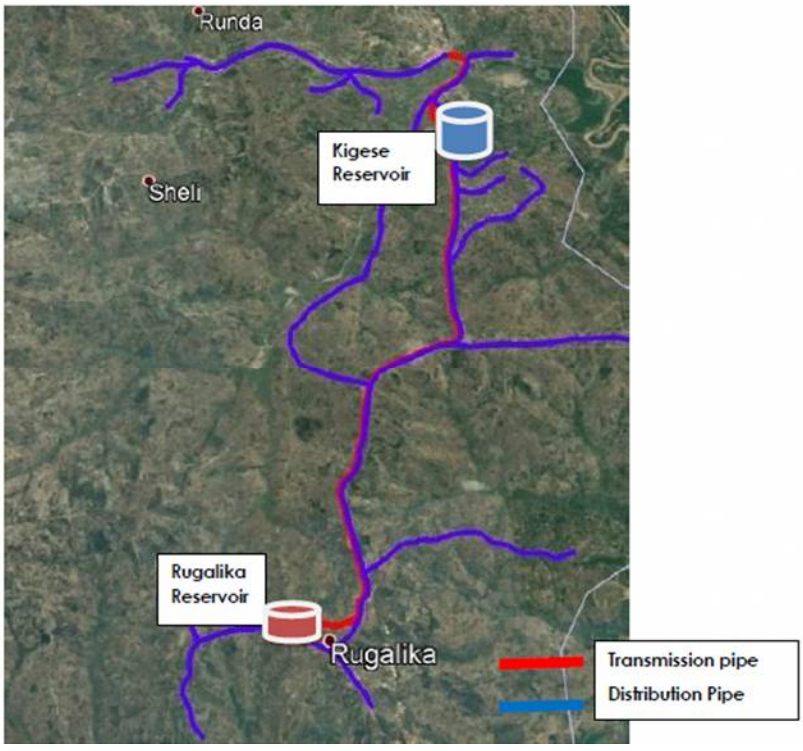
Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-2 On-going Expansion at Kanombe and Gahanga sectors



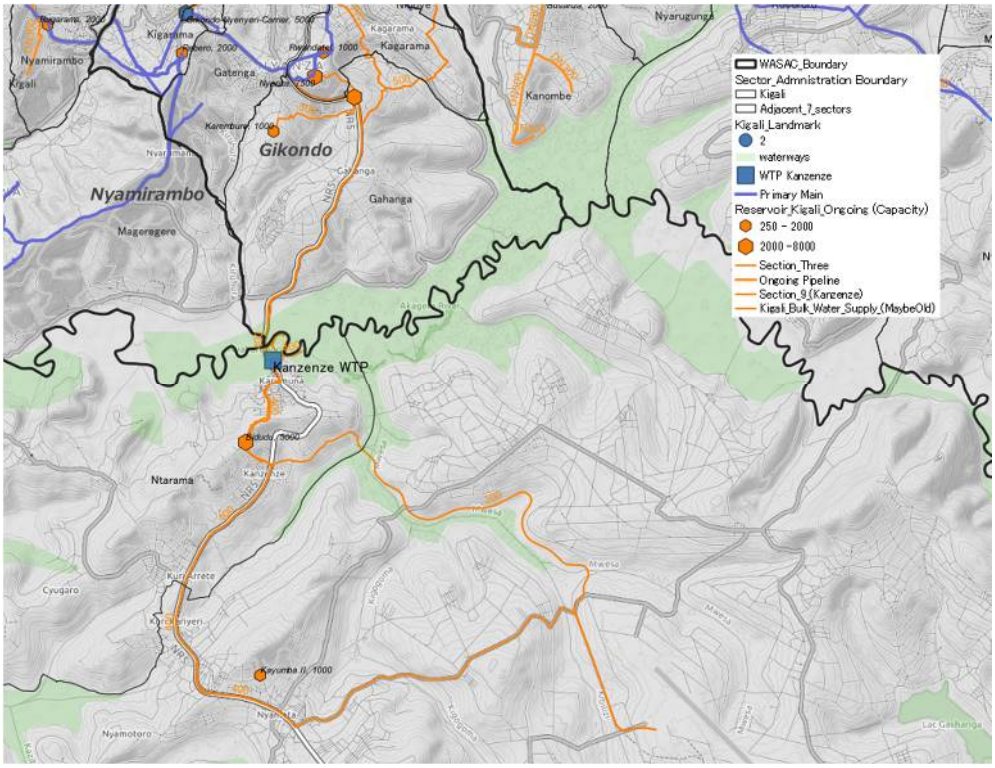
Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-3 On-going Expansion at Kanyinya and Shyorongi Sectors



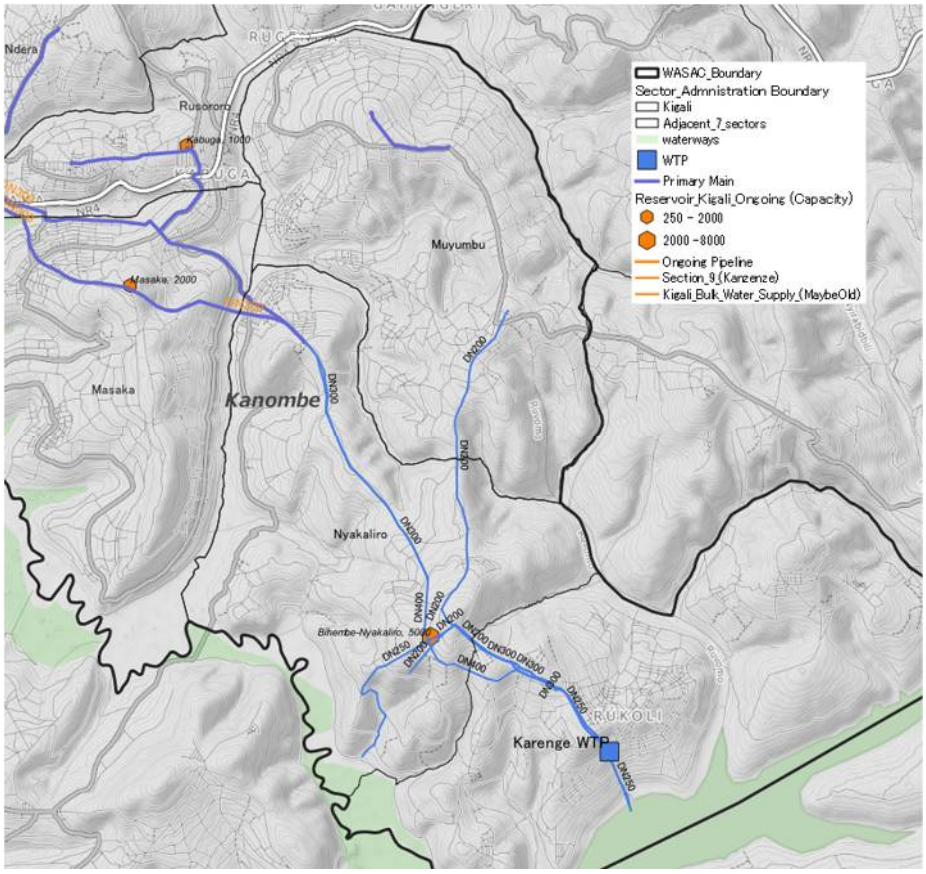
Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-4 On-going Expansion at Runda and Rugarika Sectors



Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-5 On-going Expansion at Ntarama Sector



Source: Detailed Design Draft Report, Design, Rehabilitation, Upgrading and Extension of Water Supply Network in Kigali City and Peri-urban areas Project (November 2019).

Figure 7.2-6 On-going Expansion at Nyakaliro, Muyumbu and Gahengeri Sectors

7.3 NEW NZOVE 1 PROJECT

The New Nzove 1 Project involves design and construction works to expand the Nzove WTP with the capacity of 65,000 m^3/day as described under **Section 5.4**. The project was substantially completed and inaugurated on 6th May 2019. In 2019, the total capacity from the New Nzove 1 is 40,000 m^3/day. Only the filtration basins and the appurtenant works are yet to constructed to ensure full capacity of 65,000 m^3/day.

The project also includes the expansion of transmission and distribution systems to the eastern area in the CoK as shown in **Figure 7.2-3**. The new system includes transmission pumps in the Nzove WTP, reservoirs and pumps in the Karama 2, and the new Mont-Kigali reservoirs and transmission pipelines in between those reservoirs and pumping stations (DIP ND400).

The New Nzove 1 system is operating but is yet to be fully handed over by the Contractor (Culligan) to the WASAC as of June 2018.

7.4 KIGALI BULK WATER SUPPLY PROJECT (KANZENZE WTP)

The Kigali Bulk Water Supply Project is a Public-Private Partnership Project amongst the WASAC, the Metito (a private company) and the IFC. The project aims at construction and the operation of new water sources and water treatment plant at the Kanzenze. It is a Build-Operate-Transfer (BOT) project with a contract between the WASAC and the Metito and initially coordinated and funded by the IFC. The construction for the project started in November 2017 and is on-going as of 2019. The commencement of the services is expected to be from May 2020. The operation period is 25 years, and the assets are set out to be transferred to the WASAC after the completion of the operation period by the operator.

The Kanzenze WTP is located in the Kanzenzein the southeastern part of the CoK and about 20 km from the city center. The Kanzenze WTP is designed to be a 40,000 m^3/d, extracting groundwater from the south bank of the Nyabarongo River. The summary of the Kanzenze WTP is shown in **Table 7.4-1**. The water will be allocated to the CoK (30,000 m^3/day) and the Bugesera District (10,000 m^3/day). The water from the Kanzenze WTP is expected to be supplied to the Gahanga, the Kagarama, the Gatenga, the Nuboye, the Remera, the Kimironko, the Nyarugunga and the Kanombe areas of the CoK, and the Ntarama and airport area in the Bugesera district.

Table 7.4-1 Summary of Kanzenze WTP

Item	Contents	Remarks
Design capacity	40,000 m^3/d	Supplying 30,000 m^3/d to the CoK.
Raw water source	The groundwater of Nyabarongo River	Totally 35 wells.
Design raw water quality	Turbidity: 3-5 NTU	
Treatment process	Receiving Well →Aeration → Flocculation & Sedimentation → Filtration → Chlorination → Pump Station (app. H300 m)	
Construction scheme	Public-Private Partnership (PPP)	・ Build Operate Transfer (BOT, 27 years) and bulk water supply method. ・ Metito will be responsible for the financing, design, construction, O/M of the WTP. ・ First PPP project in Rwanda.
Construction period	July 2018- May 2020	
Contractor	International Water Treatment Rwanda LTD (IWTR)	
Construction cost	60.8 mil. $ [Emerging Africa Infrastructure Fund (EAIF) and The African Development Bank (AfDB) are covering US$40.6 million of the capital cost of the project; The balance will be provided by Metito as equity finance.]	Including boreholes, river protection, borehole pumps and wellfield pipework, WTP, transmission pipeline and reservoir etc.

Source: WASAC and METITO

The project details from the contractual aspect are as follows;

- **Developer/Contractor/Operator**: The Kigali Water Limited., Special Purpose Vehicle (SPV) fully subsidized by the Metito Holdings Limited.

- **Financing**: Equity financing by the Metito from the IFC
- ***Take-or-pay* contract**: The WASAC shall pay the cost of water for full production capacity (40,000 m^3/day) at minimum, regardless of the amount which the WASAC consumed.
- **Water charge**: Approximately 0.75 USD/m^3 at the year of delivery
  The fee is calculated as per the equation presented below;

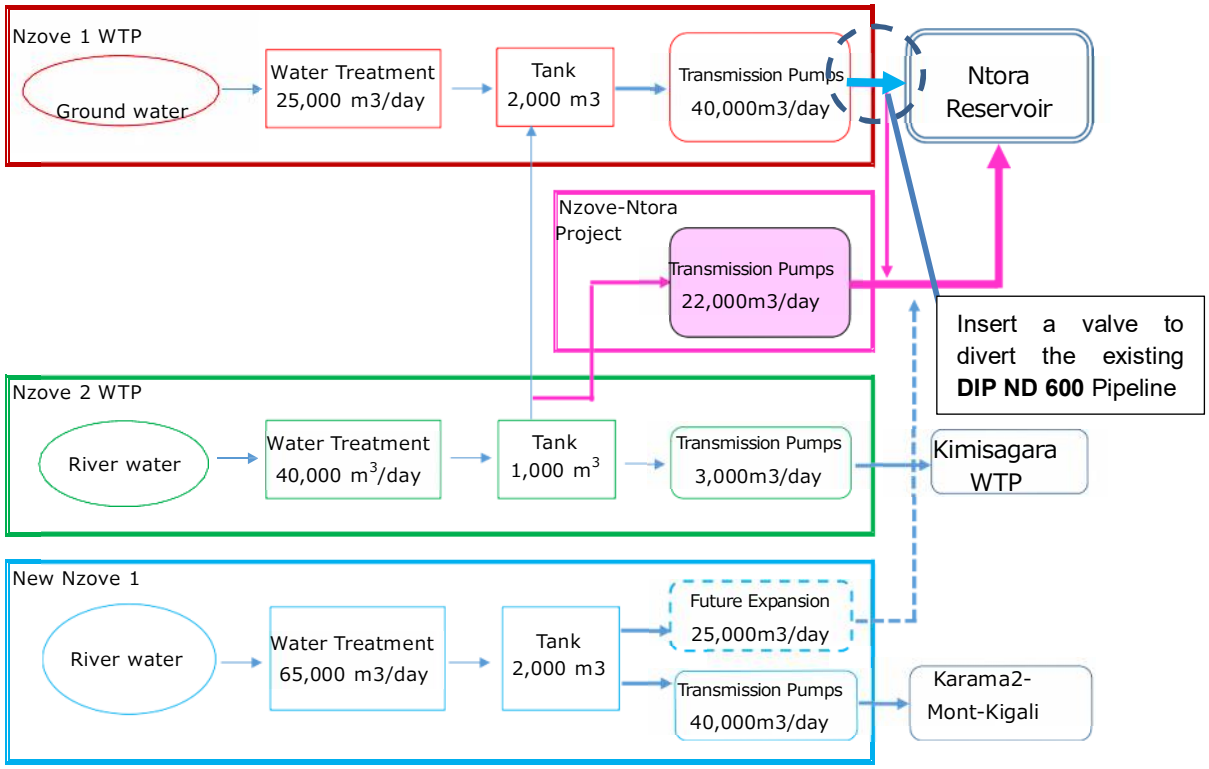
  Water charge (RWF/m^3) = FCC + (FOMC + VOMC * V)*CPI +EC
  where;
  FCC: Fixed Capacity Charge, subject to adjustment by inflation
  FOMC: Fixed Operation and Maintenance Charge,
  VOMC: Variable Operation and Maintenance Charge
  V: Volume of water supplied
  CPI: Consumer Price Index of steel in the US (rate of CPI at current/before bid)
  EC: Electricity Charge

- The breakdown of 0.75 USD/m^3 at the commencement year is as follows; the fixed cost (FCC) 0.41 USD/m^3, the electricity charge (EC) 0.20 USD/m^3 and the others 0.14 USD/m^3. Therefore, the price is variable by inflation, material prices and the electricity tariff. In a financial estimate prepared by the WASAC, the water charge will be 0.82 USD/m^3 at the 6 years after the service delivery.

- **Acceptable Degradation**: Degradation of raw water quality is subject to variation with a condition. The measures for short-term degradation within 30 days are borne by the operator; in other words, the WASAC is responsible for indemnifying if it continues for more than 30 days. The acceptable "degradation" by the operator for raw water is defined under the Contract, e.g. 150 NTU for turbidity.

7.5 THE PROJECT FOR STRENGTHENING OF THE NZOVE-NTORA WATER PRINCIPAL PIPELINE IN THE COK

The Project for Strengthening of the Nzove-Ntora Water Principal Pipeline is aimed at strengthening the transmission capacity of the Nzove WTP. The scope of the project mainly consists of a new transmission pump station with a capacity of 22,000 m^3/day and a 900 mm new pipeline (SP, DIP) from the Nzove WTP to the Ntora WTP (**Figure 7.5-1**). The project is a grant aid project from the Government of Japan and is expected to be completed by late 2021.



Source: JICA (2019) Final Report, the Project for Strengthening of Nzove-Ntora Water Principal Pipeline in the CoK

Figure 7.5-1 Modified Nzove WTP Systems after the On-going Expansion Works

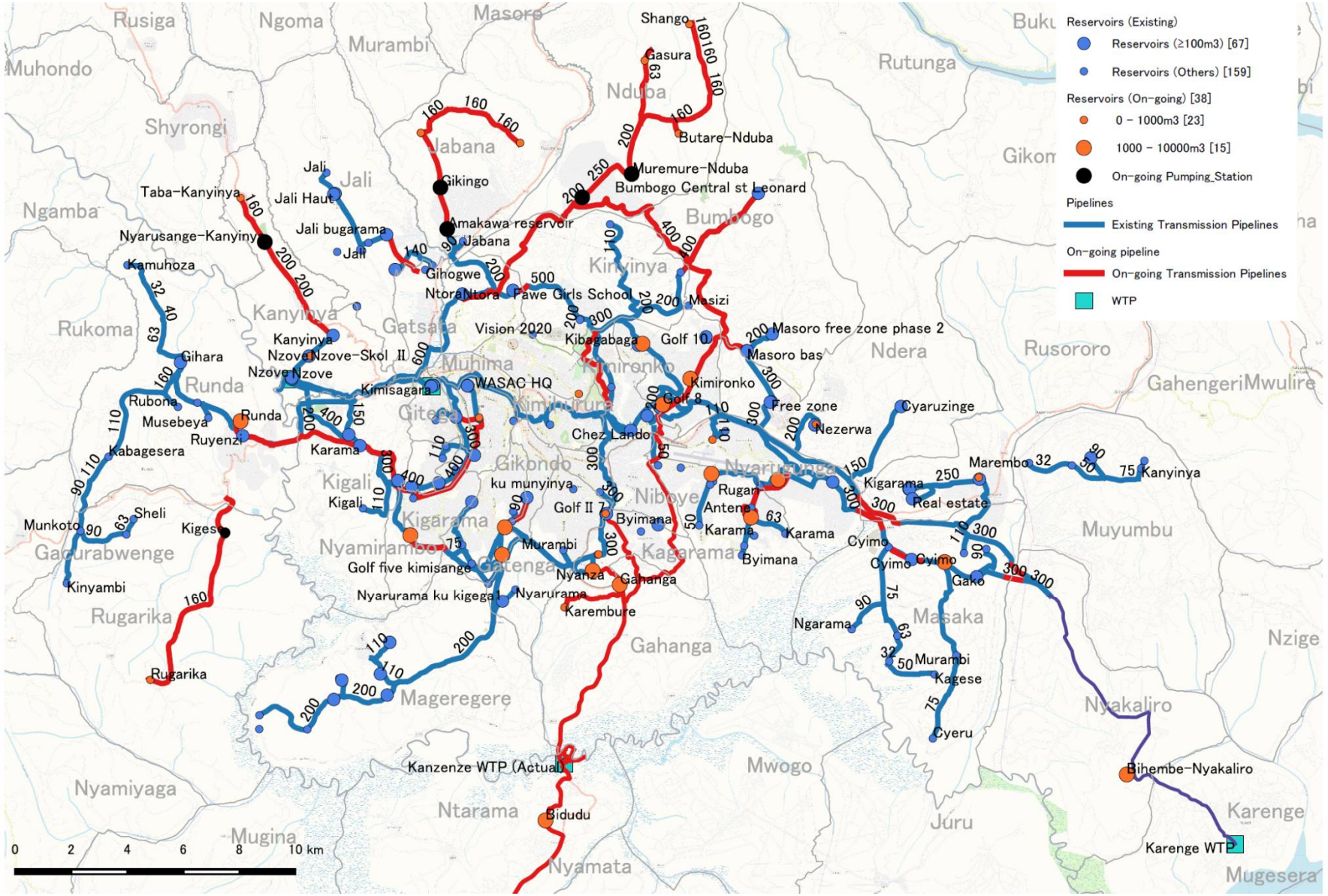
7.6 PROJECT FOR STRENGTHENING NON-REVENUE WATER CONTROL IN THE COK WATER NETWORK

The Project for Strengthening Non-Revenue Water Control in the CoK Water Network is a technical cooperation project funded by the JICA. The project is aimed at strengthening the capability of the WASAC to carry out the measures in order to reduce NRW in the CoK in a planned manner. The activity includes formulating plans for reducing NRW, the pilot projects being implemented in the Kadobogo and the Ryenzi.

The project also includes the installation of the district meters, which is aimed at comprehending the water usage at each branch in the City. The supply area in the City is divided into six branches (**Section 5.1**). Thus, the water supply is loosely separated. The location and the specification of water meters are yet to be disclosed and the same will be clarified by the end of the year 2019. SCADA system and servers are also to be procured under the WASAC's own budget by the end of the year 2019.

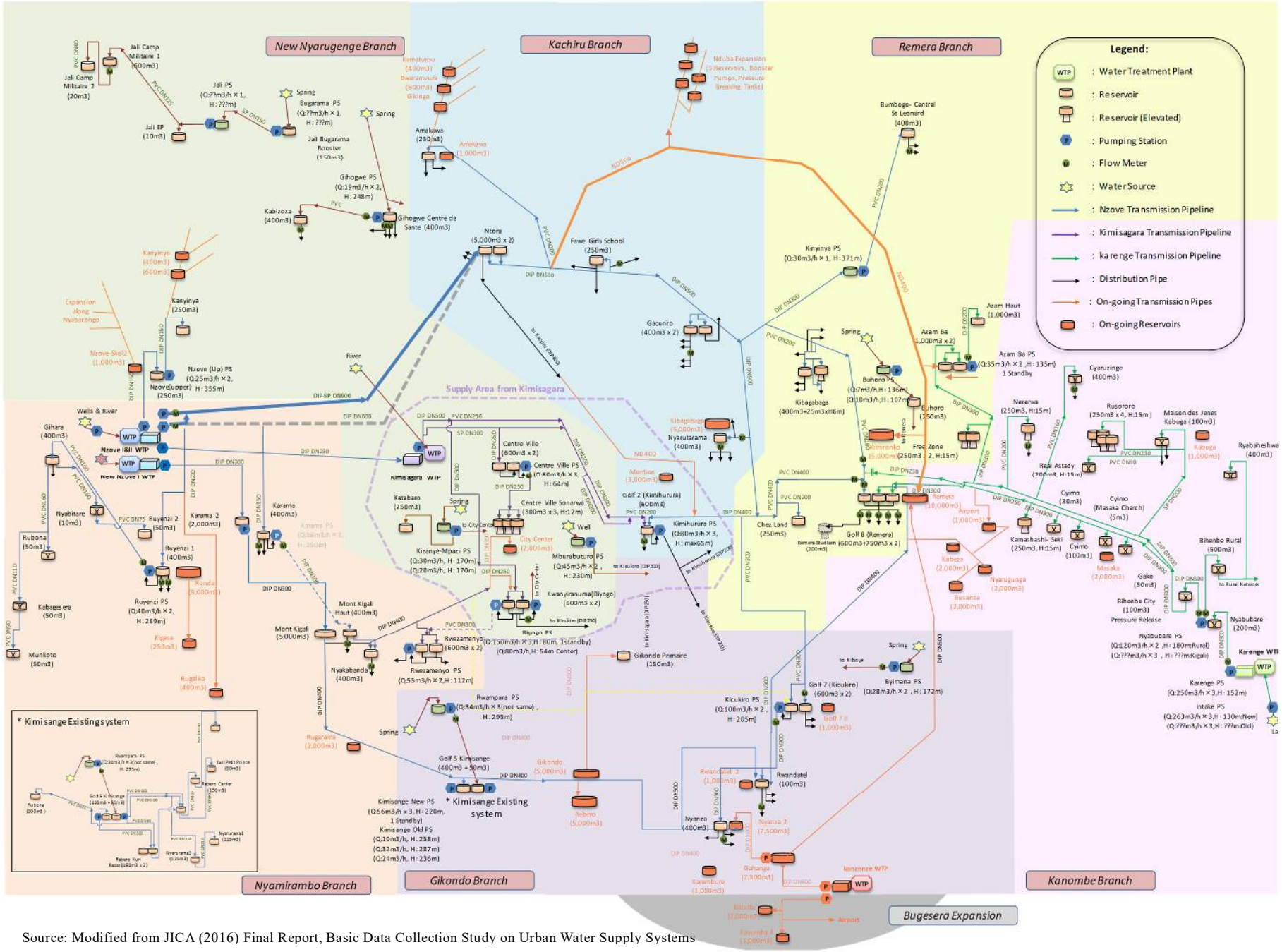
7.7 ON-GOING EXPANSION OF TRANSMISSION AND DISTRIBUTION PIPELINES

On-going expansion of transmission and distribution pipelines, including the ones described in 7.2, as of August 2021 are summarized in **Figure 7.6-1** and **Figure 7.6-2** which are visualized using the WASAC's GIS data and schematic models which are used in the WASAC UWSSD.



Source: JST

Figure 7.7-1 Water Supply Pipelines in and Surrounding of City of Kigali



Source: Modified from JICA (2016) Final Report, Basic Data Collection Study on Urban Water Supply Systems

Figure 7.6-2 Water Supply System after the Completion of On-going Project

CHAPTER 8 CAPACITY DEVELOPMENT

8.1 EVALUATION OF PLANNING CAPACITY OF THE WASAC STAFF

JST conducted first baseline questionnaire survey to the WASAC Staff who are the members of M/P working groups (17 persons) in April 2019 to evaluate their capacity on the project commencement. The final questionnaire survey is carried out in July 2021 (16 persons) for final evaluation of the capacity development in the course of the project. The positions of participants are as follows; Director of UWSS, Heads of major WTPs, Head of Leak Detection and Pressure Management, Head of Water Production Services, Acting Head of Water Central Laboratory, Manager of NRW and Head of Branches. The contents of the questionnaire for the baseline and final survey are shown in **Table 8.1-1**. Most of the questions (Q1 ~ Q12) are same between the baseline survey and the final survey to evaluate the progress while two questions (Q13 and Q14) are added to reflect the opinions of the WASAC Staff for the project.

However, the score does not completely reflect their development because two of those surveys are not conducted in a same way. One thing to be considered is that the participants of the two surveys are not same because some of the working team members moved to another position and new members joined recently. The other one is that JST conducted the final questionnaire survey using online form due to COVID-19 restriction whereas paper tests are used for the baseline questionnaire survey.

Table 8.1-1 Questionnaire

No.	Contents
Q1:	Please list up what aspects should be considered to prepare a water supply master plan.
Q2:	Please explain the major points to be considered for selection of raw water sources. (in case of surface water and groundwater)
Q3:	Please explain what average domestic per capita water consumption (lpcd) is.
Q4:	Please list up basic items which should be considered in selecting the water treatment process.
Q5:	How do you decide capacity (m^3) of a reservoir?
Q6:	Please explain why it is necessary to discriminate "Transmission pipelines" and "Distribution pipelines."
Q7:	Please explain the components of Non-Revenue Water (NRW).
Q8:	Please explain problems regarding water quality for both (1) Raw Water and (2) Treated Water in WASAC's system.
Q9:	What are the major objectives to carry out environmental and social consideration (ESC)? Please explain 3 items.
Q10:	Please explain points to be considered when the water tariff is decided.
Q11:	Please explain the most important points to improve customer satisfaction regarding water supply services.
Q12:	Please explain the role/function of each WASAC department.
Q13*:	Do you think your knowledge and skills are developed through the master plan formulation?
Q14*:	What has benefited you from participating in JICA's MP formulation project?

*Q13, 14 are only for Final Survey

Source:JST

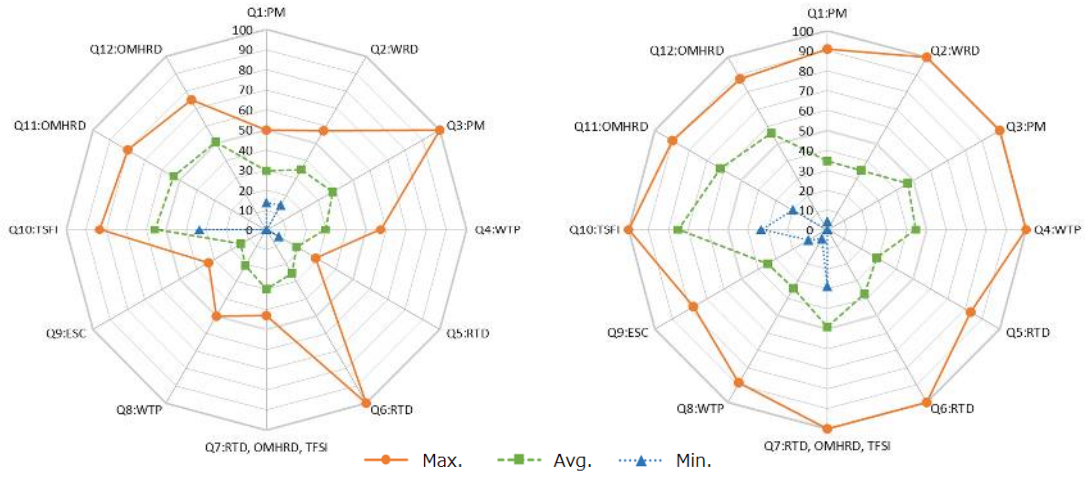
Final evaluation was conducted based on the same method with the baseline evaluation as is shown in **Table 8.1-2** using "Evaluation keywords" presented in

Table 8.1-3. The comparison of the results of the baseline and final questionnaire survey is shown in **Figure 8.1-1**. Scores are calculated based on Q1 ~ Q12.

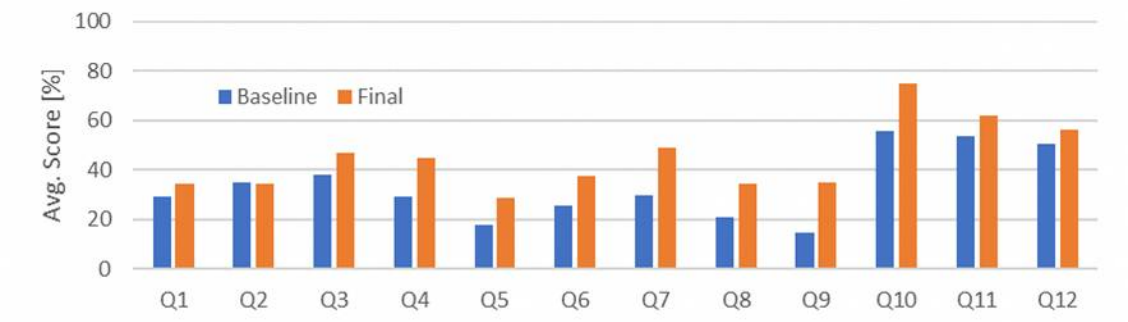
Table 8.1-2 Evaluation Method

Evaluation order	Method	Remark
No.1	Evaluation of keyword/synonym or explanation to achieve the purpose of the question.	1.0 [point / word]
No.2	Participant gave answer except No.1, but he/she understood question purpose.	0.5 [point / word]
No.3	(No.1 point + No.2 point) / (number of evaluation key words) x 100 [%]	Conversion from point to %

Source: JST



(a) Baseline Questionnaire Survey in August 2019 (b) Final Questionnaire Survey in July 2021



(c) Comparison of the scores between Baseline Questionnaire Survey and Final Questionnaire Survey

Source: JST

Figure 8.1-1 Score of Evaluation

Table 8.1-3 Results of Baseline and Final Questionnaire Survey

No.	Contents	Evaluation of keywords	Baseline Score [%]			Final Score [%]		
			Max.	Min.	Avg.	Max.	Min.	Avg.
Q1:	Please list up what aspects should be considered to prepare a water supply master plan.	1.Quantity 2.Quality 3. Pressure 4. Emergency / Disaster 5. Future expansion / Improvement 6. Environment 7. Reliable / Affordable 8. Sustainable 9. Finance / Economy / Budget 10. Organization / Institution 11. Cost for initial and O&M	50	14	29	**90.9**	**4.5**	**34.7**
Q2:	Please explain the major points to be considered for selection of raw water sources. (In case of surface water and groundwater)	1. Development potential 2. Water level measurement 3. Monitoring 4. Network 5. Discharge rate 6. Sustainability 7. Hydraulic conductivity	57	14	35	**100.0**	**0.0**	**34.4**
Q3:	Please explain what average domestic per capita water consumption (lpcd) is.	1. Planning / Projection / Used in water demand 2. Distribution quantity or amount / Consumption / Billing record 3. Served population	100	0	38	**100.0**	**0.0**	**46.9**
Q4:	Please list up basic items which should be considered in selecting the water treatment process.	1. Raw water quality and quantity 2. Treated water goals 3. Cost 4. Operation and maintenance 5. Availability of major equipment and chemicals 6. Site area 7.Environmental and social impacts	57	0	29	**100.0**	**0.0**	**44.6**
Q5:	How do you decide capacity (m3) of a reservoir?	1. Water Demand (in supply area) 2. Hourly fluctuation (of water demand) 3. Power suspension period 4. Repair time of transmission pipe 5. Water Demand for firefighting 6. Water transmission volume to other reservoirs 7. Stable water supply / Acceptable water suspension period (or water supply hour) / Restriction of water supply	29	7	18	**83.3**	**0.0**	**28.6**
Q6:	Please explain why it is necessary to discriminate "Transmission pipelines" and "Distribution pipelines"	1. To keep transmission capacity 2. Reduction of leakage 3. Water Pressure control (in distribution system)	100	0	25	**100.0**	**0.0**	**37.5**
Q7:	Please explain components of Non-Revenue Water	1. Unbilled, 2. Unauthorized consumption 3. Metering inaccuracy	43	0	30	**100.0**	**28.6**	**49.1**

No.	Contents	Evaluation of keywords	Baseline Score [%]			Final Score [%]		
			Max.	Min.	Avg.	Max.	Min.	Avg.
	(NRW).	4. Real loss / Leakage 5. Pressure management 6. Repair 7. Asset management						
Q8:	Please explain problems regarding water quality for both (1) Raw Water and (2) Treated Water in WASAC's system.	(1) Raw water 1. High Iron (Fe) and Manganese (Mn) 2. High turbidity and color 3. Ammonia and organic matter 4. Heavy metals 5. Algae for lake water (2) Treated water 1. Organic matter->Disinfection by-products (DBPs such as THMs) 2. High residual chlorine->DBPs (or THM) 3. Odor 4. Inefficient disinfection for spring water	50	0	21	**88.9**	**5.6**	**34.2**
Q9:	What are the major objectives to carry out environmental and social consideration (ESC)? Please explain 3 items.	1. Democratic process / Procedure / Decision-making, 2. Transparency, 3. Participation 4. Accountability 5. Stakeholder, 6. Basic / Fundamental human rights 7. Disclosure (of information) 8. Environmental cost / External cost, 9. Reduction / Mitigation of environmental impact	33	0	15	**77.8**	**11.1**	**34.7**
Q10:	Please explain points to be considered when the water tariff is decided.	1. O&M cost 2. Capital cost 3. Customers' affordability to pay	83	33	56	**100.0**	**33.3**	**75.0**
Q11:	Please explain the most important points to improve customer satisfaction regarding water supply services.	1. Tariff 2. Service 3. Quality of water 4. Customer 5. Stable supply	80	0	54	**90.0**	**20.0**	**61.9**
Q12:	Please explain the role/function of each WASAC department.	Explanation of each department or using the following keywords. 1. Human resource 2. Department 3. Policy 4. Manual	75	0	51	**87.5**	**0.0**	**56.3**

Source: JST

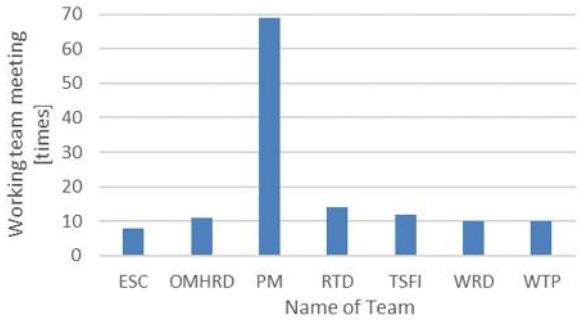
As the scores of the final survey are higher than the one for the previous survey, their knowledge and skill are developed through the collaborate work with JST for M/P formulation.

Many participants have a good understanding of "Water tariff (Q10)", "Customer satisfaction (Q11)" and "the WASAC department role/function (Q12)" both for the baseline survey and the final survey, indicating that they have a clear understanding of the importance of customer service and the organization of the

WASAC. On the other hand, the average scores for the other questions Q1 ~ Q9 are less than 50% because the question was too technical to answer because they have less understanding of the field if it is different from their own field. However, the maximum score for each question is significantly increased. the minimum scores are not increased as the maximum scores, because some working group members are new due to the position change. For Q13: "Do you think your knowledge and skills are developed through the M/P formulation?", 100% of the participants answered "Yes" or "Maybe". It indicates that most of them were satisfied to be part of the M/P formulation. Some new members answered "Maybe" because they have less opportunity to work together for M/P formulation under COVID-19 pandemic. For Q14: "What has benefited you from participating in JICA's MP formulation project?", they answered that this collaborate work is beneficial because they have learned how to elaborate the M/P in terms of the long-term planning, water resource management, investment plan and finance. Because they contributed to the work and understand the importance of the M/P, they will be the key persons to implement and revise the M/P after this project.

8.2 ACTIVITIES OF WORKING TEAM

Working team meetings have been held as shown in **Figure 8.2-1**. Total number of the meetings is more than 90 times. The cumulative number of C/P participating working team meetings is more than 200 persons as shown in **Figure 8.2-2**. C/P and JST had a frequent communication through the project. Even after the spread of COVID-19, to maximize the collaboration, JST and WASAC (mainly PM team) had a meeting remotely almost every week over a year.



Note1: Plenary meeting was counted as one time to each working team.
Note2: It was counted from Mar 2019 to July 2021.
Source: JST

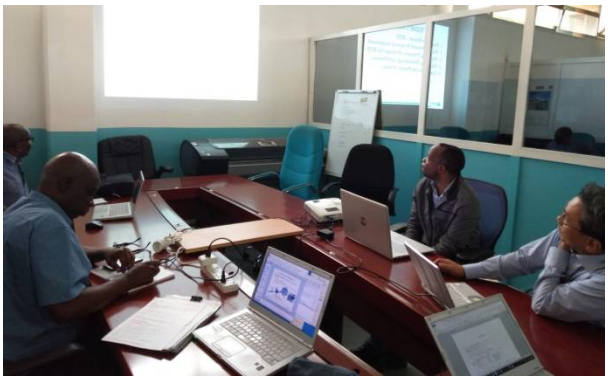
Figure 8.2-1 Implementation Times of Working Team Meeting



Note: It was counted from Mar 2019 to July 2021.
Source: JST

Figure 8.2-2 Cumulative Number of C/P for Working Team Meeting

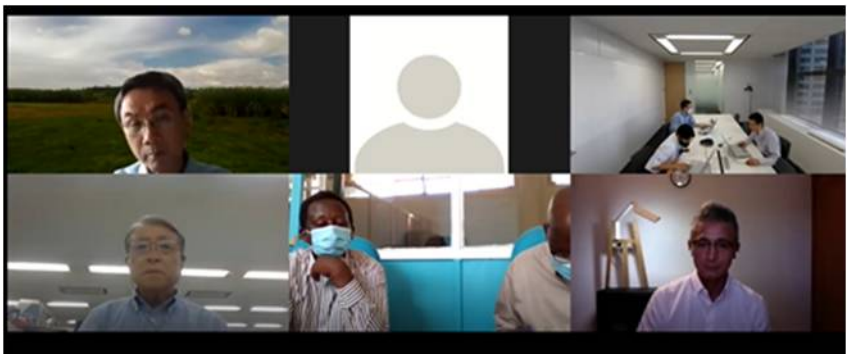
The photos of working team meetings are shown in **Figure 8.2-3**.




Source:JST

Figure 8.2-3 RTD Team Meeting (Left) and All Team Meeting (Right)

The weekly online meeting was useful to maintain the continuous exchange of information, data, idea and contents of M/P (**Figure 8.2-4**).



Source: JST

Figure 8.2-4 Weekly Online Meeting with C/P

After the 1st Joint Coordinating Committee (JCC) for the Progress Report in July 2019, the 1st Stake Holder Meeting (SHM) was held in August 2019 by WASAC. During the meeting, the background and outline of the project were explained to the stakeholders. The future water demand was shared by the JST. The WASAC mainly addressed the Q&A session. However, the JST rendered due support to WASAC, as needed. The photos during the stakeholder meeting are shown in **Figure 8.2-5**.




Source: JST

Figure 8.2-5 1st Stake Holder Meeting

The 2nd JCC and the Thematic Working Group (TWG) was held in February 2020 to explain the contents of the Interim Report (IT/R). All JCC members confirmed the content of the IT/R that includes the revision after the Progress Report presented in July 2019 and the newly added parts such as Water Resource Development Plan, Master Scenario and the candidate projects for 15-Year Investment Plan. The photos are shown in **Figure 8.2-6**.



Source: JST

Figure 8.2-6 2nd Joint Coordinating Committee

The third JCC was held remotely in November 2020 to explain the contents of the M/P focusing on the newly added parts of Water Resource Development Plan, the finalized Master Scenario, 15-Year Investment Plan, Financial and Economic Analysis of 15-Year Investment Plan, a proposal for the new organizational arrangement and the overall recommendation for the M/P. All JCC members confirmed the contents of the M/P.

The final JCC was held remotely in August 2021 to explain the Draft Final Report (DF/R) of the M/P focusing on the explanation of Karenge Feasibility Study (F/S) and Masaka F/S (**Figure 8.2-7**).



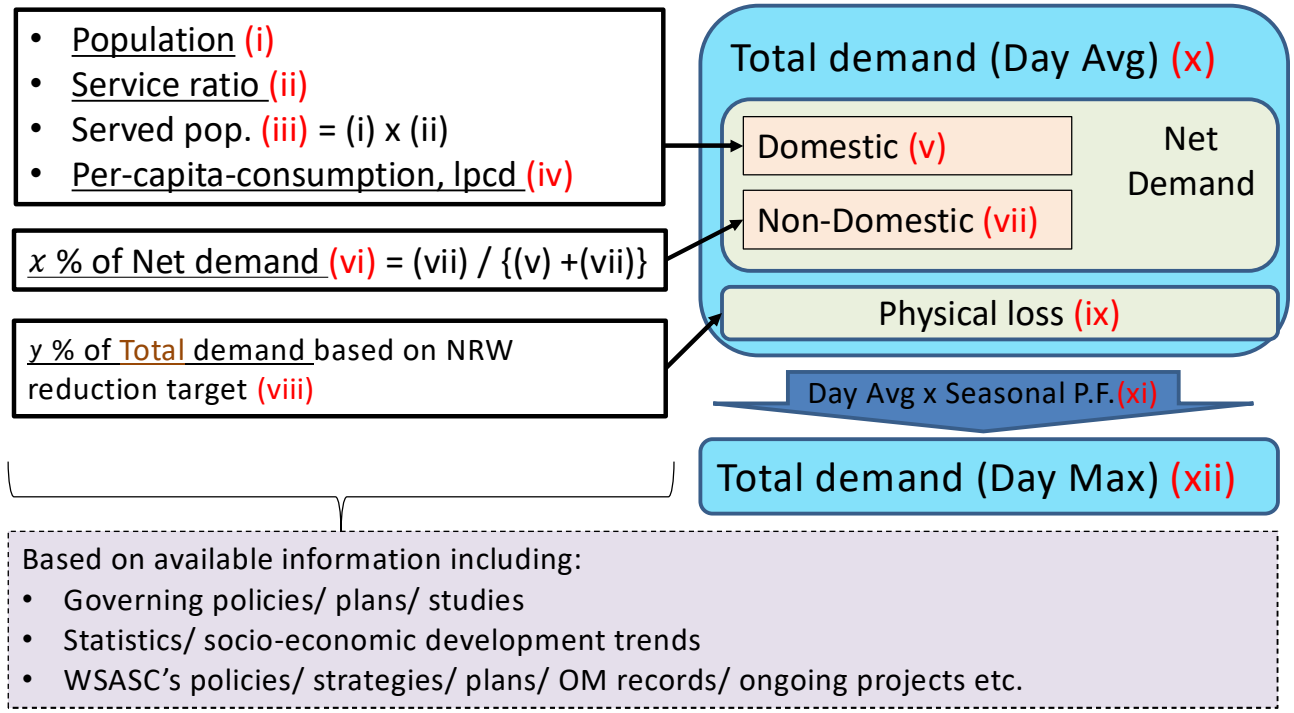
Source: JST

Figure 8.2-7 Final Joint Coordinating Committee

The final SHM was held in August 2021 by WASAC C/Ps with the support of JST. WASAC explained the contents of the M/P in Kinyarwanda to WASAC staff, NGOs and Media.

CHAPTER 9 FRAMEWORK OF THE MASTER PLAN

Determination of the framework for planning as well as estimation of current and future water demands toward the target year in the Study Area is one of the key steps for developing the KWSMP. These projected water demands will become the basis for the future water supply facility development. In general, the changes in water demand are mainly driven by a number of factors including population, land use, timing of development, per capita consumption, service level, NRW ratio, seasonal peak factor, type of water use (e.g., domestic and non-domestic including industrial, commercial, and institutional), and socio-economic conditions prevailing in the target area. Hence, the water demand estimates and projections are developed with due consideration to the above factors. Methodology adopted for the estimation is outlined in **Figure 9.1-1**.



Source: JST

Figure 9.1-1 Methodology for the Water Demand Projection

9.1 TARGET OF THE MASTER PLAN

The target of the KWSMP is set to achieve 100% for individual house connections by 2050 as discussed in the following subsections. The strategy for water supply facilities shall be monitored and enhanced by targets and key performance indicators (KPIs). Proposed KPIs are presented in **Chapter 16.**

9.2 SOCIO-ECONOMIC DEVELOPMENT SCENARIO

The following information and data were studied carefully. Development scenarios such as population and GDP projection were formulated based on the careful study of the following information and data.

- 2012 Population Census
- Vision 2020
- The City of Kigali Master Plan Report, 2013
- The National Strategy for Transformation (NST 1)
- The District Development Plan or District Development Strategy of each district
- The Development of National Integrated Water Supply and Sanitation Master Plan for Rwanda, AfDB Baseline Data Report
- The CoK M/P, 2019 Final Report

9.2.1 Population Projection

The most reliable population projection of the CoK towards 2050 is the one available in the CoK M/P. The official population projection by the NISR is only limited to 2032 and is based on the national census data carried out in 2012. The JST understands that the Baseline Report of the AfDB M/P was formulated based on the data from the NISR and extrapolating the projection towards 2032 at the national to the district level. Geographical, especially the sector-wise breakdown of the population is not available for both the NISR's projection and the assumption considered in the AfDB M/P. Therefore, population projection in the CoK M/P deems to prevail the one done in the AfDB M/P, especially in terms of the population in the CoK.

The comparison of the population projection of the CoK M/P and the AfDB M/P is presented in **Table 9.2-1**. The projected population in 2050 is at a similar level in both the M/Ps (104%, the CoK M/P compared to the AfDB M/P).

Table 9.2-1 Two Scenarios of Population Projection

Sources		2012 Census	2050 Projection	
Population in the CoK				
1. Master Plan Report (2019 Edition)	Interim Report	1,132.7	**3,845.6**	High scenario
2. Development of AfDB M/P	Baseline Report	1,132.7	3,687.4	Medium scenario

Source: Elaborated by JST

9.2.2 GDP Growth

The GDP growth is important to determine the future commercial/industrial sector water demand. However, the GDP growth of the CoK is not available at the moment. Thus, **Table 9.2-2** presents the GDP growth of Rwanda only. The JST will consider that the same growth can also be utilized for the CoK.

Table 9.2-2 GDP Growth Projection

Nation and City	Actual: NISR		NST 1	Key Statistic of Rwanda, MINECOFIN	
	2017	2018	2017 - 24	2025- 35	2036 - 50
Rwanda	6.1%	8.6%	9.1%	12%	9%
Kigali	n/a	n/a	n/a	n/a	n/a

Source: NISR, NST, MINECOFIN

9.2.3 Zoning and Land Requirement

CoK M/P 2019 proposes for the phase-wise "Zoning and Land Requirement Plan" under its Chapter 5 which is based on the population and industrial projection. The concept for the same is presented in **Table 9.2-3**.

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Table 9.2-3 Concept of Zoning and Land Requirement

Zone		Purpose	Projection (up to 2050)	
Residence	R1	Low density residential zone	Number of dwelling units	Land required
	R1A	Low density residential densification zone		
	R1B	Rural Residential Zone		
	R 2	Medium density residential improvement zone		
	R 3	Medium density residential expansion zone		
	R 4	Highly density residential zone		
Commercial	C 1	Mixed use zone	Number of employments	
	C 3	City commercial zone		
Industry	I 1	Light industrial zone		
	I 2	General industrial zone		
	I 3	Mining/extraction zone		
Other 18 zones		Forest, education, health, religious/culture, agriculture, etc.	-	

Source: CoK M/P 2019

9.3 POPULATION PROJECTION

9.3.1 Population Projection in Other Relevant/ Superior Plans

9.3.1.1 AfDB M/P

The population projection used in the AfDB M/P is presented in its Baseline Data Report that was shared with the JST in March 2019. Population projection presented in the AfDB M/P is based on the following:

- Sector-wise population in 2012: Based on the result of CENSUS 2012 published by the National Institute of Statistic of Rwanda (NISR).
- Total national population and urban population from 2012 to 2032: Based on the NISR's estimation with low, medium, and high scenarios.
- Total national population in 2050: Based on the NISR's estimation as 22,086,371 inhabitants (without specifying low, medium or high scenarios)
- District-wise population projection in 2050: Estimated by the AfDB M/P, adopting the following assumptions:

- Based on the total national population projection in 2017 that includes the share of Urban and Rural. The district-wise population with breaking up into Urban and Rural areas is estimated by means of keeping the share of population per district same as the one presented in CENSUS 2012.
- The national entire urbanization rate and population growth rate from 2012 to 2032 and 2050 is estimated based on the one available in the NISR's estimation from 2012 to 2032 and 2050.
- In order to keep consistency with the on-going CoK M/P, the projected population by 2050 in the CoK is adjusted to be around 3.5 million.
- Based on the discussion with the WASAC,
  - ✧ Urbanization rate by 2050 in three districts in the CoK is set as 100%.
  - ✧ Population growth rate for individual districts in the milestone years are being set to keep consistency with the CoK M/P (e.g., the Nyarugenge from 2.7% (2012) to 4.2% (2050), the Gasabo from 5.0% (2012) to 7.8% (2050) and the Kicukiro from 3.0% (2012) to 4.7%(2050))

As mentioned above, the sector-wise population is available under CENSUS 2012. However, only district-wise population projection is available and sector-wise one is not available in the Baseline Data Report of the AfDB M/P.

Apart from the Baseline Data Report, the AfDB M/P side shared the sector-wise population in 2050 with the JST, and it is presented in the following **Table 9.3-1**.

Table 9.3-1 Sector-wise Population in 2012 and 2050 Provided by AfDB M/P

District & Sector		CENSUS 2012						PROJECTION 2050					
		Total		Urban		Rural		Total		Urban		Rural	
Nyarugenge	Gitega	28,728	0.3%	28,728	100.0%	0	0.0%	**93,522**	**0.4%**	88,846	95.0%	4,676	5.0%
Nyarugenge	Kanyinya	21,859	0.2%	0	0.0%	21,859	100.0%	**71,160**	**0.3%**	67,602	95.0%	3,558	5.0%
Nyarugenge	Kigali	30,023	0.3%	4,748	15.8%	25,275	84.2%	**97,737**	**0.4%**	92,851	95.0%	4,887	5.0%
Nyarugenge	Kimisagara	46,753	0.4%	46,753	100.0%	0	0.0%	**152,201**	**0.7%**	144,590	95.0%	7,610	5.0%
Nyarugenge	Mageregere	23,407	0.2%	0	0.0%	23,407	100.0%	**76,200**	**0.3%**	72,390	95.0%	3,810	5.0%
Nyarugenge	Muhima	29,768	0.3%	29,768	100.0%	0	0.0%	**96,907**	**0.4%**	92,062	95.0%	4,845	5.0%
Nyarugenge	Nyakabanda	25,666	0.2%	25,666	100.0%	0	0.0%	**83,554**	**0.4%**	79,376	95.0%	4,178	5.0%
Nyarugenge	Nyamirambo	40,292	0.4%	40,292	100.0%	0	0.0%	**131,167**	**0.6%**	124,609	95.0%	6,558	5.0%
Nyarugenge	Nyarugenge	21,302	0.2%	21,302	100.0%	0	0.0%	**69,347**	**0.3%**	65,880	95.0%	3,467	5.0%
Nyarugenge	Rwezamenyo	16,763	0.2%	16,763	100.0%	0	0.0%	**54,571**	**0.2%**	51,842	95.0%	2,729	5.0%
Gasabo	Bumbogo	35,381	0.3%	4,246	12.0%	31,135	88.0%	**115,180**	**0.5%**	109,421	95.0%	5,759	5.0%
Gasabo	Gatsata	37,110	0.4%	37,110	100.0%	0	0.0%	**120,809**	**0.5%**	114,768	95.0%	6,040	5.0%
Gasabo	Gikomero	16,625	0.2%	0	0.0%	16,625	100.0%	**54,121**	**0.2%**	51,415	95.0%	2,706	5.0%
Gasabo	Gisozi	44,003	0.4%	44,003	100.0%	0	0.0%	**143,248**	**0.6%**	136,086	95.0%	7,162	5.0%
Gasabo	Jabana	33,577	0.3%	9,271	27.6%	24,306	72.4%	**109,307**	**0.5%**	103,842	95.0%	5,465	5.0%
Gasabo	Jali	25,057	0.2%	3,808	15.2%	21,249	84.8%	**81,571**	**0.4%**	77,492	95.0%	4,079	5.0%
Gasabo	Kacyiru	37,088	0.4%	37,088	100.0%	0	0.0%	**120,737**	**0.5%**	114,700	95.0%	6,037	5.0%
Gasabo	Kimihurura	21,672	0.2%	21,672	100.0%	0	0.0%	**70,551**	**0.3%**	67,024	95.0%	3,528	5.0%
Gasabo	Kimironko	57,430	0.5%	57,430	100.0%	0	0.0%	**186,959**	**0.8%**	177,611	95.0%	9,348	5.0%
Gasabo	Kinyinya	57,846	0.6%	53,162	91.9%	4,684	8.1%	**188,313**	**0.9%**	178,897	95.0%	9,416	5.0%
Gasabo	Ndera	41,764	0.4%	33,469	80.1%	8,295	19.9%	**135,959**	**0.6%**	129,161	95.0%	6,798	5.0%
Gasabo	Nduba	25,370	0.2%	0	0.0%	25,370	100.0%	**82,590**	**0.4%**	78,460	95.0%	4,129	5.0%
Gasabo	Remera	43,279	0.4%	43,279	100.0%	0	0.0%	**140,891**	**0.6%**	133,847	95.0%	7,045	5.0%
Gasabo	Rusororo	35,453	0.3%	20,833	58.8%	14,620	41.2%	**115,414**	**0.5%**	109,644	95.0%	5,771	5.0%
Gasabo	Rutunga	17,906	0.2%	0	0.0%	17,906	100.0%	**58,291**	**0.3%**	55,377	95.0%	2,915	5.0%
Kiukilo	Gahanga	27,808	0.3%	11,698	42.1%	16,110	57.9%	**90,527**	**0.4%**	86,000	95.0%	4,526	5.0%
Kiukilo	Gatenga	48,640	0.5%	46,306	95.2%	2,334	4.8%	**158,343**	**0.7%**	150,426	95.0%	7,917	5.0%
Kiukilo	Gikondo	17,146	0.2%	17,146	100.0%	0	0.0%	**55,817**	**0.3%**	53,027	95.0%	2,791	5.0%
Kiukilo	Kagarama	14,385	0.1%	14,385	100.0%	0	0.0%	**46,829**	**0.2%**	44,488	95.0%	2,341	5.0%
Kiukilo	Kanombe	44,426	0.4%	44,426	100.0%	0	0.0%	**144,625**	**0.7%**	137,394	95.0%	7,231	5.0%
Kiukilo	Kicukiro	16,450	0.2%	16,450	100.0%	0	0.0%	**53,552**	**0.2%**	50,874	95.0%	2,678	5.0%
Kiukilo	Kigarama	43,907	0.4%	43,907	100.0%	0	0.0%	**142,936**	**0.6%**	135,789	95.0%	7,147	5.0%
Kiukilo	Masaka	39,548	0.4%	19,369	49.0%	20,179	51.0%	**128,745**	**0.6%**	122,308	95.0%	6,437	5.0%
Kiukilo	Niboye	26,197	0.2%	26,197	100.0%	0	0.0%	**85,282**	**0.4%**	81,018	95.0%	4,264	5.0%
Kiukilo	Nyarugunga	40,057	0.4%	40,057	100.0%	0	0.0%	**130,402**	**0.6%**	123,882	95.0%	6,520	5.0%
Rulindo	Shyorongi	23,545	0.2%	4,408	18.7%	19137	81.3%	**46,168**	**0.2%**	21,397	46.3%	24,770	53.7%
Kamonyi	Runda	34,839	0.3%	12,995	37.3%	21844	62.7%	**68,313**	**0.3%**	63,081	92.3%	5,232	7.7%
Kamonyi	Rugarika	34,860	0.3%	0	0.0%	34860	100.0%	**68,354**	**0.3%**	0	0.0%	68,354	100.0%
Bugesera	Ntarama	17,978	0.2%	0	0.0%	17978	100.0%	**35,252**	**0.2%**	0	0.0%	35,252	100.0%
Rwamagana	Muyumbu	24,242	0.2%	0	0.0%	24242	100.0%	**47,534**	**0.2%**	0	0.0%	47,534	100.0%
Rwamagana	Gahengeri	23,517	0.2%	0	0.0%	23517	100.0%	**46,113**	**0.2%**	0	0.0%	46,113	100.0%
Rwamagana	Nyakaliro	20,196	0.2%	0	0.0%	20196	100.0%	**39,601**	**0.2%**	0	0.0%	39,601	100.0%

Source: AfDB M/P side

9.3.1.2 CoK M/P

(1) General

The CoK M/P side shared the Master Plan Report (2019 Edition) with the JST in Oct/2019, which is regarded as the final version of the master plan. This report incorporates revision on its Interim Master Plan Update Report having been shared earlier in April 2019. While there are minor modifications in the zoning of the phasing development plan and classification of land use type in the final one, there is no change in the population projection from the interim version.

This 2019 edition is the updated version of the CoK M/P 2013. Following discussion with the CoK M/P side, the JST understands that the update version incorporates an adjustment of planning orientation considering actual incremental development after 2013, promoting more flexible zoning strategy (e.g., allowing mixed land use for commercial and residential purpose), and encouraging the involvement of stakeholders in the planning process.

(2) Trend of Development

The CoK M/P also presents a phased development plan that is divided into five phases (Phase 1: 2019 – 2024, Phase 2: 2025 – 2031, Phase 3: 2032 – 2038, Phase 4: 2039 – 2045, Phase 5: 2046 – 2050), indicating priority areas of development. These are presented in **Figure 9.3-1** to **Figure 9.3-3**.

As shown in the above-mentioned figures, the Master Plan Report of the CoK M/P pointed out that the trend of development and growth in the CoK would be moving toward the eastern and southern parts of the city. In addition, development along major roads would be also expected.

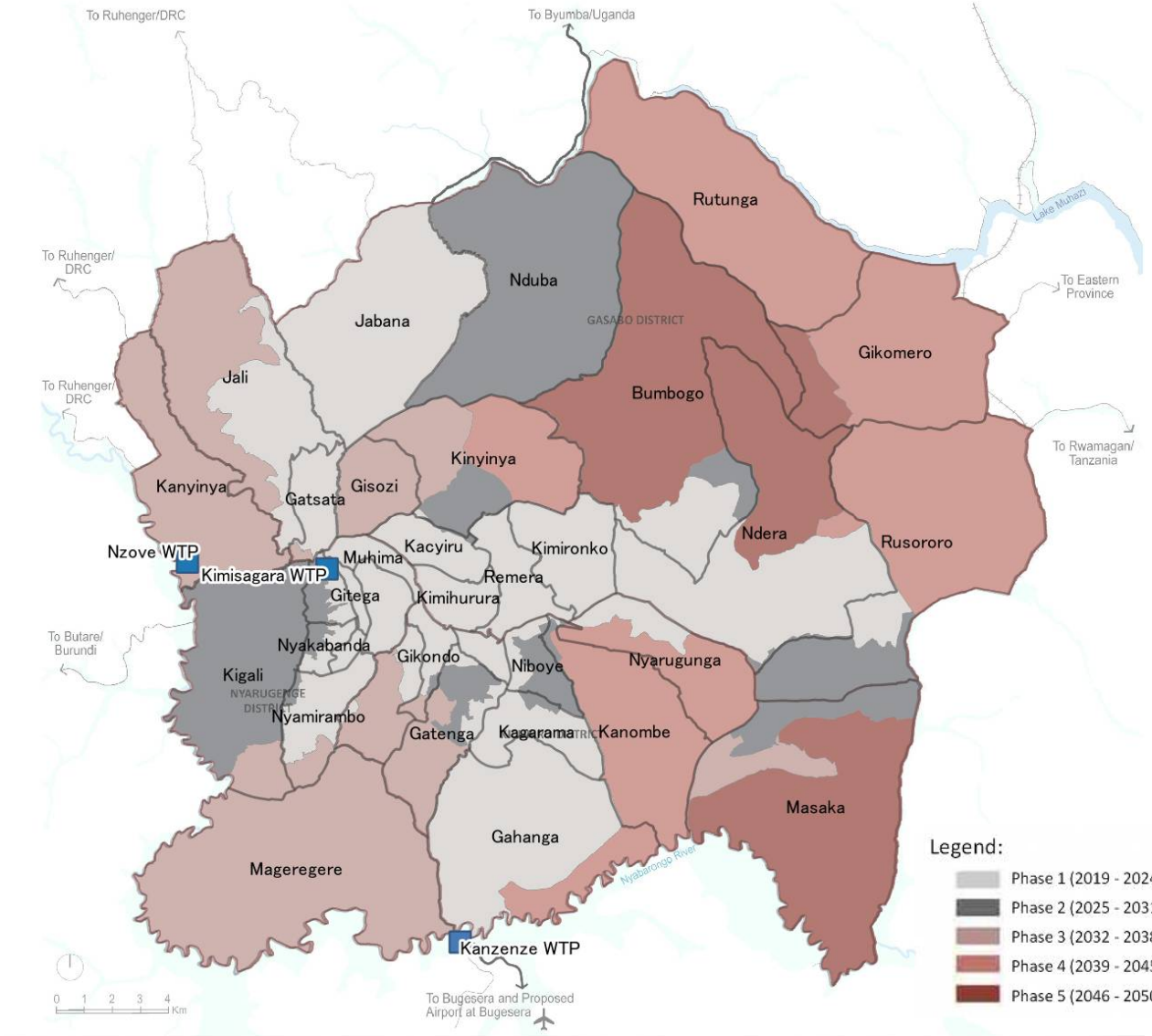
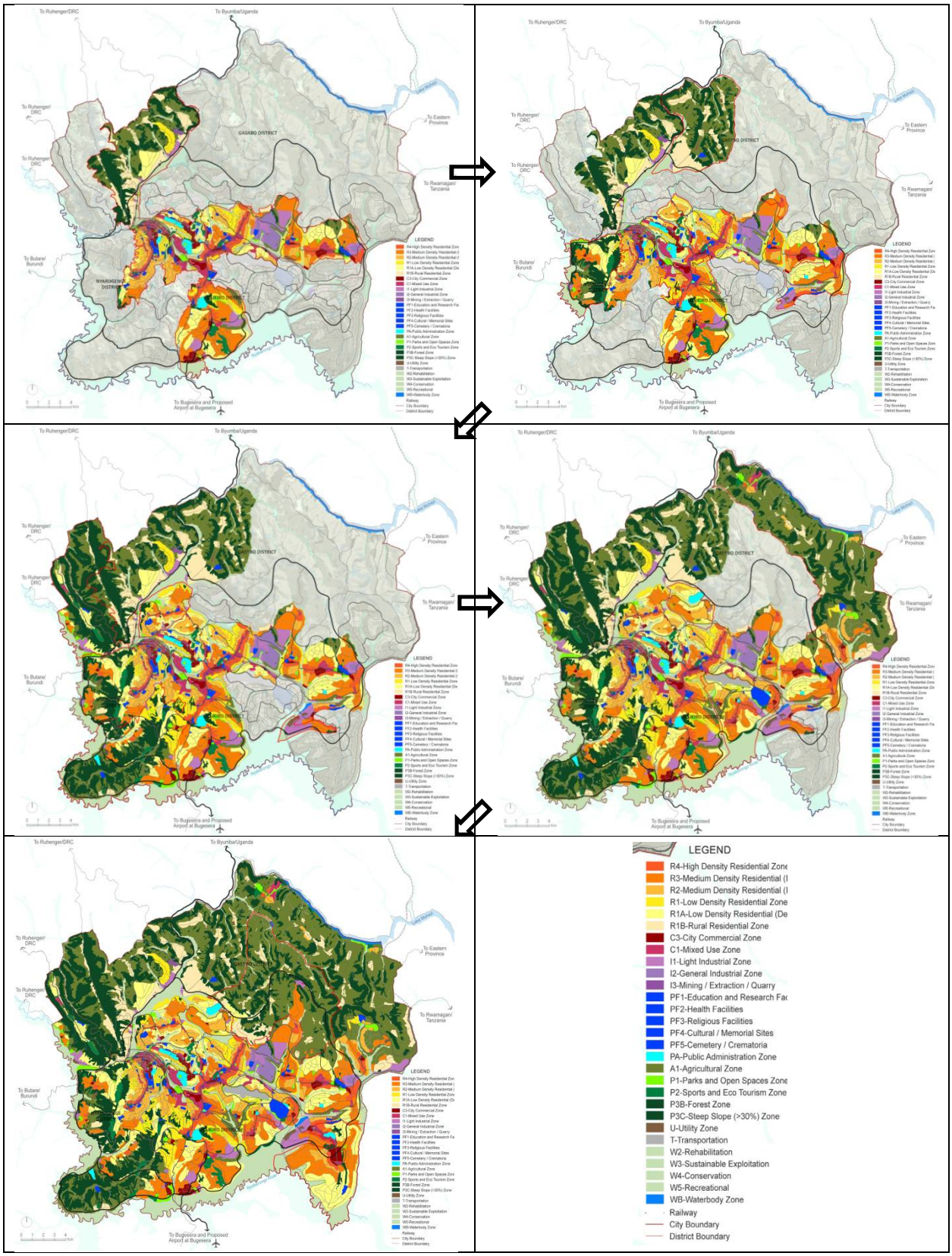


Figure 9.3-1 Development Phase and Corresponding Sectors

Source: Master Plan Report (2019 Edition) of CoK M/P



Source: Master Plan Report (2019 Edition) of CoK M/P

Figure 9.3-2 Transition of Development Phase with Land Use Details

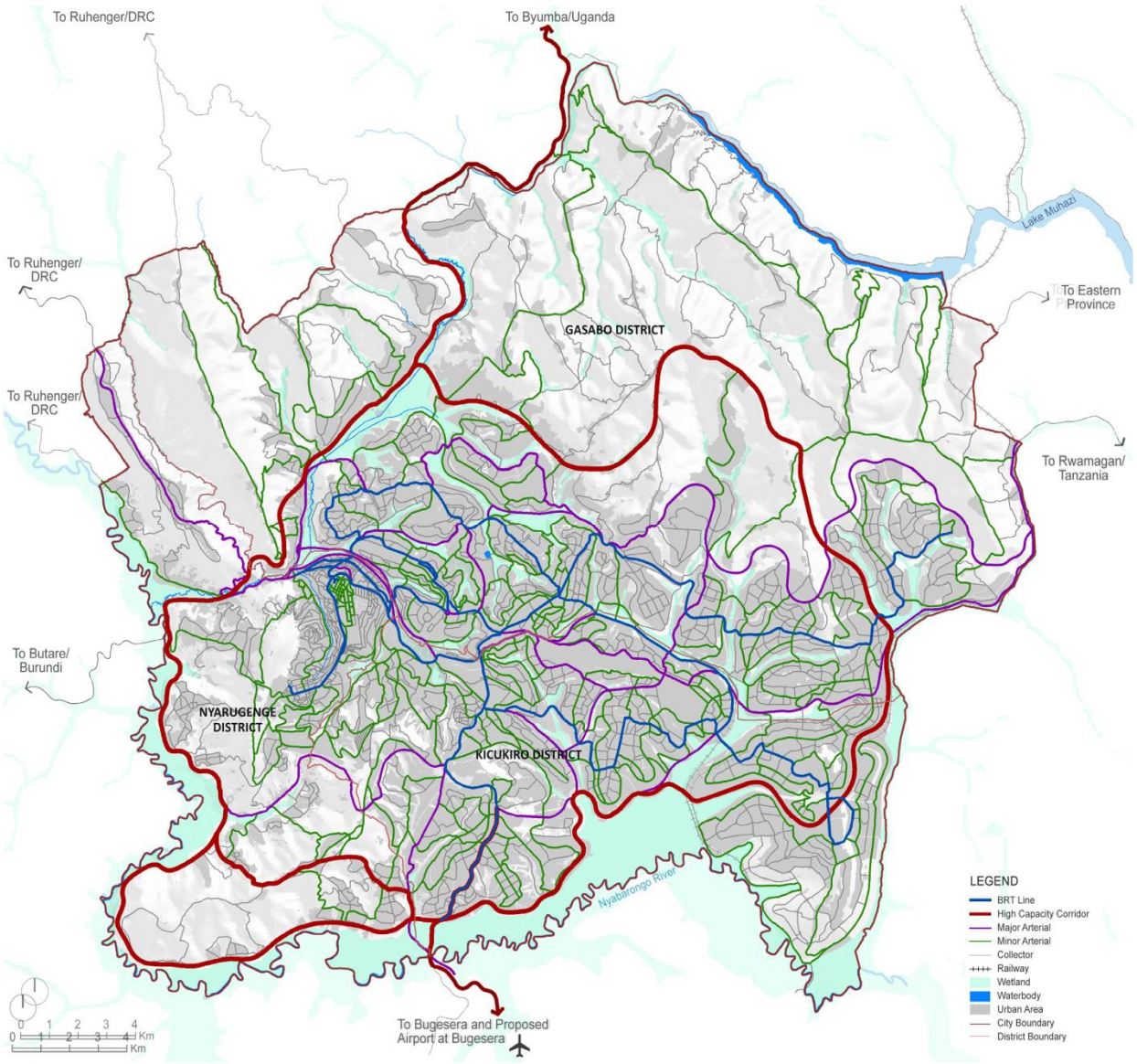


Figure 9.3-3 Planned Road Network in CoK M/P

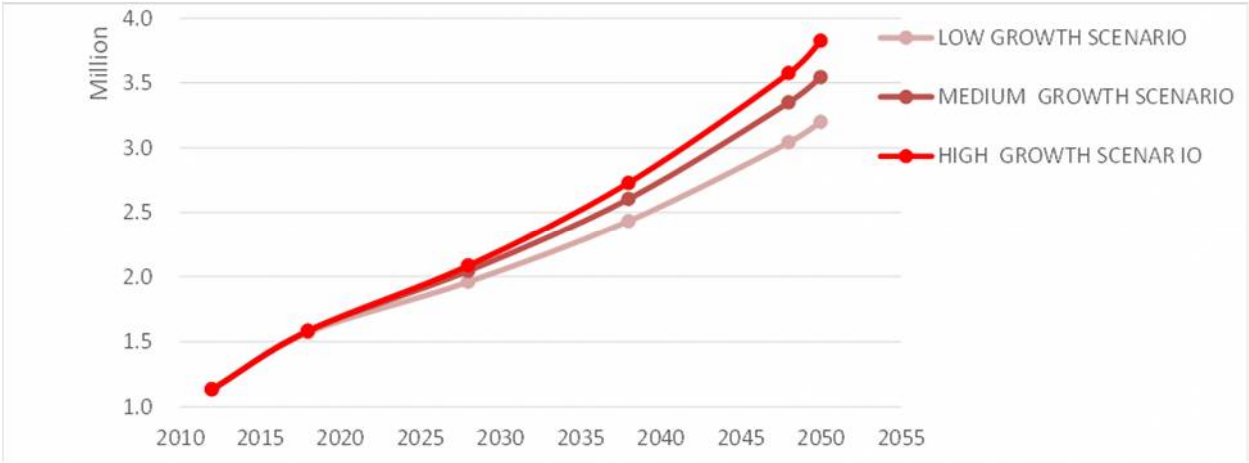
Source: Master Plan Report (2019 Edition) of CoK M/P

(3) Population Projection

Population projection of the CoK M/P is based on the following:

- Sector-wise population in 2012: Based on the result of the census 2012 published by the National Institute of Statistic of Rwanda (NISR), likewise the one for the AfDB M/P
- Amongst a number of forecast methods, the Cohort Component Method used in the census 2012 by the NISR is employed.
- Trends of migration from one district to another follow the one as indicated under the Integrated Household Living Conditions Survey 5 (EICV 5).

Following **Figure 9.3-4** and **Figure 9.3-5** present the total city population in the 2018, 2028, 2038, 2048, and 2050 with low, medium, and high scenarios presented in the CoK M/P.



Source: Master Plan Report (2019 Edition) of CoK M/P

Figure 9.3-4 Population Growth Scenarios Presented in CoK M/P up to 2050

Table 9.3-2 Population at Each Milestone Year by Scenarios Presented in CoK M/P

Year	Low growth Scenario	Medium growth Scenario	High growth Scenario
2012(Census year)	1,132,686	1,132,686	1,132,686
2018	1,569,579	1,582,659	1,582,659
2028	1,960,047	2,044,282	2,084,897
2038	2,431,149	2,603,307	2,728,598
2048	3,040,986	3,349,960	3,575,300
2050	3,199,857	3,545,015	3,824,708

Source: Master Plan Report (2019 Edition) of CoK M/P

In addition above, the WASAC shared the sector-wise population projection in 2050 that is used in water demand estimation in the CoK M/P with the JST, and it is presented in the following **Table 9.3-3**.

Table 9.3-3 Population in 2012 and 2050 in CoK M/P

District	Sector	2012 (Census)	2050 (Projection)
Nyarugenge	Gitega	28,728	12,792
	Kanyinya	21,859	32,152
	Kigali	30,023	87,964
	Kimisagara	46,753	14,080
	Mageregere	23,407	134,948
	Muhima	29,768	33,828
	Nyakabanda	25,666	18,840
	Nyamirambo	40,292	81,012
	Nyarugenge	21,302	34,908
	Rwezamenyo	16,763	20,544

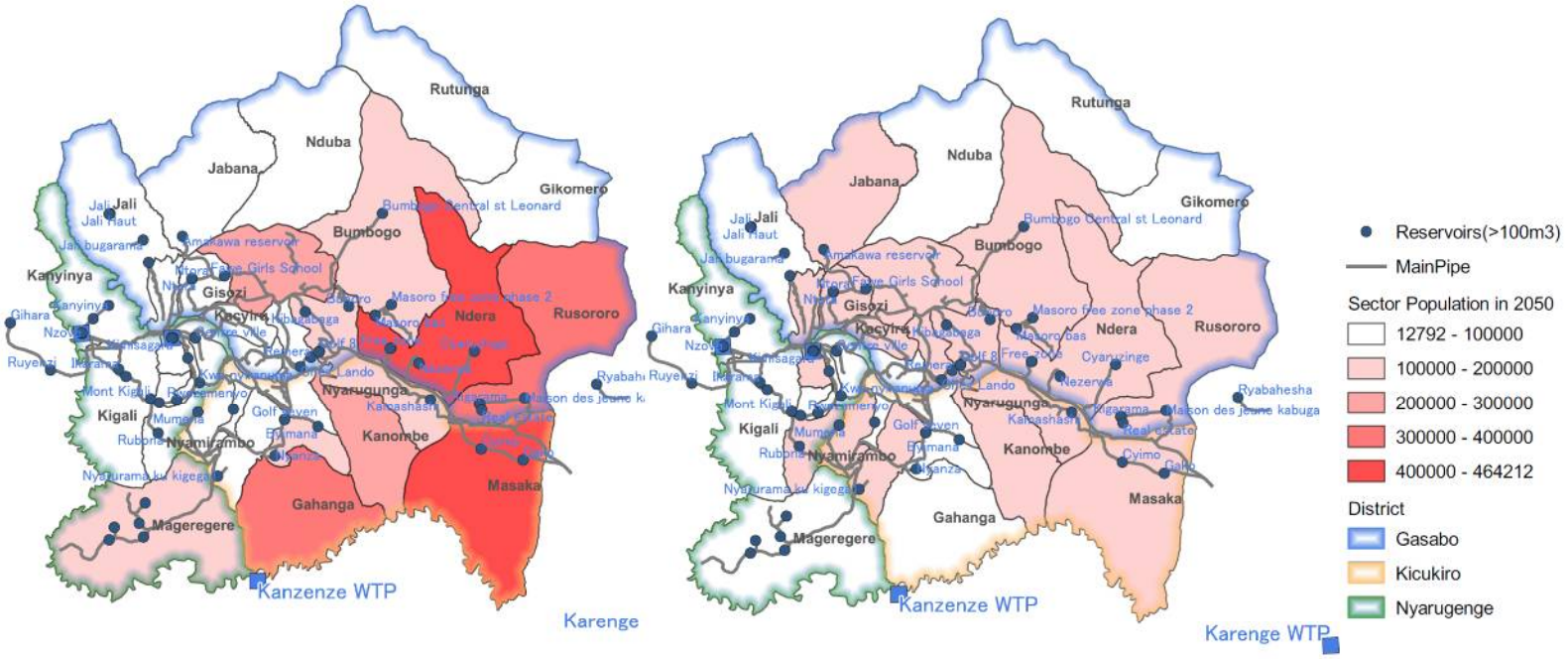
District	Sector	2012 (Census)	2050 (Projection)
Gasabo	Bumbogo	35,381	170,472
	Gatsata	37,110	16,312
	Gikomero	16,625	16,180
	Gisozi	44,003	78,520
	Jabana	33,577	68,292
	Jali	25,057	36,676
	Kacyiru	37,088	54,296
	Kimihurura	21,672	30,268
	Kimironko	57,430	149,876
	Kinyinya	57,846	243,392
	Ndera	41,764	412,496
	Nduba	25,370	58,220
	Remera	43,279	90,288
	Rusororo	35,453	359,244
	Rutunga	17,906	31,920
Kicukiro	Gahanga	27,808	355,568
	Gatenga	48,640	83,472
	Gikondo	17,146	31,512
	Kagarama	14,385	110,484
	Kanombe	44,426	240,888
	Kicukiro	16,450	26,724
	Kigarama	43,907	56,380
	Masaka	39,548	464,212
	Niboye	26,197	66,024
	Nyarugunga	40,057	122,856
		1,132,686	**3,845,640***

Source: WASAC
* Total projected population in the above table does not match up precisely with the total population in 2050 (high) in the previous table possibly due to error that would have taken place during exporting process from GIS data.

9.3.2 Comparison of AfDB M/P and CoK M/P

Following are the major findings of the comparison between the CoK M/P and the AfDB M/P.:

- Projected population in the CoK M/P under high scenario in 2050 is approximately 3.8 million, which is generally the same as the one projected under the AfDB M/P (3.7 million).
- However, there is a significant difference in the sector-wise distribution in both the master plans.
- The CoK M/P predicts that population increase in a present urbanized area (sectors in the Nyarugenge District) will be more moderate than the one predicted in the AfDB M/P.
- The CoK M/P predicts that significant population will be expected in the eastern and southern part of the city due to the development activities including new housing schemes and industrial areas, especially in the sectors of the Masaka, the Gahanga, the Ndera, the Rusororo, and the Kanombe.
- Population projection in AfDB M/P by 2050 for is a district-wise estimation based on population growth rates of the total national population up to 2050. On the other hand, projection specified in the CoK M/P by 2050 is a sector-wise estimation that incorporates phasing development plan towards 2050.
- Therefore, it is reasonable to employ population projection by the CoK M/P in principle. Values and/or assumptions used in Census 2012 and the AfDB M/P can also be considered when it is necessary.



Population Projection by City Master Plan

Population Projection by AfDB

Highly populated sectors in City M

	City Master Plan
Nyarugenge	
Mageregere	134,948
Gasabo	
Kimironko	149,876
Kinyinya	243,392
Ndera	412,496
Rusororo	359,244
Kicukiro	
Gahanga	355,568
Kagarama	110,484
Kanombe	240,888
Masaka	464,212
Nyarugunga	122,856

Summary of Population Projection in 2050 by District

	Projection in 2050		Comparison
	City Master Plan	AfDB	City Master Plan / AfDB
Nyarugenge	471,068	926,365	0.51
Gasabo	1,816,452	1,723,942	1.05
Kicukiro	1,558,120	1,037,059	1.50
Total	3,845,640	3,687,365	1.04

Source: JST

Figure 9.3-5 Comparison of Population Projection in 2050 (CoK M/P vs AfDB M/P)

9.4 WATER DEMAND PROJECTION

9.4.1 Projection Basis

9.4.1.1 Population

(1) City of Kigali (COK)

As mentioned under **Section 9.3.2**, it is reasonable to employ the population projection as depicted in the CoK M/P in principle. Therefore, the future population for the CoK is estimated with the following data:

- Sector-wise population in 2012 is based on the 2012 Census (as shown in **Table 9.3-3**).
- Sector-wise population in 2050 (High growth scenario) is based on the breakdown data shared by the CoK M/P side through the WASAC (as shown in **Table 9.3-3**).

The sector-wise population in-between 2013 and 2049 was not estimated by the CoK M/P. As the CoK M/P presents a development phasing plan, the following assumptions are developed in order to estimate a sector-wise population:

- Population growth trend will follow the Phasing Development Plan as proposed in the CoK M/P in principle. For example, in a sector with the earlier development phase, the timing of rapid population growth also comes earlier.
- In a sector where the population difference between 2050 and 2013 is negative, the population will decrease linearly toward 2050.
- In a sector where population difference between 2050 and 2012 is positive, and population density in 2050 is regarded to be relatively high (4,000 pop/km^2 and more[1]), the population will increase linearly toward 2050 as there could be an enhancement on the environmental capacity to accommodate more people.
- In a sector where population difference between 2050 and 2012 is positive (i.e., increasing), and population density in 2050 is regarded to be relatively low (less than 4,000 pop/km^2), population growth trend will follow logistic function curve so that the rapid population growth occurs in line with the development phase expected in the sector.
- Among the sectors having the development phase of 4 or 5, rapid population growth would take place earlier than the scheduled development phases in the sectors along main roads (e.g., BRTs, high-capacity corridor, major arterial road as shown in **Figure 9.3-3**).

Table 9.4-1 summarizes assumptions considered for population growth trend scenario by sector.

[1] Statistics Bureau of Japan defines criteria that a district containing basic unit blocks, etc. with a population density of 4,000 or more per square kilometer, such districts being adjacent to each other in a municipality, with 5,000 or more population in the district, can be regarded as Densely Inhabited Districts (DIDs).
https://www.stat.go.jp/english/data/chiri/did/1-1.html

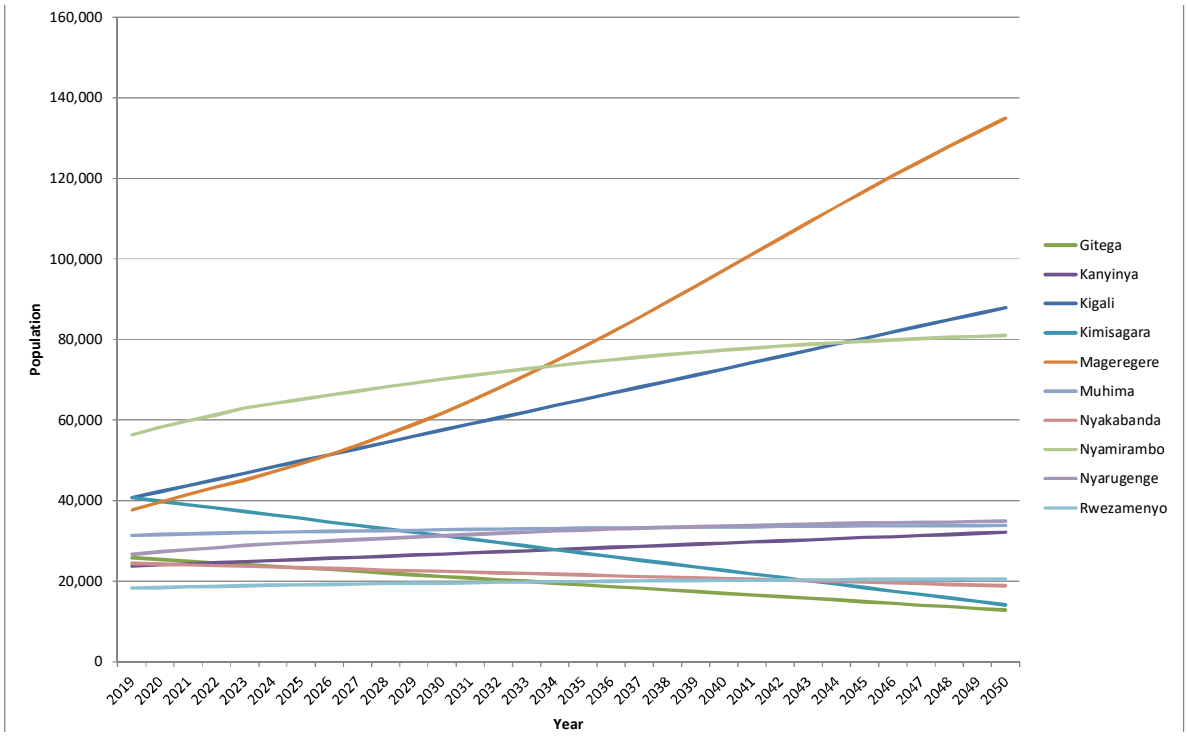
Table 9.4-1 Population Growth Scenarios by Sector

Sector		Corresponding development phase	Adopted hypothesis
Nyarugenge	Gitega	1	Decreasing linearly toward 2050
	Kanyinya	3	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Kigali	2	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Kimisagara	1	Decreasing linearly toward 2050
	Mageregere	3	Rapid population increase takes place in line with the timing of developing phase 3 in CoK M/P
	Muhima	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Nyakabanda	1	Decreasing linearly toward 2050
	Nyamirambo	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Nyarugenge	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Rwezamenyo	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
Gasabo	Bumbogo	5	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Gatsata	1	Decreasing linearly toward 2050
	Gikomero	4	Decreasing linearly toward 2050
	Gisozi	3	Rapid population increase takes place in line with the timing of developing phase 3 in CoK M/P
	Jabana	1	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Jali	1	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Kacyiru	2	Rapid population increase takes place in line with the timing of developing phase 2 in CoK M/P
	Kimihurura	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Kimironko	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Kinyinya	4	Rapid population growth would take place earlier than the scheduled development phases in this sector because it is in/around a planned major road.
	Ndera	5	Rapid population growth would take place earlier than the scheduled development phases in this sector because it is in/around a planned major road.
	Nduba	2	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)
	Remera	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Rusororo	4	Rapid population growth would take place earlier than the scheduled development phases in this sector because it is in/around a planned major road.
	Rutunga	4	Increasing linearly toward 2050 (since population density in 2050 is relatively low (less than 4,000 pop/km^2), it is considered that the population increases linearly)

Sector		Corresponding development phase	Adopted hypothesis
Kicukiro	Gahanga	3	Rapid population increase takes place in line with the timing of developing phase 3 in CoK M/P
	Gatenga	3	Rapid population increase takes place in line with the timing of developing phase 3 in CoK M/P
	Gikondo	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Kagarama	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Kanombe	4	Rapid population growth would take place earlier than the scheduled development phases in this sector because it is in/around a planned major road.
	Kicukiro	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Kigarama	1	Rapid population increase takes place in line with the timing of developing phase 1 in CoK M/P
	Masaka	5	Rapid population increase takes place in line with the timing of developing phase 5 in CoK M/P
	Niboye	2	Rapid population increase takes place in line with the timing of developing phase 2 in CoK M/P
	Nyarugunga	4	Rapid population growth would take place earlier than the scheduled development phases in this sector because it is in/around a planned major road.

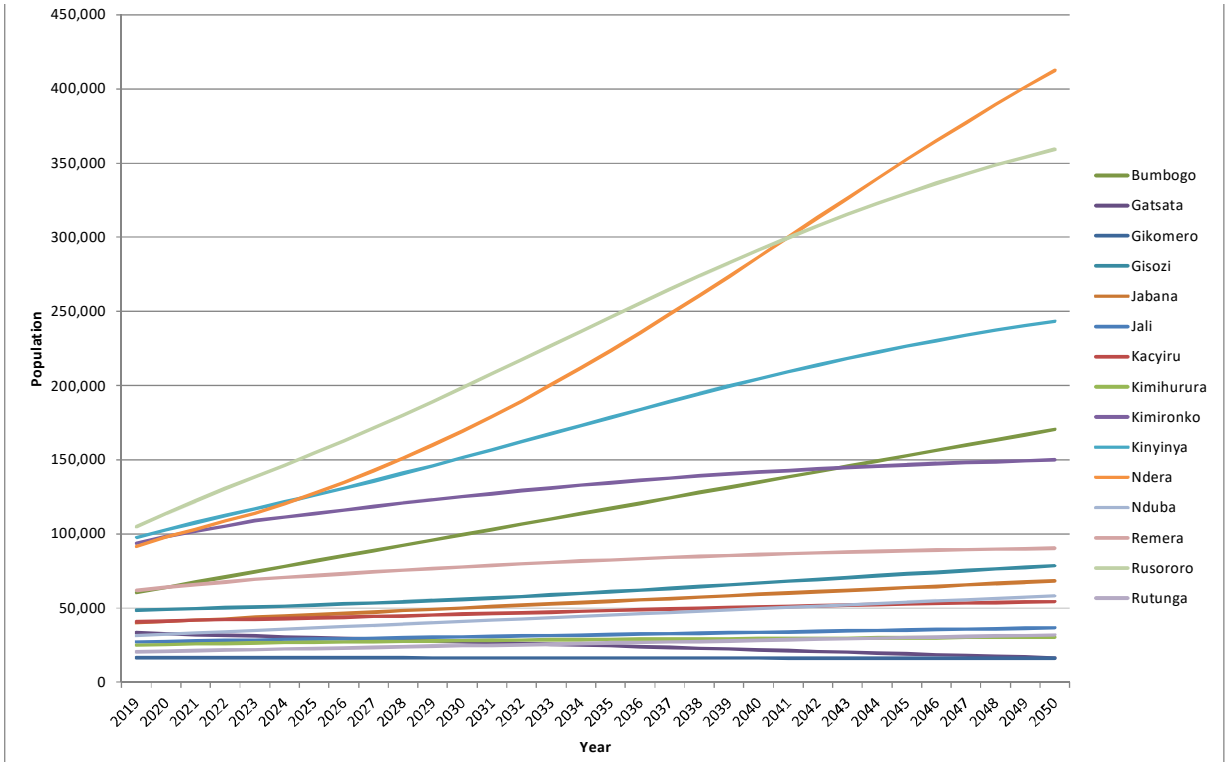
Source: Assumed by JST based on Development Phasing Plan presented in Master Plan Report (2019 Edition) of CoK M/P

Based on the above data and hypothesis, sector-wise population from 2019 to 2050 is estimated as presented under **Appendix-18(1)**, **Figure 9.4-1**, **Figure 9.4-2**, and **Figure 9.4-3**:



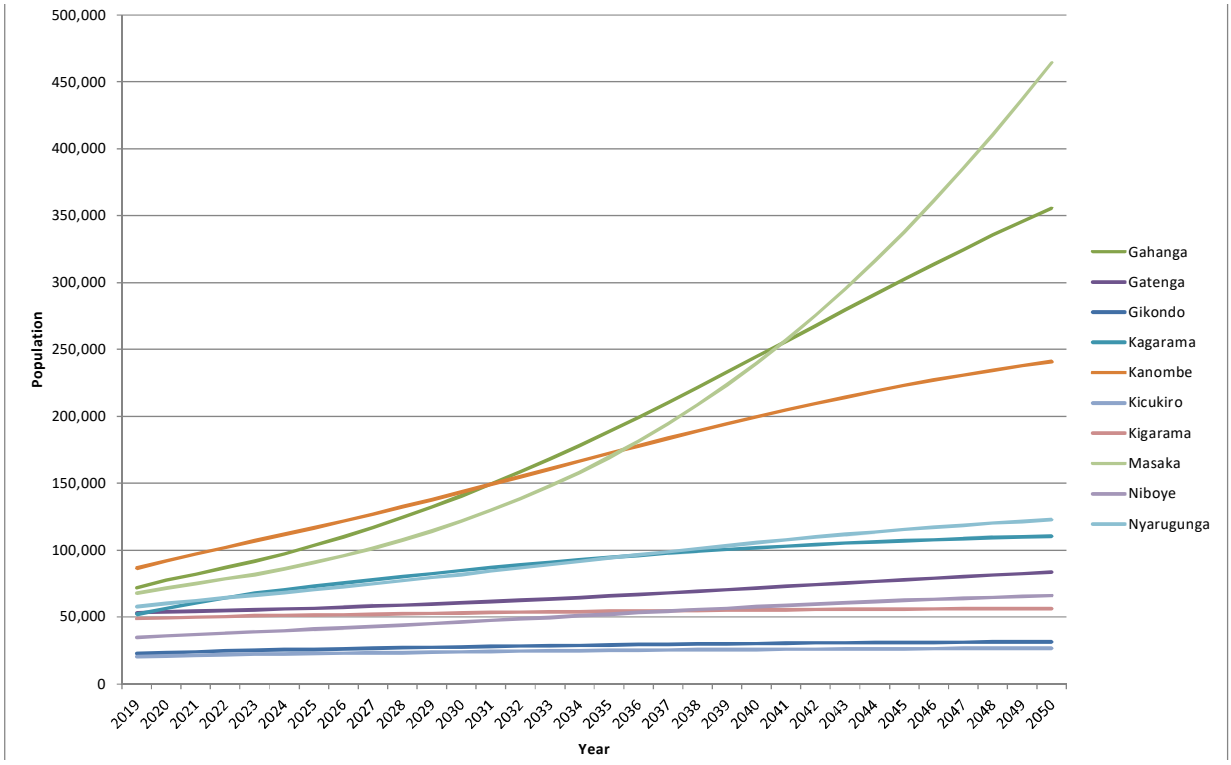
Source: JST

Figure 9.4-1 Sector-wise Population for CoK (Nyarugenge District)



Source: JST

Figure 9.4-2 Sector-wise Population for CoK (Gasabo District)

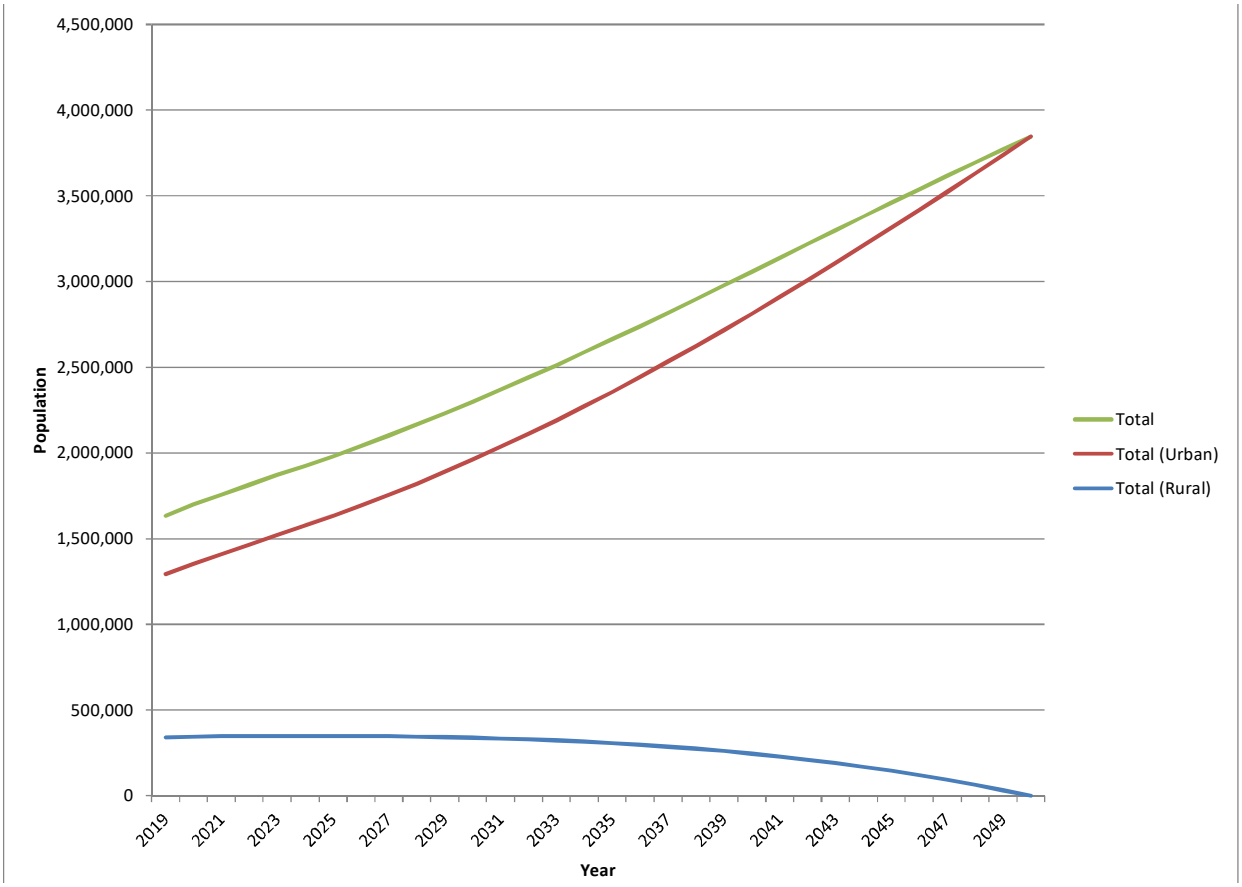


Source: JST

Figure 9.4-3 Sector-wise Population for CoK (Kicukiro District)

Further, with reference to the sector-wise distribution percentages of people living in an urban area and rural area as presented in **Table 9.3-1**, the total population that is broken down into area-wise (i.e., the population living in an urban area and rural area) is calculated for the years 2012 and 2050.

Then, individual percentages of urban and rural in between 2013 to 2050 are estimated by interpolating linearly[2]. **Appendix-18(2)** and **Figure 9.4-4** present total population for the CoK by area (Urban area and Rural area)



Source: JST

Figure 9.4-4 Population Projection for CoK (total with urban vs. rural)

[2] Percentage of living in urban area in the CoK is regarded as 100% in 2050, based on the assumption that entire area of the city will be urbanized by 2050.

(2) Adjacent 7 Sectors

Sector-wise populations for the adjacent 7 sectors are determined in the following manner:

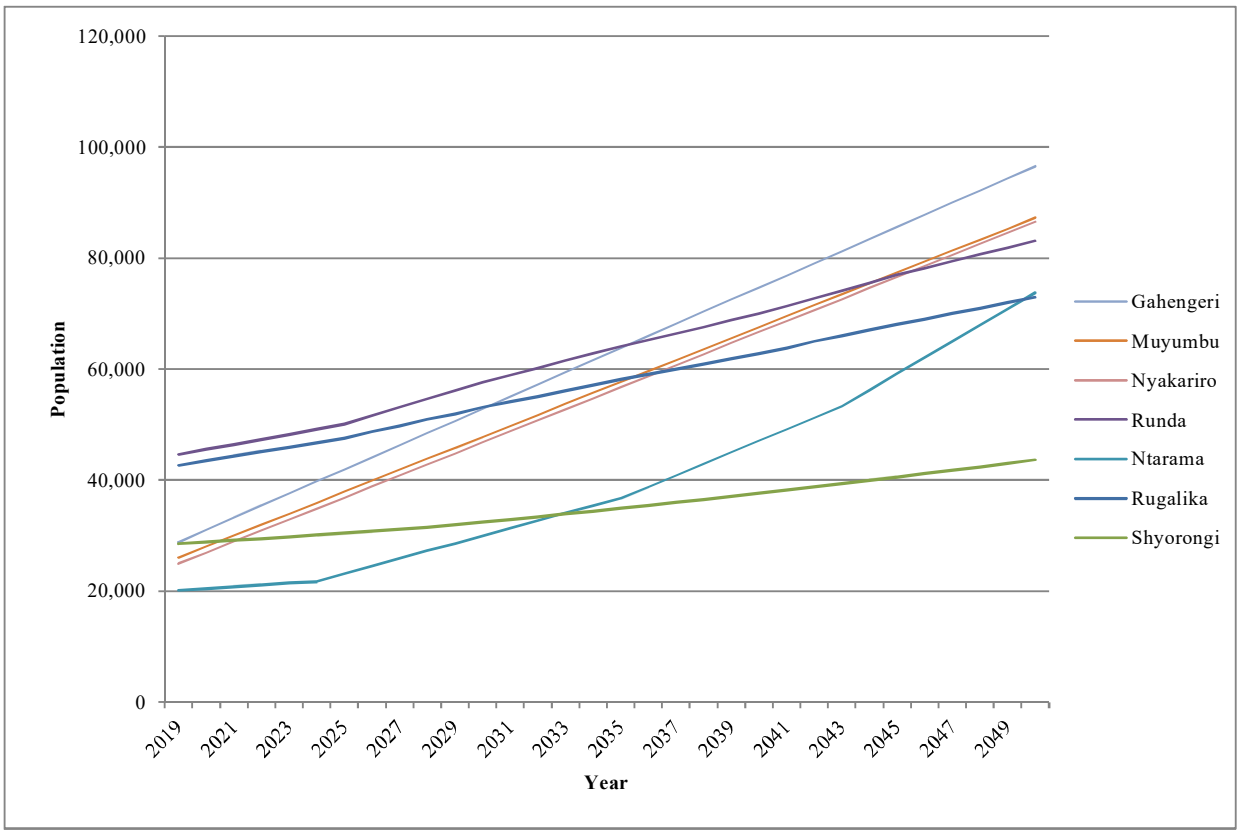
- Populations in 2019 for all the 7 sectors are based on information provided by the respective sector offices. Therefore, these are regarded as baseline populations for individual sectors
- The Runda and the Rugarika Sector offices provided population projection for every 5 years starting from 2025 up to 2050. Population in-between every 5 years is estimated by interpolating linearly.
- Ntarama Sector office provided population projection based on milestone years (for 2024, 2035, 2043, and 2050). Populations in-between each milestone year are estimated by interpolating linearly.
- Shyorongi Sector office provided population projection for every year up to 2050.
- For the sectors of Muyumbu, Gahengeri, and Nyakaliro, populations in 2050 are estimated with reference to the average rate of population increase at the corresponding nearest sector and as shown in **Table 9.4-4**. This methodology is adopted as per the discussion with the C/P in June 2019.

Table 9.4-2 Population Growth Scenarios for Sectors of Ntarama, Muyumbu, Gahengeri, and Nyakaliro

Sectors (in adjacent 7 sectors)	Growth rate		Population	
	Reference sector in CoK	Growth rate from 2019 to 2050	2019	2050
Muyumbu	Rusororo	4.0%	26,073	87,312
Gahengeri	Rusororo	4.0%	28,836	96,564
Nyakaliro	Masaka	4.1%	24,938	86,555

Source: Sector offices of Muyumbu, Gahengeri, and Nyakariro

Based on the above data and hypothesis, sector-wise population from 2019 to 2050 is estimated and is presented under **Appendix-18(2)** and **Figure 9.4-5**:

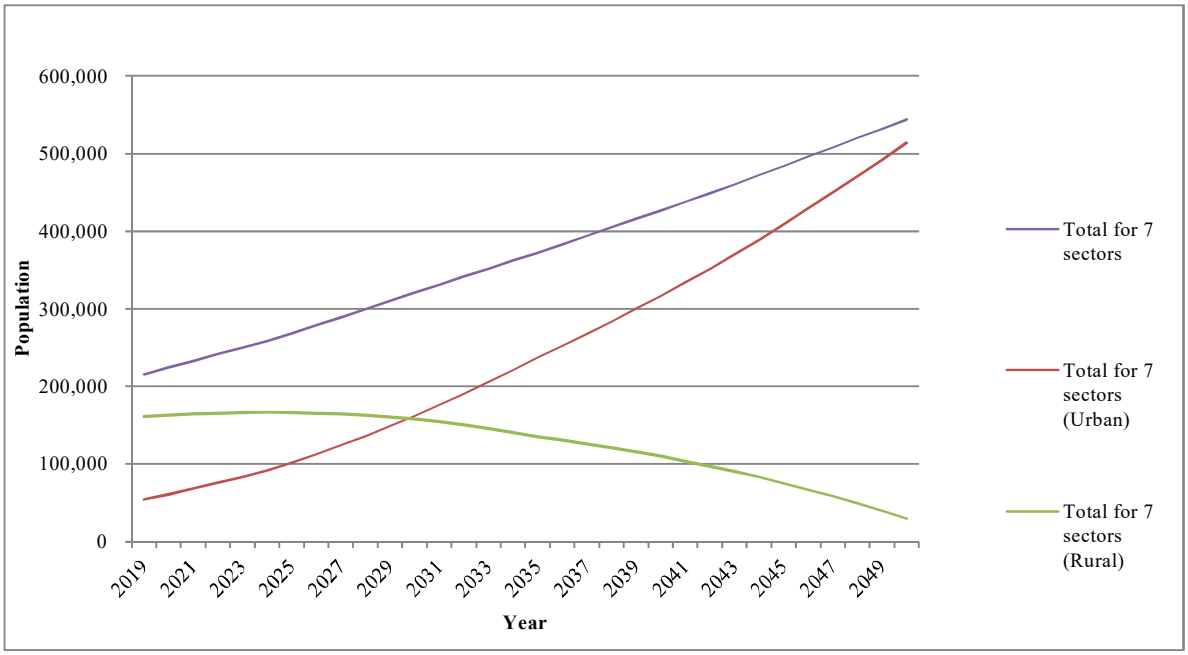


Source: JST

Figure 9.4-5 Sector-wise Population Projection for Adjacent 7 sectors

Further, likewise for the CoK, with reference to the sector-wise distribution percentages living in an Urban area and Rural area as presented in **Table 9.3-1**, total population that is broken down into area-wise (i.e., the population living in an Urban area and Rural area) is calculated for the years 2012 and 2050. Then, individual percentages of urban and rural in between 2013 to 2050 are estimated by interpolating linearly[3]. **Appendix-18(3)** and **Figure 9.4-6** present the total population for the adjacent 7 sectors by area (Urban area and Rural area).

[3] Percentage of living in urban area in the sectors of Rugarika, Ntarama, Muyumbu, Gahengeri, and Nyakaliro is regarded as 100% in 2050, based on the assumption that entire area of those sectors will be urbanized by 2050.



Source: JST

Figure 9.4-6 Population Projection for Adjacent 7 Sectors (total with urban vs. rural)

9.4.1.2 Service Coverage Level

In order to estimate the served population in the Study Area, service coverage ratio for baseline and target shall be determined.

As mentioned under **Chapter 4** and discussed under **Chapter 5**, several governing plans present service coverage figures for an urban area, for example,

- The EDPRS II: present rate for access to an improved water source within 200 m in urban households is 86.4% as of 2012.
- The NWSPIS: % of urban households within 200 m of an improved water source is 60.5% as of 2015.

(1) Determination of Baseline Service Coverage Ratio

Since the exact service coverage ratio for estimating the served population in the Study Area is not available, the JST estimated the service ratio to set the baseline service coverage rate for calculation purpose in the following manner:

- Under this Study, it is defined that the service coverage consists of the following components
  - Coverage ratio of individual house connection (supplied by the WASAC's piped supply service).
  - Coverage ratio of public tap (supplied by the WASAC's public stand posts).
  - Others by the WASAC (e.g., shared connection: this consumption is regarded to be included in the above individual connection for calculation purpose)
- Coverage ratio of individual house connections and houses utilizing public tap are estimated based on the billing record as of March 2019 for 6 branches (Kacyiru, Kanombe, Gikondo, Nyamirambo, Nyarugenge, and Remera) in the Study Area.

- Total registered connection in the billing record of the WASAC as of March 2019: 105,850 connections:
  - Residential 97,022
  - Non-Residential 7,911
  - Industry 183
  - Public Tap 734
- The total population at the end of 2018: 1,582,659 (this Study)
- An average family member in a household: 4.0 (the EICV5)[4]
- Average users per one public tap: 350 (the WASAC's standard)
- Served population for individual house connection:388,088 (=Number of residential connection x Average family member in a household)
- Served population for public tap:256,900 (= Number of public tap x Average users per one public tap)
- Coverage ratio of individual house connection as of 2019 (baseline): 25% (= Served population for piped coverage / Total population at the end of 2018)
- Coverage ratio of houses utilizing public tap as of 2019 (baseline): 16% (= Served population for public tap / Total population at the end of 2018)

(2) Determination of Target Service Coverage Ratio

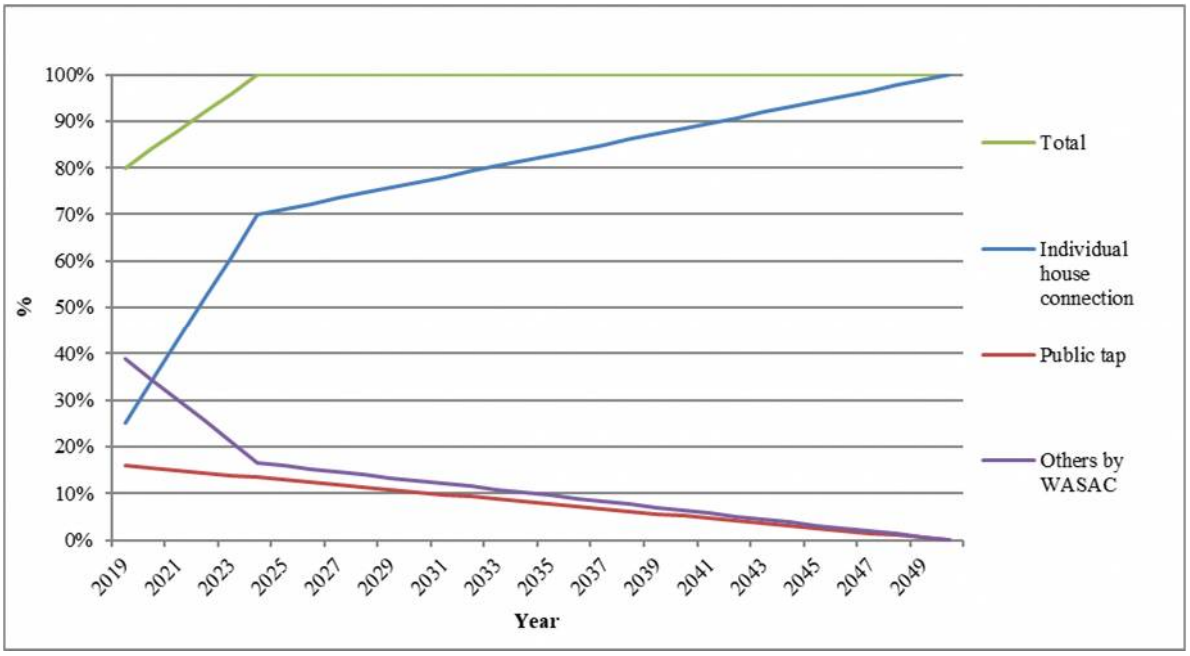
As mentioned under **Section 4.1**, the Vision 2050 is under preparation by the government of Rwanda. The MINECOFIN's Minister gave a presentation on the content of the Vision 2050 in 2016. According to this presentation, the Vision 2050 is about ensuring high standards of living for all the Rwandans, including the achievement of universal, sustainable, and reliable access to water (in houses) and sanitation.
Hence, under this Study, the target of service coverage ratio is set to achieve 100% for individual house connections by 2050.

In addition, as per the discussion with the C/P in April 2019, the WASAC expressed its intention to achieve 70% of individual house connections by 2024.
Accordingly, under this Study, two cases are considered, namely:

- Case-1:
  - 25% of the coverage ratio of individual house connection in 2019 which increases linearly towards 70% by 2024, and further increases linearly towards 100% by 2050.
  - 16% of the coverage ratio of public tap in 2019 decreases linearly to 0% toward 2050.
- Case-2:
  - 25% of coverage ratio of individual house connection in 2019 increases linearly toward 100% in 2050.
  - Same as the Case-1.

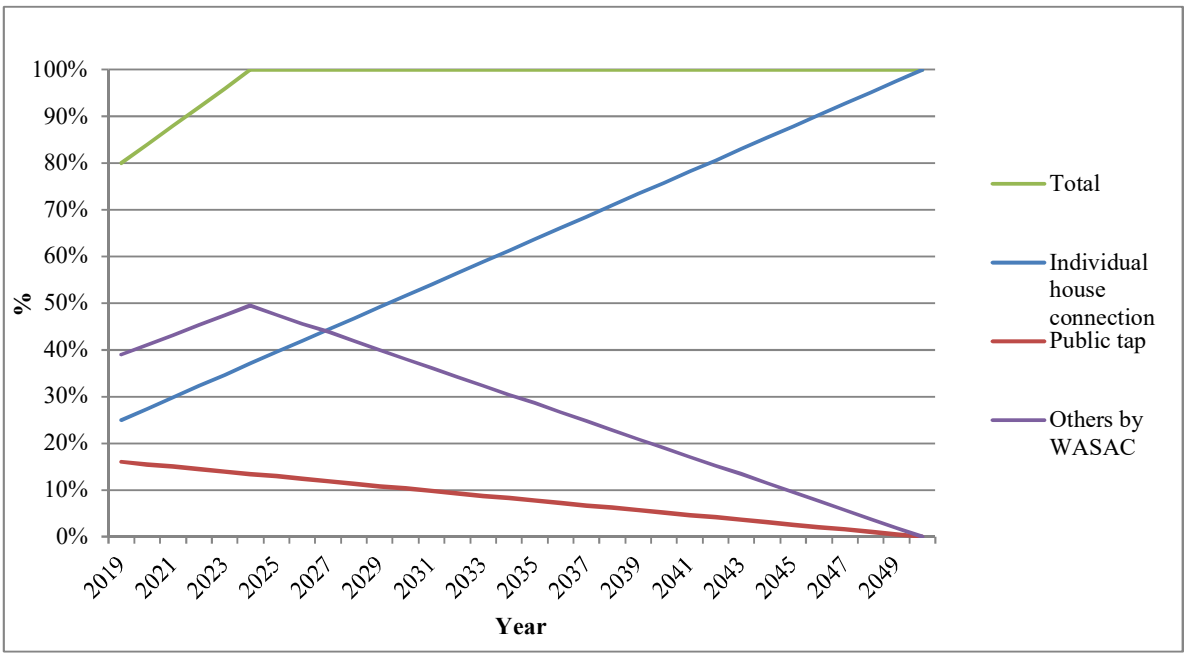
[4] Source: https://www.dropbox.com/s/zke2y7qs5r01g4w/EICV5_Main_Indicators.pdf?dl=1

Figure 9.4-7 and **Figure 9.4-8** present the baseline and target service coverage ratio toward the target years under both the cases.



Source: JST

Figure 9.4-7 Target Service Coverage Ratio by Type (Case-1)



Source: JST

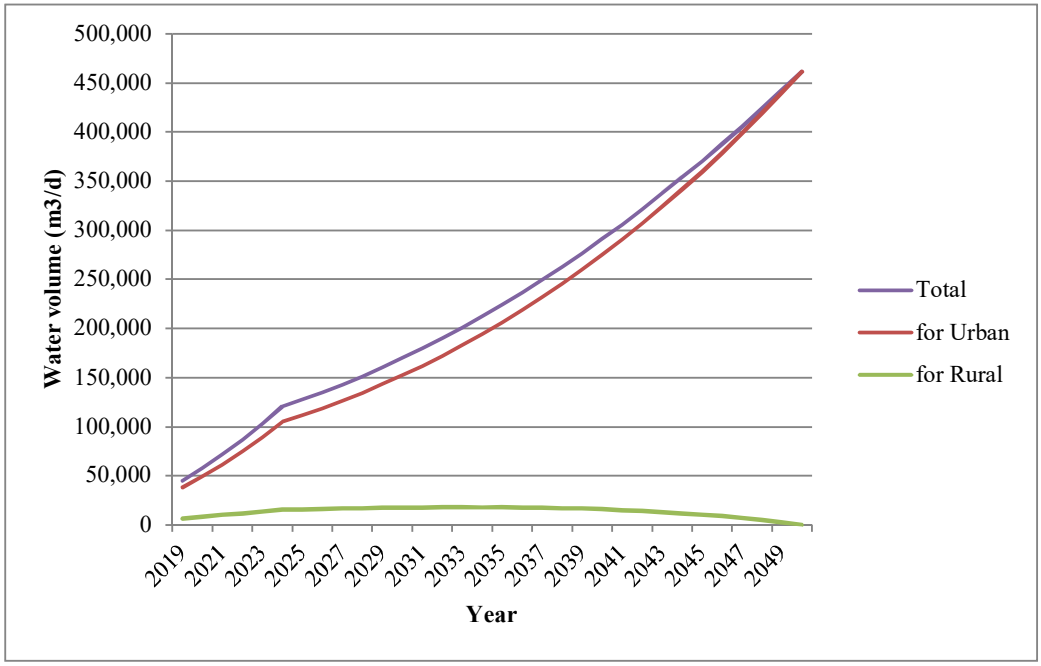
Figure 9.4-8 Target Service Coverage Ratio by Type (Case-2)

9.4.1.3 Served population

(1) For the CoK

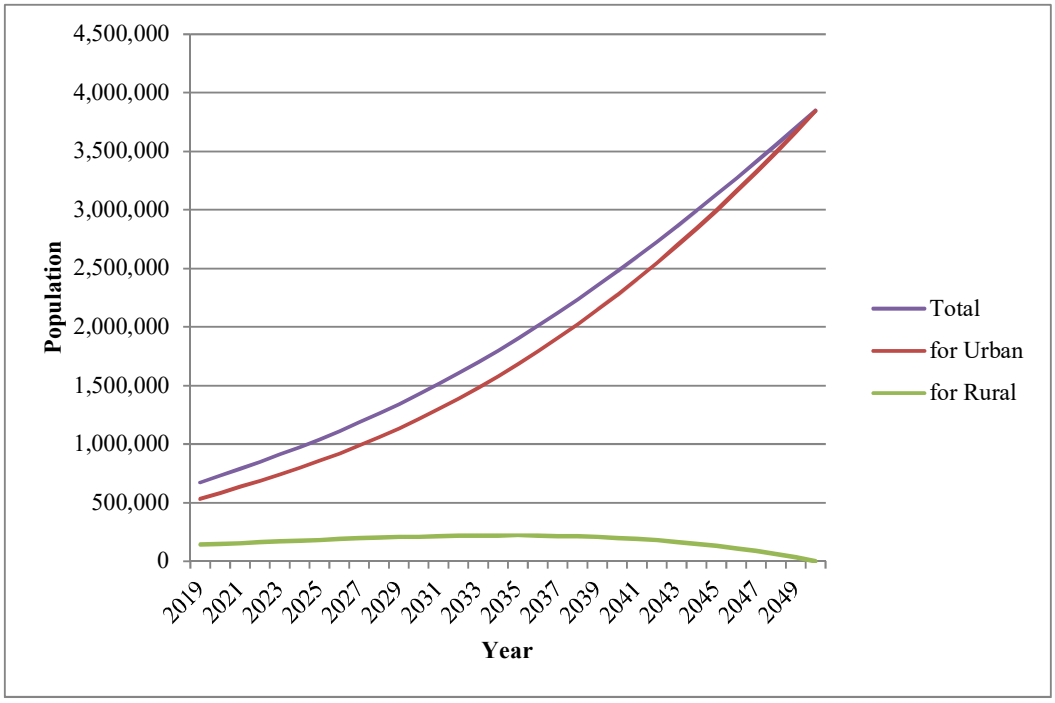
By multiplying service coverage ratio for individual house connection with total population, the served

populations for the above mentioned two cases are calculated. **Figure 9.4-9** and **Figure 9.4-10** present served population in the CoK under both the cases.



Source: JST

Figure 9.4-9 Service Population for CoK (Case-1)

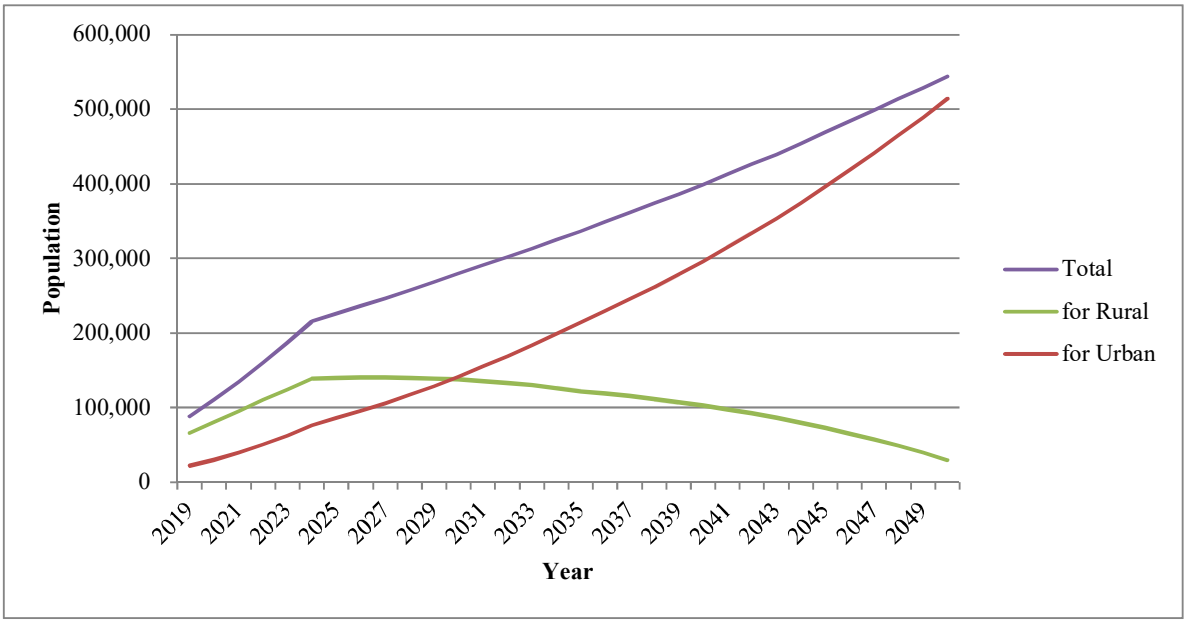


Source: JST

Figure 9.4-10 Service Population for CoK (Case-2)

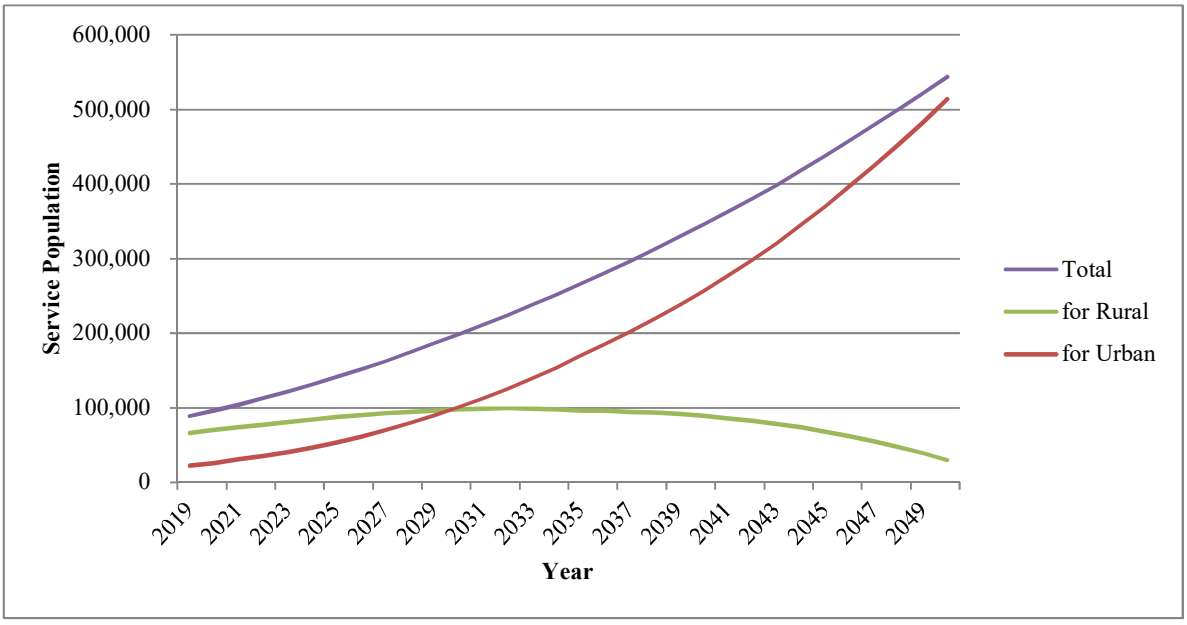
(2) For Adjacent 7 Sectors

Similarly as calculated for the CoK, served populations for the adjacent 7 sectors under both the cases are calculated, and are presented in **Figure 9.4-11** and **Figure 9.4-12**.



Source: JST

Figure 9.4-11 Service Population for Adjacent 7 Sector (Case-1)



Source: JST

Figure 9.4-12 Service Population for Adjacent 7 Sector (Case-2)

9.4.1.4 Average Consumption of Domestic Use

With Reference to the relevant governing plans including the Cok M/P and the AfDB M/P, the unit per capita consumption in 2050 is set as follows:

- Urban (for piped water users living in urban areas): 120 lpcd
- Rural (for stand post users living in rural areas): 80 lpcd

Trend of unit per capita consumption change with time are assumed as shown in **Table 9.4-3** so that the daily average demand fits closely with the current actual production in the year of 2019, which is the starting point of the demand projection, and they ultimately reach 120 lpcd for urban area and 80 lpcd by the year 2050.

Table 9.4-3 Unit Per Capita Consumption Setting (unit: lpcd)

	2019	2025	2030	2035	2040	2045	2050
For Urban	80	88	94	101	107	114	120
For Rural	50	56	61	65	70	75	80

Source: Assumed by JST based on discussion with WASAC

9.4.1.5 Consumption of Non-Domestic Use

According to the billing record as in March 2019 for 6 branches provided by the WASAC, the non-domestic consumption is ranging from 17% (in the Nyakaliro Branch) to 49% (in the Nyarugenge) and as shown in the figure under **Section 5.1** of this report.

Under the CoK M/P, non-domestic consumption in 2050 is accounted for 22.7% of net demand[5] (130,328 m^3/d for Non-domestic, 442,823 m^3/d for domestic). This is calculated by using the following assumptions which are also as presented in **Appendix-18(5)**.

- Sector-wise land use area (in hectare) by land-use type (commercial, industries, open space, public facilities)
- Unit consumption rates for non-domestic use according to the type of use per unit area per day with reference to the following guidelines as used in South Africa:
  - 32 m^3/ha/d for commercial,
  - 24 m^3/ha/d for industrial,
  - 4 m^3/ha/d for public/admin,
  - 10 m^3/ha/d for open space.

For calculation purposes, 20% of net demand is regarded as percentage of non-domestic use {i.e., 20% = non-domestic / (domestic + non-domestic)} for the entire period towards 2050.

9.4.1.6 NRW Ratio

Under the 5 Years Strategic Plan for NRW Reduction, the WASAC indicates NRW reduction targets from 2018/2019 up to 2022/2023. The indicated reduction targets are shown in **Table 9.4-4**.

Table 9.4-4 NRW Target in 5 Years Strategic Plan for NRW Reduction

Year	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023
NRW target	35%	32%	30%	28%	25%

[5] Net demand = domestic demand + non-domestic demand

Source: 5 Years Strategic Plan for NRW Reduction, WASAC

In addition, during the meeting with the C/P in April 2019, the C/P expressed that the WASAC intends to reduce NRW rate by 20% towards 2050.

Accordingly, the target NRW rate is set with the following concept:

- Target NRW ration up to 2023: follow the 5 Years Strategic Plan for NRW Reduction as indicated by the WASAC.
- NRW ratio in 2050 (target year): 20%.
- NRW ratio shall be regarded the same as physical loss for demand projection purposes under this Study.
- NRW ratio from 2024 to 2049: decrease linearly towards the target year.

Table 9.4-5 presents the NRW ratio used under this Study. In this water demand projection, it is regarded that leakage accounts for the majority of the NRW, considering the actual situation in the Study Area.

Table 9.4-5 NRW Ratio Toward 2050

	2019	2025	2030	2035	2040	2045	2050
NRW Ratio	35%	25%	24%	23%	22%	21%	20%

Source: JST

9.4.1.7 Seasonal Peak Factor

The seasonal peak factor, which is the ratio of maximum demand to an average demand (and expressed as the reciprocal of the load factor rate) is used to determine the capacity of production facilities. The Basic Data Collection Study on Urban Water Supply Systems in the Republic of Rwanda which was conducted by JICA in 2017 (JICA's Basic Data Collection Report) indicates that the load factor rates for the WTPs in the CoK are as follows:

- Load factor for the Nzove WTP: 77% (= seasonal peak factor: 1.30)
- Load factor for the Karenge WTP: 94% (= seasonal peak factor: 1.06)
- Load factor for the Kimisagara WTP: 89% (= seasonal peak factor: 1.12)

The above-mentioned load factor rates are based on the actual operational records from December 2015 to October 2016 for the WTPs.

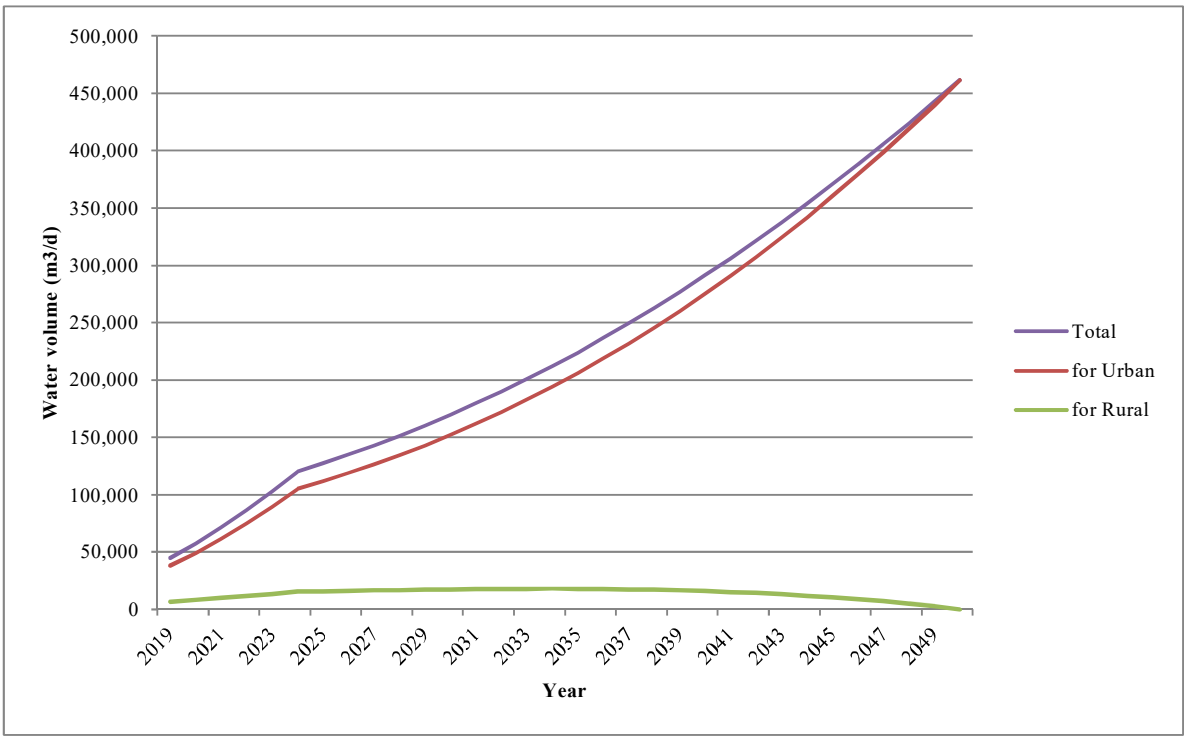
Under this study, 77% (= seasonal peak factor: 1.3) is used to estimate the daily maximum demand.

9.4.2 Water Demand Projection

9.4.2.1 Domestic Demand for CoK

(1) Case-1

The domestic demand projection for the CoK under the Case-1 scenarios is summarized in **Figure 9.4-13**.

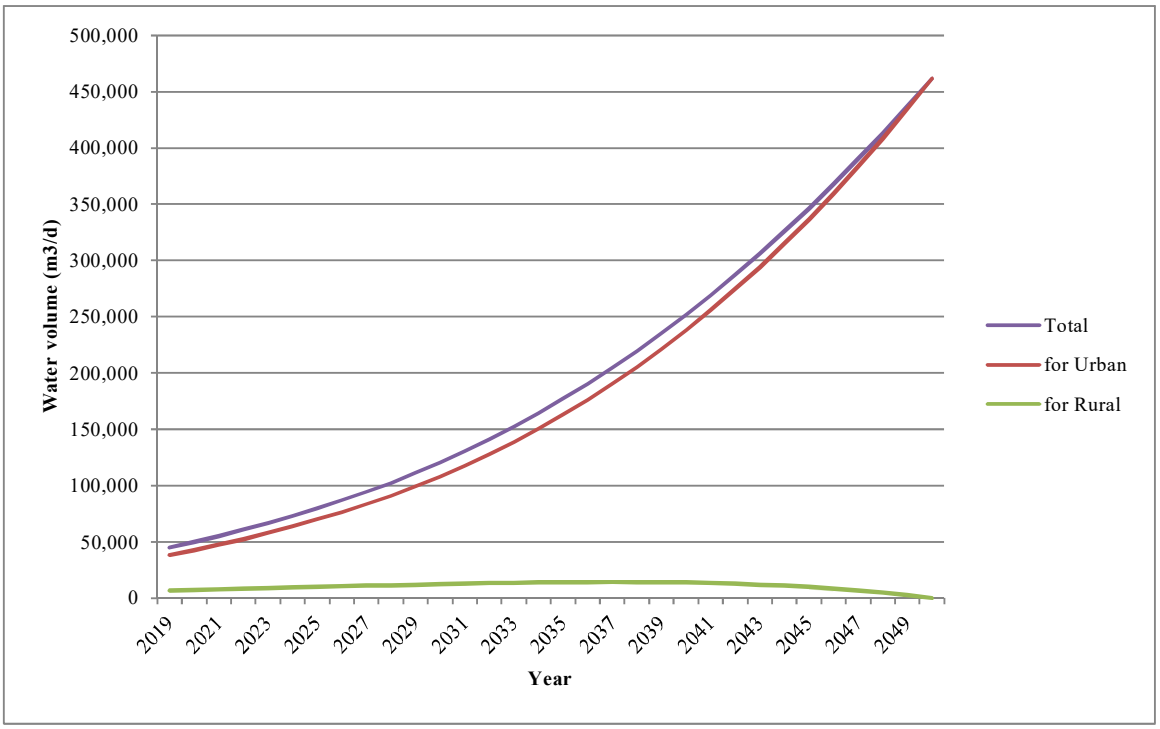


Source: JST

Figure 9.4-13 Domestic Demand for CoK (total demand with demand of urban vs rural, Case-1)

(2) Case-2

The domestic demand projection for the CoK under the Case-2 scenarios is summarized in **Figure 9.4-14**.



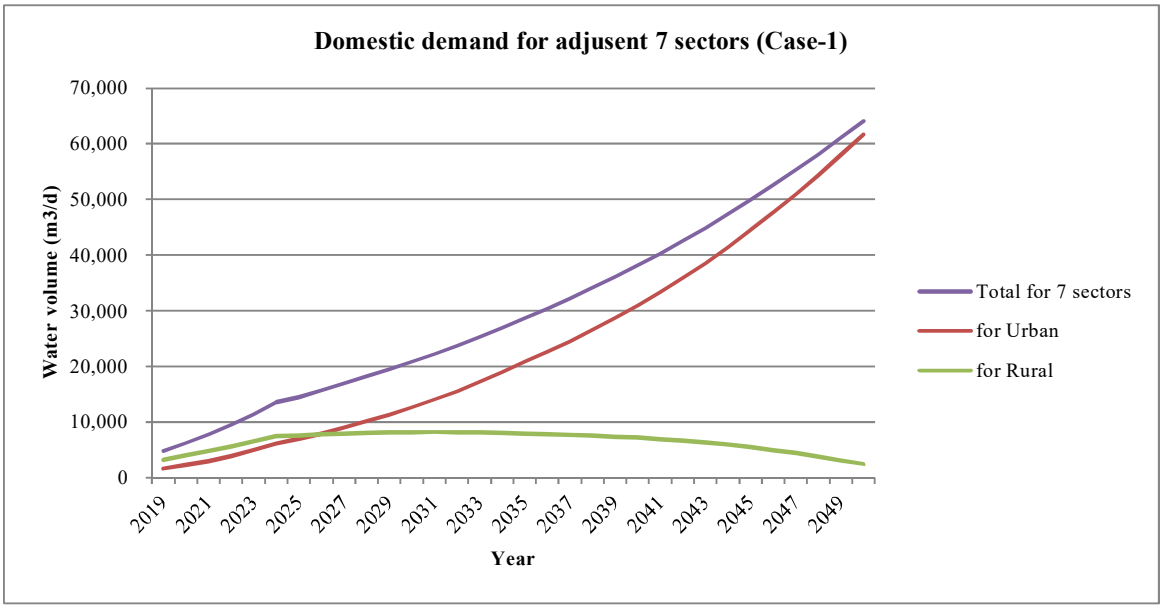
Source: JST

Figure 9.4-14 Domestic Demand for CoK (total demand with demand of urban vs rural, Case-2)

9.4.2.2 Domestic Demand for Adjacent 7 Sectors

(1) Case-1

The domestic demand projection for the adjacent 7 sectors under the Case-1 scenario is summarized in **Figure 9.4-15**.

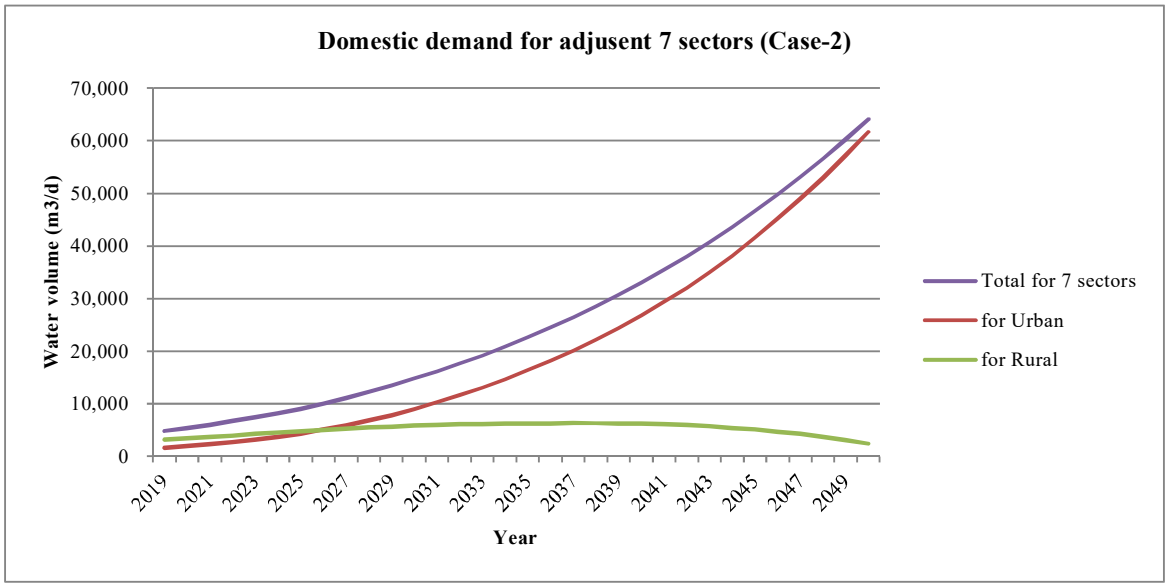


Source: JST

Figure 9.4-15 Domestic Demand for Adjacent 7 Sectors (total demand with demand of urban vs rural, Case-1)

(2) Case-2

The domestic demand projection for the adjacent 7 sectors under the Case-2 scenarios is summarized in **Figure 9.4-16**.



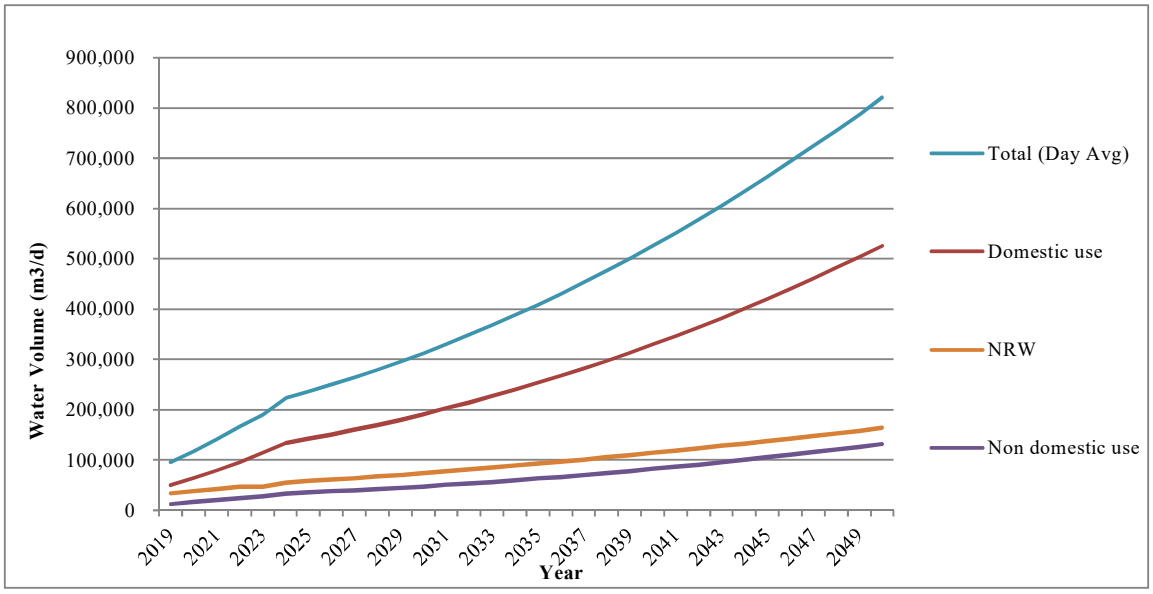
Source: JST

Figure 9.4-16 Domestic Demand for Adjacent 7 Sectors (total demand with the demand of urban vs. rural, Case-2)

9.4.2.3 Total Projected Demand

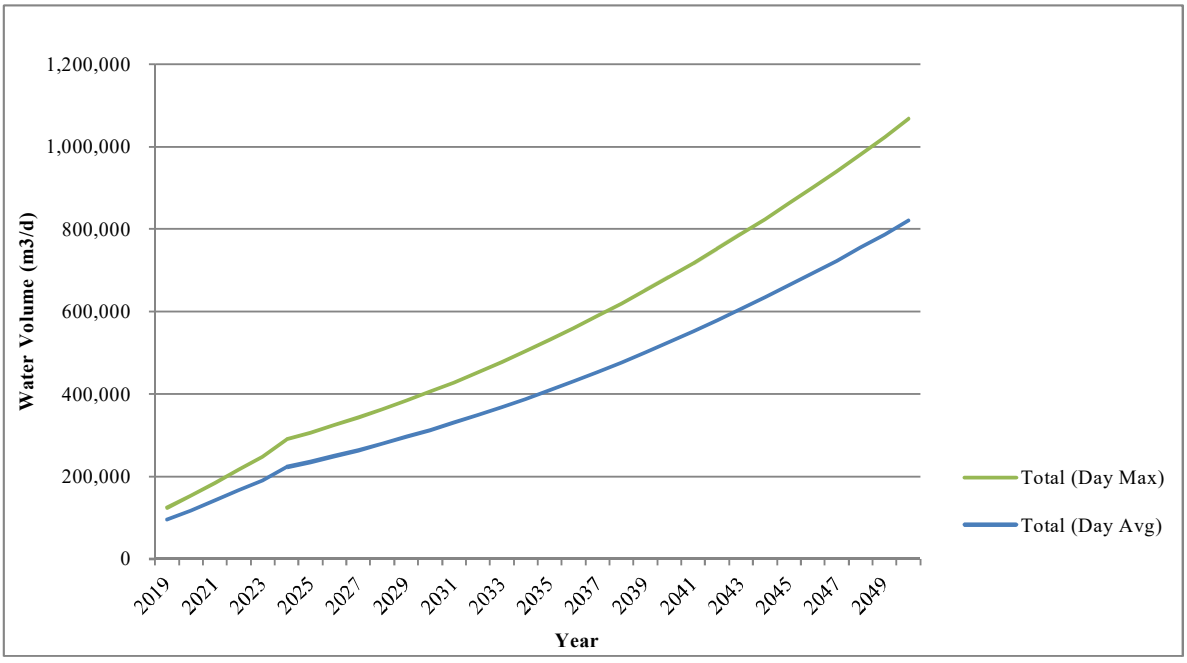
(1) Case-1

The total projected demand under the Case-1 scenarios is summarized **Figure 9.4-17**, **Figure 9.4-18**, and **Table 9.4-6**.



Source: JST

Figure 9.4-17 Breakdown of Projected Day Average Demand (Case-1)



Source: JST

Figure 9.4-18 Projected Demand (day average vs day maximum, for Case-1)

Table 9.4-6 Projected Demand and its Breakdown (Case-1)

Category		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
(a) Domestic use	Domestic use in CoK	49,409	63,158	77,932	93,922	111,158	129,590	136,774	144,361	152,365	160,799	169,673
	Domestic use in adjacent 7 sectors	5,091	6,571	8,216	10,036	12,039	14,235	15,293	16,458	17,679	18,957	20,302
	Total	54,500	69,728	86,148	103,958	123,197	143,825	152,067	160,819	170,044	179,756	189,975
(b) Non domestic use	Non domestic use in CoK	12,352	15,789	19,483	23,481	27,789	32,398	34,193	36,090	38,091	40,200	42,418
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	1,273	1,643	2,054	2,509	3,010	3,559	3,823	4,114	4,420	4,739	5,076
domestic use rate)}	Total	13,625	17,432	21,537	25,989	30,799	35,956	38,017	40,205	42,511	44,939	47,494
(c) = (a) + (b)	Net demand	68,125	87,160	107,685	129,947	153,996	179,781	190,083	201,023	212,555	224,695	237,469
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	36,683	41,017	46,151	50,535	51,332	59,314	62,068	64,962	67,974	71,106	74,359
(e) = (c) + (d)	Total (Day Avg)	104,808	128,177	153,836	180,482	205,328	239,096	252,151	265,985	280,529	295,801	311,828
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	136,251	166,630	199,986	234,627	266,926	310,824	327,797	345,781	364,688	384,541	405,376

	NRW rate	35%	32%	30%	28%	25%	25%	25%	24%	24%	24%	24%
	Non domestic use rate	20%	of net demand for entire period									
	Seasonal Peak Factor	1.3	for entire period									

Category		2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
(a) Domestic use	Domestic use in CoK	178,998	188,781	199,031	209,751	220,946	232,617	244,765	257,387	270,481	284,042	298,064
	Domestic use in adjacent 7 sectors	21,708	23,155	24,664	26,238	27,878	29,584	31,330	33,140	35,015	36,956	38,965
	Total	200,705	211,936	223,695	235,989	248,823	262,201	276,095	290,527	305,496	320,998	337,029
(b) Non domestic use	Non domestic use in CoK	44,749	47,195	49,758	52,438	55,236	58,154	61,191	64,347	67,620	71,011	74,516
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	5,427	5,789	6,166	6,560	6,969	7,396	7,833	8,285	8,754	9,239	9,741
domestic use rate)}	Total	50,176	52,984	55,924	58,997	62,206	65,550	69,024	72,632	76,374	80,250	84,257
(c) = (a) + (b)	Net demand	250,882	264,920	279,619	294,986	311,029	327,752	345,118	363,159	381,870	401,248	421,286
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	77,729	81,207	84,797	88,496	92,300	96,206	100,196	104,273	108,432	112,666	116,966
(e) = (c) + (d)	Total (Day Avg)	328,611	346,127	364,415	383,482	403,330	423,957	445,314	467,432	490,302	513,913	538,252
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	427,194	449,965	473,740	498,527	524,329	551,144	578,908	607,662	637,393	668,087	699,728

	NRW rate	24%	23%	23%	23%	23%	23%	23%	22%	22%	22%	22%
	Non domestic use rate	20%	of net demand for entire period									
	Seasonal Peak Factor	1.3	for entire period									

Category		2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
(a) Domestic use	Domestic use in CoK	312,539	327,459	342,813	358,592	374,784	391,376	408,355	425,708	443,420	461,477
	Domestic use in adjacent 7 sectors	41,078	43,263	45,522	47,948	50,454	53,014	55,655	58,380	61,188	64,082
	Total	353,617	370,722	388,335	406,540	425,238	444,390	464,010	484,088	504,608	525,559
(b) Non domestic use	Non domestic use in CoK	78,135	81,865	85,703	89,648	93,696	97,844	102,089	106,427	110,855	115,369
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	10,269	10,816	11,380	11,987	12,614	13,254	13,914	14,595	15,297	16,021
domestic use rate)}	Total	88,404	92,680	97,084	101,635	106,309	111,097	116,003	121,022	126,152	131,390
(c) = (a) + (b)	Net demand	442,021	463,402	485,418	508,175	531,547	555,487	580,013	605,109	630,760	656,949
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	121,339	125,764	130,234	134,771	139,338	143,916	148,506	153,100	157,690	164,237
(e) = (c) + (d)	Total (Day Avg)	563,360	589,166	615,653	642,947	670,885	699,403	728,519	758,209	788,451	821,186
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	732,368	765,916	800,348	835,831	872,150	909,223	947,074	985,672	1,024,986	1,067,542

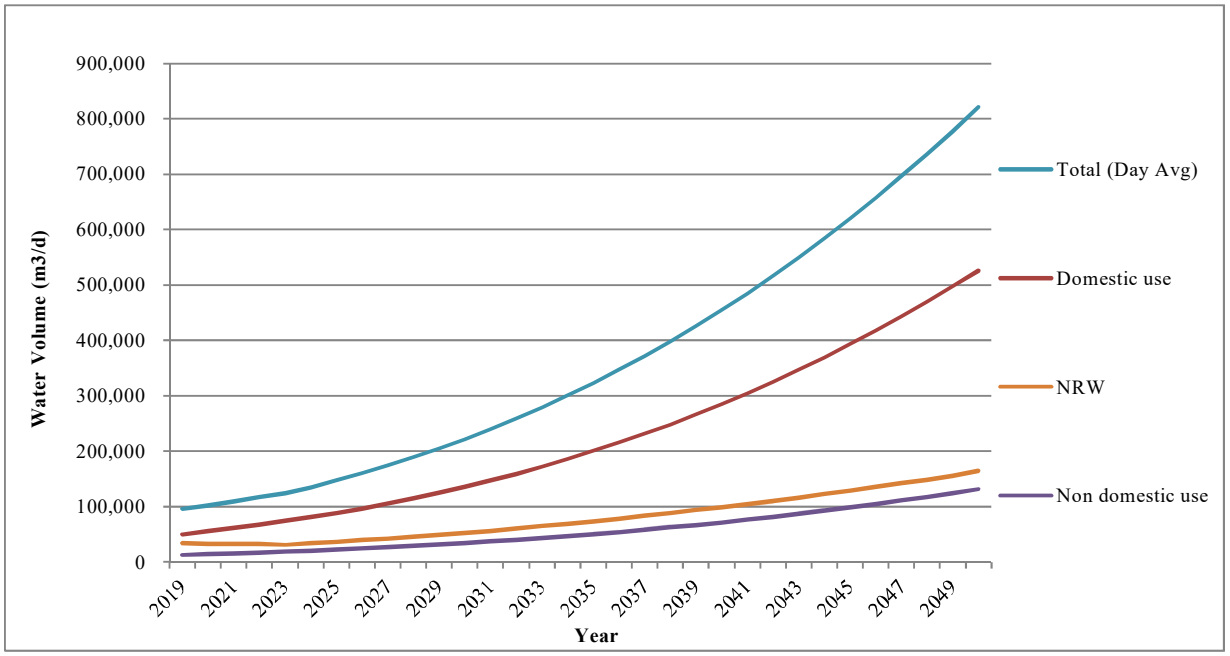
	NRW rate	22%	21%	21%	21%	21%	21%	20%	20%	20%	20%
	Non domestic use rate	20%	of net demand for entire period								
	Seasonal Peak Factor	1.3	for entire period								

Source: JST

Note: NRW ratio shall be regarded the same as physical loss for demand projection purposes under this Study.

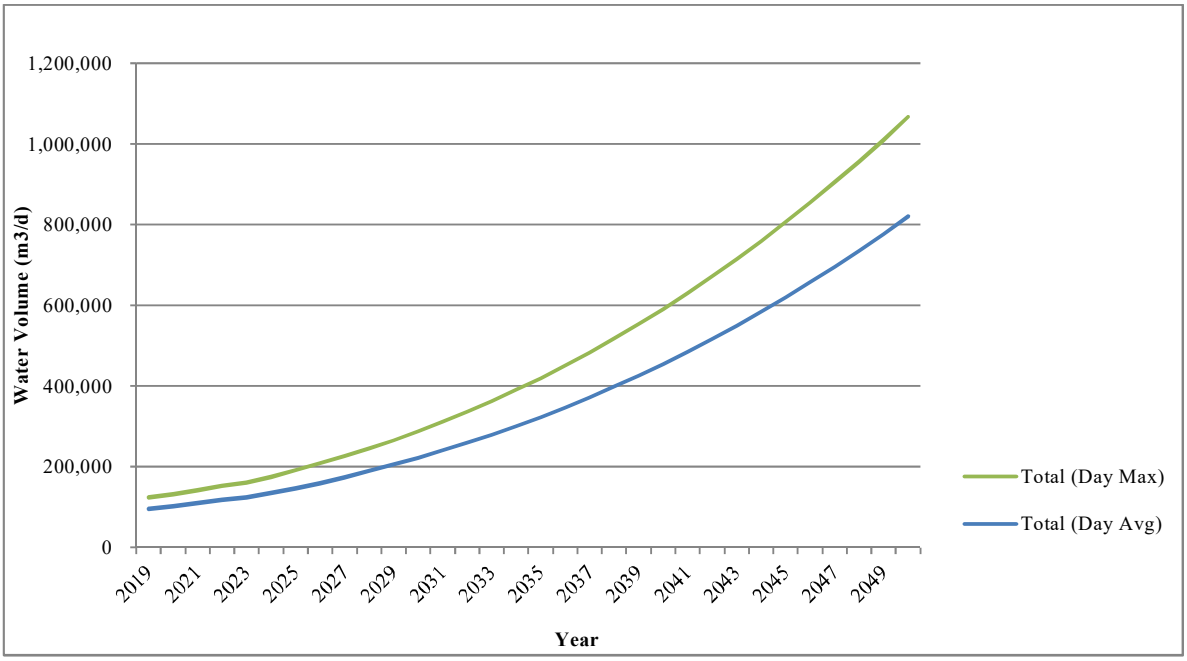
(2) Case-2

The total demand projection under the Case-2 scenarios is summarized in **Figure 9.4-19**,**Figure 9.4-20** **Figure 9.4-20**, and **Table 9.4-7**.



Source: JST

Figure 9.4-19 Breakdown of Projected Day Average Demand (Case-2)



Source: JST

Figure 9.4-20 Projected Demand (day average vs day maximum, for Case-2)

Table 9.4-7 Projected Demand and Its Breakdown (Case-2)

Category		2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
(a) Domestic use	Domestic use in CoK	49,409	54,759	60,238	66,019	72,111	78,476	85,294	92,592	100,394	108,725	117,609
	Domestic use in adjacent 7 sectors	5,091	5,697	6,350	7,054	7,810	8,620	9,537	10,556	11,649	12,818	14,072
	Total	54,500	60,455	66,588	73,073	79,921	87,096	94,831	103,148	112,042	121,543	131,681
(b) Non domestic use	Non domestic use in CoK	12,352	13,690	15,060	16,505	18,028	19,619	21,324	23,148	25,098	27,181	29,402
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	1,273	1,424	1,588	1,764	1,952	2,155	2,384	2,639	2,912	3,204	3,518
domestic use rate)}	Total	13,625	15,114	16,647	18,268	19,980	21,774	23,708	25,787	28,011	30,386	32,920
(c) = (a) + (b)	Net demand	68,125	75,569	83,236	91,342	99,902	108,870	118,539	128,935	140,053	151,928	164,601
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	36,683	35,562	35,672	35,522	33,301	35,919	38,707	41,666	44,789	48,079	51,542
(e) = (c) + (d)	Total (Day Avg)	104,808	111,131	118,908	126,863	133,202	144,789	157,246	170,601	184,841	200,007	216,143
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	136,251	144,471	154,580	164,922	173,163	188,225	204,419	221,781	240,294	260,009	280,986

	NRW rate	35%	32%	30%	28%	25%	25%	25%	24%	24%	24%	24%
	Non domestic use rate	20%	of net demand for entire period									
	Seasonal Peak Factor	1.3	for entire period									

Category		2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
(a) Domestic use	Domestic use in CoK	127,070	137,131	147,814	159,139	171,125	183,789	197,148	211,215	226,002	241,519	257,774
	Domestic use in adjacent 7 sectors	15,410	16,820	18,318	19,907	21,592	23,374	25,235	27,195	29,257	31,423	33,698
	Total	142,480	153,951	166,132	179,046	192,716	207,164	222,383	238,410	255,258	272,942	291,472
(b) Non domestic use	Non domestic use in CoK	31,768	34,283	36,954	39,785	42,781	45,947	49,287	52,804	56,500	60,380	64,444
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	3,853	4,205	4,579	4,977	5,398	5,844	6,309	6,799	7,314	7,856	8,424
domestic use rate)}	Total	35,620	38,488	41,533	44,761	48,179	51,791	55,596	59,602	63,815	68,236	72,868
(c) = (a) + (b)	Net demand	178,100	192,439	207,664	223,807	240,896	258,955	277,979	298,012	319,073	341,178	364,340
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	55,180	58,989	62,976	67,142	71,488	76,012	80,704	85,568	90,601	95,799	101,156
(e) = (c) + (d)	Total (Day Avg)	233,280	251,427	270,640	290,950	312,383	334,966	358,683	383,580	409,674	436,976	465,496
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	303,264	326,855	351,832	378,235	406,098	435,456	466,288	498,654	532,576	568,069	605,145

	NRW rate	24%	23%	23%	23%	23%	23%	23%	22%	22%	22%	22%
	Non domestic use rate	20%	of net demand for entire period									
	Seasonal Peak Factor	1.3	for entire period									

Category		2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
(a) Domestic use	Domestic use in CoK	274,775	292,524	311,026	330,281	350,288	371,045	392,549	414,794	437,773	461,477
	Domestic use in adjacent 7 sectors	36,114	38,647	41,301	44,162	47,157	50,260	53,501	56,883	60,409	64,082
	Total	310,889	331,172	352,326	374,443	397,445	421,306	446,050	471,677	498,182	525,559
(b) Non domestic use	Non domestic use in CoK	68,694	73,131	77,756	82,570	87,572	92,761	98,137	103,699	109,443	115,369
{= (c) x Non domestic use rate / (1 - Non	Non domestic use in adjacent 7 sectors	9,029	9,662	10,325	11,041	11,789	12,565	13,375	14,221	15,102	16,021
domestic use rate)}	Total	77,722	82,793	88,082	93,611	99,361	105,326	111,513	117,919	124,545	131,390
(c) = (a) + (b)	Net demand	388,611	413,965	440,408	468,054	496,806	526,632	557,563	589,596	622,727	656,949
(d) = (c) x NRW rate / (1 - NRW rate)	NRW	106,678	112,347	118,158	124,131	130,231	136,440	142,758	149,175	155,682	164,237
(e) = (c) + (d)	Total (Day Avg)	495,289	526,312	558,566	592,185	627,036	663,072	700,321	738,771	778,409	821,186
(f) = (e) x "Seasonal peak factor"	Total (Day Max)	643,875	684,206	726,136	769,841	815,147	861,994	910,417	960,402	1,011,931	1,067,542

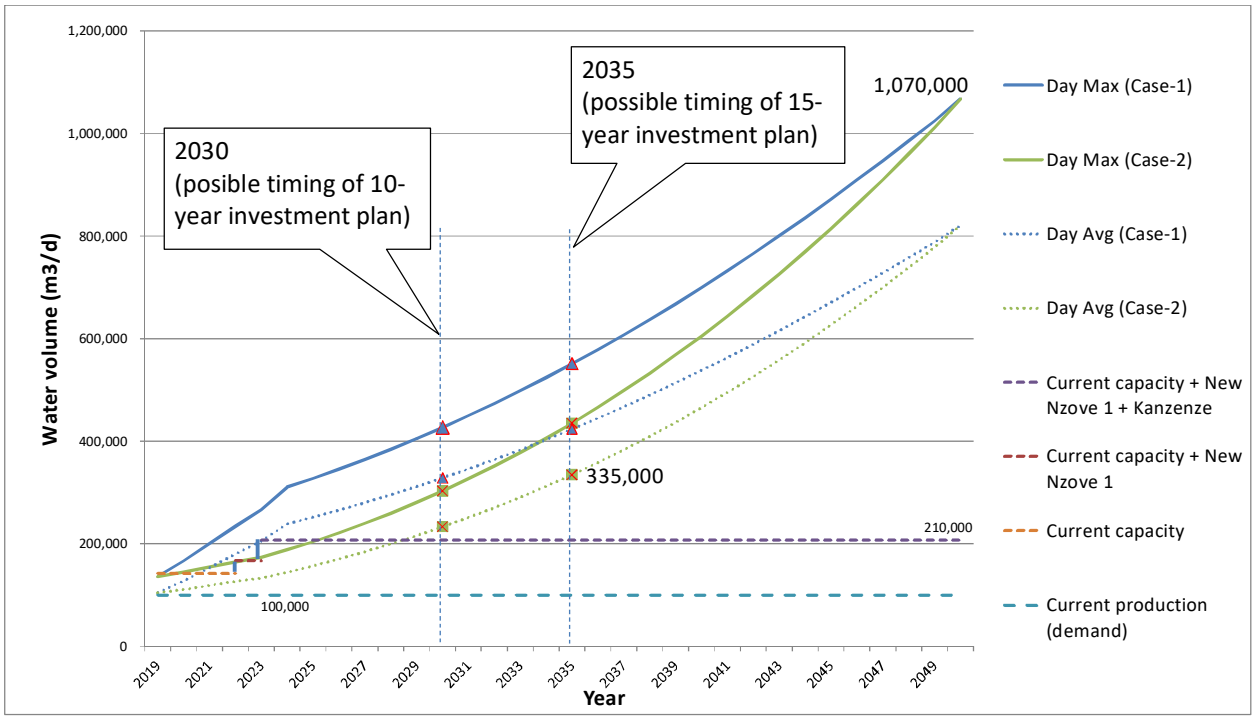
	NRW rate	22%	21%	21%	21%	21%	21%	20%	20%	20%	20%
	Non domestic use rate	20%	of net demand for entire period								
	Seasonal Peak Factor	1.3	for entire period								

Source: JST

Note: NRW ratio shall be regarded the same as physical loss for demand projection purposes under this Study.

(3) Case-1 vs Case-2

Comparison between the Case-1 and Case-2 is presented in **Figure 9.4-21**. Demands during the 10 Year Investment Plan (2030) and the 15 Year Investment Plan (2035) by cases are presented in **Table 9.4-8**.



Source: JST

Figure 9.4-21 Projected Demand (Case-1 vs. Case-2 with day maximum vs day average)

Table 9.4-8 Estimated Water Demand in 2030, 2035 and 2050 (m^3/d)

Scenario of demand projection		2030	2035	2050
Case-1	Day Maximum	427,194	551,144	1,067,542
	Day Average	328,611	423,957	821,186
Case-2	Day Maximum	303,264	435,456	1,067,542
	Day Average	233,280	334,966	821,186

Source: JST

As presented in the above **Figure 9.4-21** and **Table 9.4-8**:

- Approximately 1,070,000 m^3/d of production capacity is required to meet the day maximum demand in 2050 under the two cases. This is nearly five times larger than the production capacity that is to be realized in 2023 (i.e., 210,000 m^3/d which is the current capacity plus the New Nzove 1 plus the Kanzense).
- In order to cover the maximum demand in 2035 under Case-1 scenario (i.e., 551,000 m^3/d), the WASAC has to seek an expansion of the water sources capacity as well as the supply facilities with more than 2.6 times of its capacity in 2023.
- On the other hand, given the target of the capacity of sources and facilities could be relaxed to the daily average demand in 2035 under Case-2 Scenario (i.e., approximately 335,000 m^3/d), the required additional capacity in 2035 is around 140,000 m^3/d, which is approximately 1.7 times of the capacity in 2023.

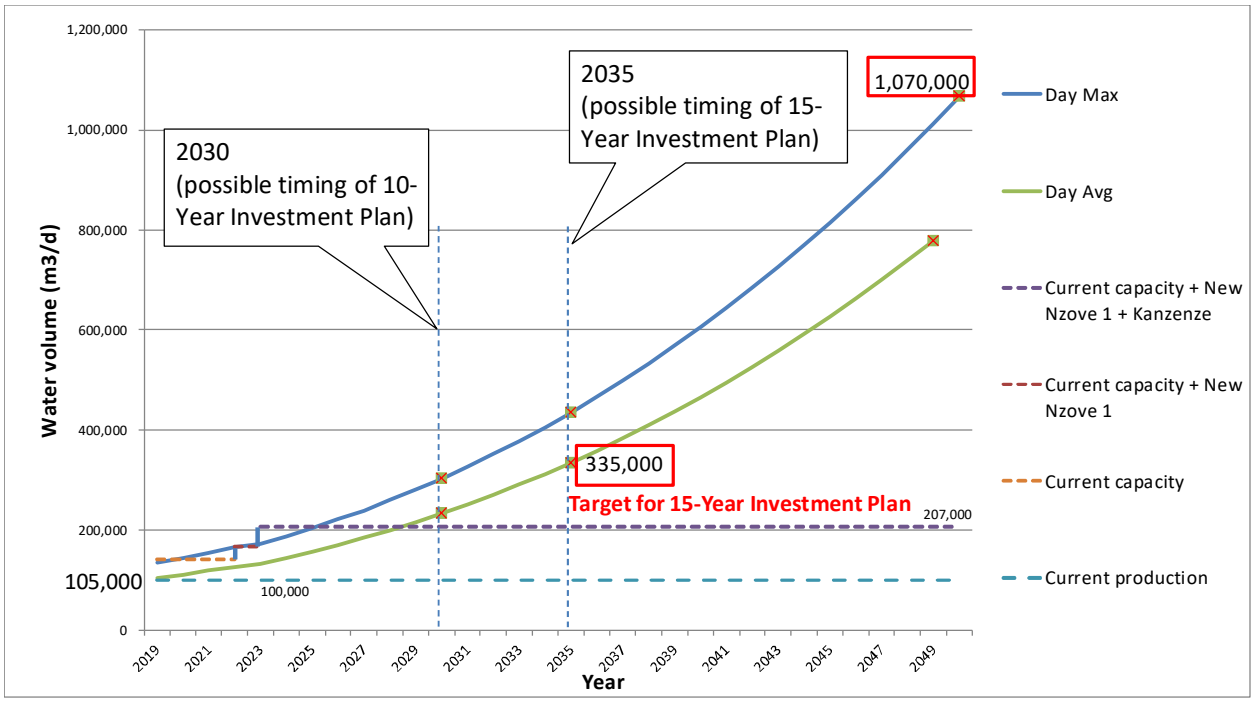
9.5 TARGET SETTING FOR FACILITY PLANNING TOWARD YEAR 2050

In order for the Study to proceed for facility planning as the next step, it is necessary to define the target water demand for each milestone year. It should be noted that the future facility plan should be reasonable and realistic for the Rwandan side considering its present and future available resource and circumstances.

As a result of the demand forecast, the WASAC and the JST shared the same view that the targets for the facility planning for the Study should follow the following orientation:

- The target water demand in the year 2035 (timing of the 15-Year Investment Plan) shall be the Day Average Demand under the Case 2 scenario (approximately 335,000 m^3/d),
- The target water demand in the year 2050 shall be the Day Maximum Demand (approximately 1,070,000 m^3/d).

Water demand projection towards 2050 with its milestone targets are presented in **Figure 9.5-1**.



Source: JST

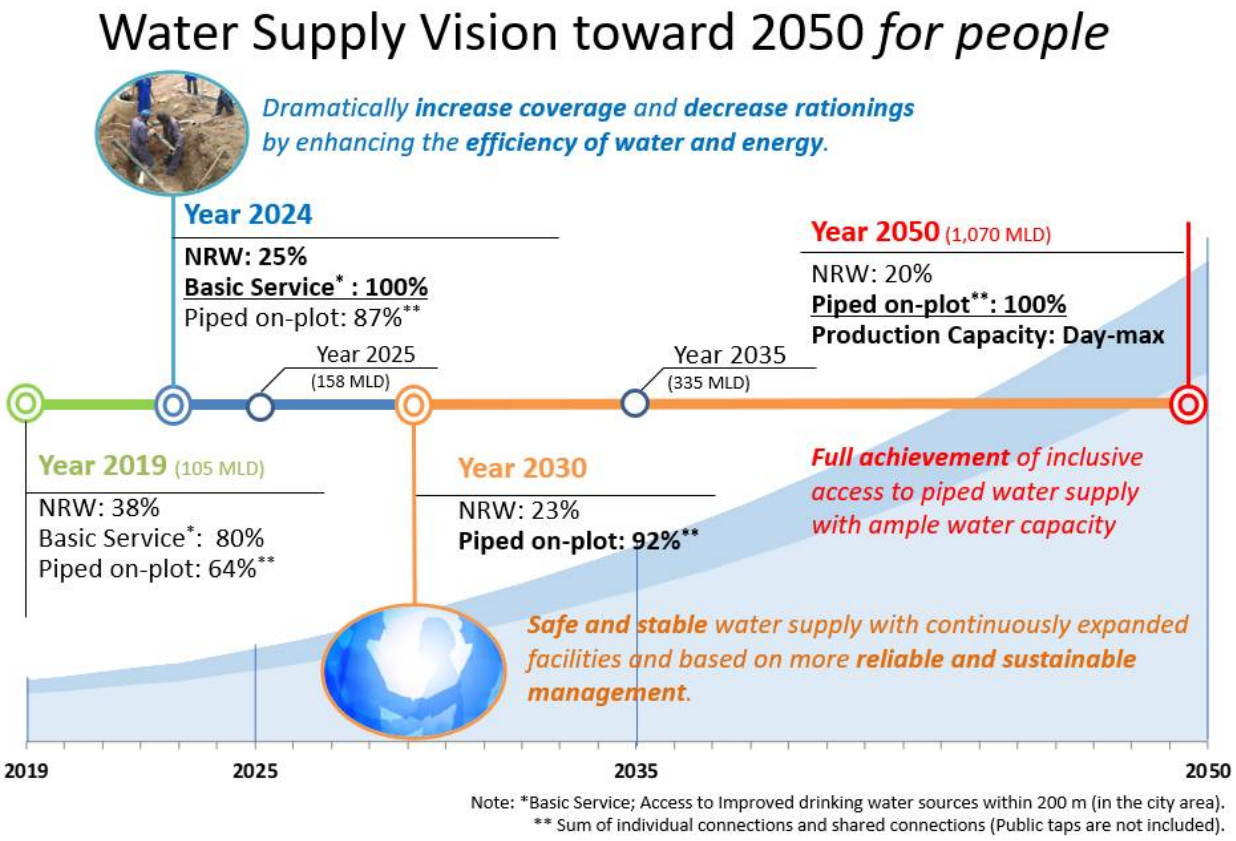
Figure 9.5-1 Projected Water Demand and Target of Facility Planning

The necessary options for future water sources to be developed are discussed and summarized under the "New Water Resources Development Plan" presented in **Chapter 10**. In addition, based on the above water source development plan, the necessary options for water supply facilities as well as the sequence of development are discussed and summarized under the "Master Scenario" in **Chapter 13**. Further, a brief summary of the possible proposed candidate projects is presented in **Chapter 14**.

9.6 WATER SUPPLY VISION

Towards 2050, WASAC needs to focus not only to increase the production capacity but also to improve the efficiency of water supply systems through safe and stable water supply systems with continuous expansion based on more reliable and sustainable management. The vision is in accordance with the One National Strategy for Transformation (NST-1) as the universal access to safe water for urban areas by 2024.
Considering the limited financial resources, WASAC needs a progressive approach to achieve universal access to safely managed drinking water services as shown in **Figure 9.6-1**. The visions for the benchmark years are as follows;

In 2024: *Dramatically increase coverage and decrease rationings by enhancing the efficiency of water and energy.*
In 2030: *Safe and stable water supply with continuously expanded facilities and based on more reliable and sustainable management.*
In 2050*: Fully achieve inclusive access to piped water supply with ample water capacity.*



Source: JST

Figure 9.6-1 Visions for Safely Managed Water Services

9.7 STRATEGY FOR MASTERPLAN

Considering the current issues (presented in **Chapter 5**), financial situation (**Chapter 6**), ongoing projects (**Chapter 7**), and the water demand discussed under the previous sections of this chapter, this sub-section proposes the strategy to formulate the KWSMP for the year 2050.

9.7.1 Water Supply Facilities

In response to the current issues summarized under **Section 5.4.6**, the strategies and possible solutions are presented in **Figure 9.7-1**.

Strategies (Suggestion):

1. **Reduce water shortage area**
   Additional transmission and distribution facilities shall be constructed in line with the new water source development and the WTPs. Specifically; these areas are seriously in need of transmission and distribution systems, including capable pipelines and reservoirs: Kabuga, Rusororo, Rebero/ Masaka, Kanombe, Busanza, Rwinyana, Free zone, Remera, Kabeza, Gikondo.

2. **Realize 24/7 water supply everywhere**
   There are emerging and persistent needs for pipe replacement and pressure management, which needs large investment. Strong policy enhancement for ensuring 24/7 (twenty-four-hours-seven-days -a-week) water supply everywhere is necessary to implement those investments. Average supply hours or the ratio of the household with 24/7 hours will be the key performance indicator for the policy.

3. **Realize resilient and stable water supply, minimizing the effect by accident**
   Minimizing the water supply interruption by accidents has to be addressed in order to minimize the effect of pipe breaks. Highlighting the resiliency will enhance the formulation of secondary pipe network and reservoir capacity.

4. **Implement appropriate zonings and pressure control**
   Zonings refer to the wider distribution system for monitoring and control of pressure and flow rate by centering the service reservoir. In contrast, District Metered Area (DMA) highlights water metering and is generally a small area such as 500-1,000 households per area. The strategy will be more effective if the zoning concept is introduced for enhancing efficiency.

5. **Accelerate NRW reduction activities and continue sustainably**
   Dissemination of the experience and continuous implementation are the keys to the NRW reduction under the current WASAC. To achieve this, “continuous sustainably” is the most important strategy for accelerating the activities.

6. **Strength the Operational and Maintenance (O&M) capacity**

The improvement of operational and maintenance procedures is an essential factor for the secured water supply. An increase in the number of O&M staff along with the establishment of a new organizational structure shall be studied for the existing/new facilities. These O&M issues shall be identified and a new operational/structural proposal shall be presented.

7. Improve comprehensive organizational system

The comprehensive issues of the WASAC organizational system shall be studied with the objective to improve the water supply business operation.

The issues shall pertain to 1) Structure, 2) Function, 3) Resource and 4) Culture, and shall be proposed as an organizational development plan.

8. Secure Sustainable Profits

Splitting from the department of the Energy Water and Sanitation Authority (EWSA), the WASAC was corporatized in August 2014. The WASAC has to encourage the responsible authorities including RURA so that they can set out an appropriate water tariff and undertake maximum efforts in cost-cutting for achieving the profit sustainably in terms of both 'Profit and Loss' and 'Cash Flow', even though the corporation is presently 100% owned by the GOR.

The above mentioned eight strategies are tagged by two keywords; "inclusiveness" and "efficiency". The inclusiveness is the strategy to supply water to everyone leaving no one behind in line with the basic discipline of the Sustainable Development Goals. The "efficiency" is in line with the most important keyword of the WASAC's vision.

Solutions:

The followings are the basic principles for solutions along with the strategies. The solutions shall be updated with the actual and specific solutions which will be presented in the final report of the KWSMP.

A. To expand water supply capacities (water sources and plants)

- Development of new water sources and construction of new WTPs
- Expansion of existing water treatment plant
- Extensive rehabilitation of pipelines, especially in and the surrounding area of the City Business District

B. To increase reservoirs for water stability and pressure control

- Construction of new water reservoirs where capacities are not sufficient.
- Establishment of the policy and guideline for allowable control pressure
- Construct a model Zone for 24/7 supply with adequate pressure monitoring and control.

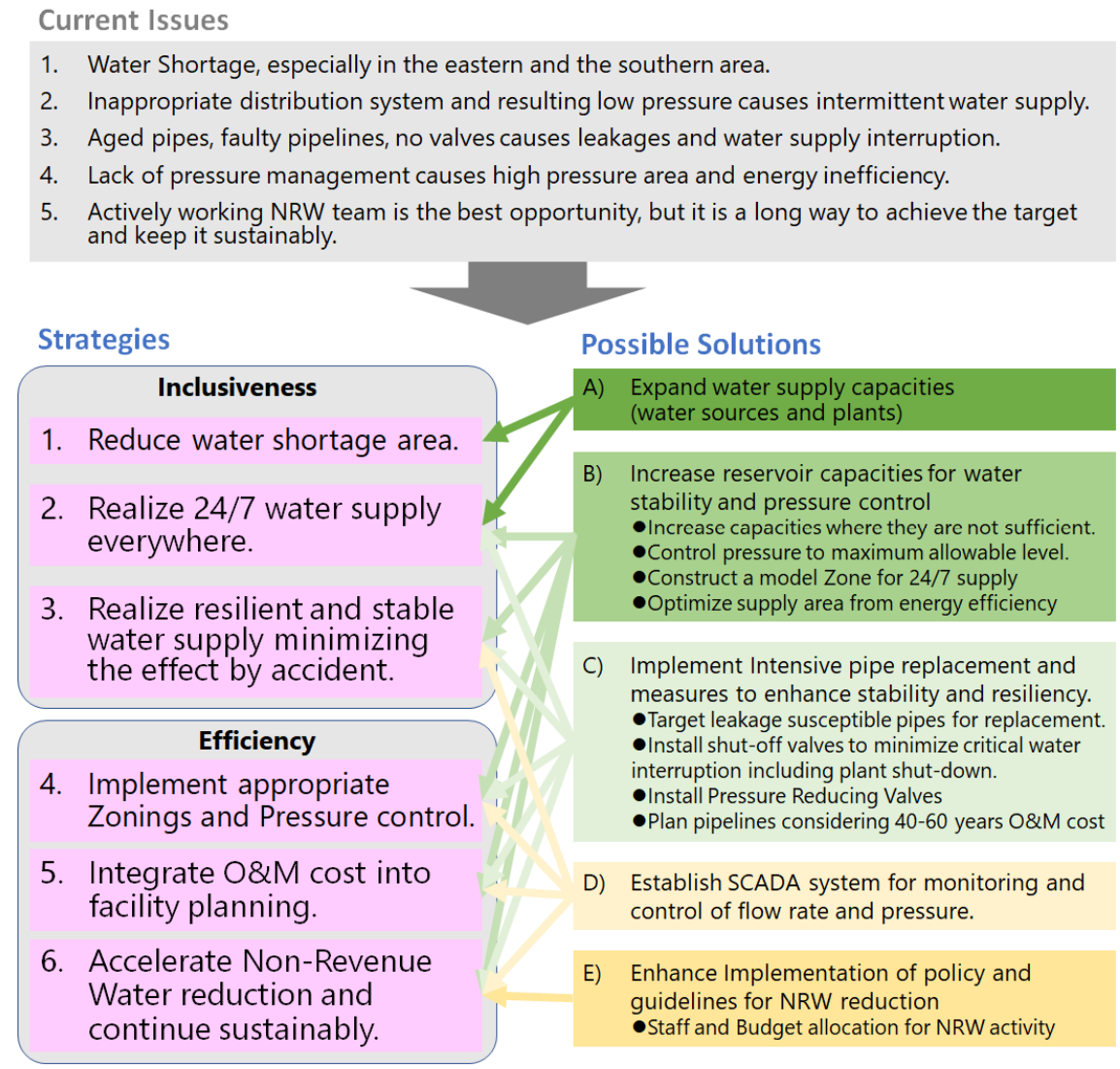
C. To implement Intensive pipe replacement and measures to enhance stability and resiliency.

- Screening and targeting the leakage of susceptible pipes for replacement from the existing GIS

knowledge and NRW activities
- Installation of shut-off valves to minimize critical water interruption including plant shut-down
- Construct block systems to control the pressures in distribution networks.

D. To integrate SCADA system for monitoring and control of flow rate and pressure.
- *Purpose oriented* monitoring and control; Integrate the fragmented SCADA system to control the pressure and minimize the NRW.
- Capacity building for utilizing SCADA system for NRW reduction activities

E. To enhance the implementation of policy and guidelines for NRW reduction
- Capacity building for the implementation of the policies and guidelines developed in the JICA NRW project
- Capacity building for the dissemination of the NRW activities to the branch level



Source: JST

Figure 9.7-1 Strategies for Water Supply Facility Development

9.7.2 New Water Sources

In addition to the existing water sources, new water sources are needed in the future as described under the policy of water supply development. Extra water can be taken from the Nyabarongo River since the volume of river flow is enough to supply water. However, as explained previously, the treatment cost is high due to poor water quality. Therefore, in addition to the river water, it can be considered to use groundwater from the river bed and spring water. Presently, the following extra water sources could be considered.

- **Surface water intake from the Nyabarongo river**
  Although the river water is of poor water quality and has high turbidity, it has a high potential to supply water. The minimum flow at the Nyabarongo River ranges from 37 to 44 m^3/sec during the dry season. It is also known as the risk of moving the river channel.

- **Groundwater abstraction from boreholes along the Nyabarongo river**
  The high potential aquifer consists of sands and gravels in alluvium sediments underlying the floodplain of the Nyabarongo River and groundwater can be extracted from this aquifer.

- **Springs from the volcanic formation of the Ruhengeri region in the north of Rwanda**
  Potential groundwater source to the CoK is from the volcanic region of Ruhengeri. Numerous springs exist in the area and groundwater discharge occurs from the volcanic lavas which comprise of basalts at the Mutobo, the Rubindi and the Mpenge. From previous studies, it was observed that the maximum flow rate recorded at spring sources at the Mutobo was 498 L/sec, at the Rubidi the flow was 278 L/sec and at the Mpenge it was 278 L/sec.

- **Muhazi and Mugesera Lakes**
  Raw water from the Muhazi and Mugesera Lakes are being used by the WASAC WTPs. RWB is presently carrying out the environmental study of the two lakes. In order to use more amount of water from the lakes, the sustainability of the lake water environment has to be understood and proven.

9.7.3 Measures against Climate Change

Risks of Climate Change are identified as water quality degradation and increase of water consumption duly impacted by global warming in the Guidelines to Mainstream Climate Change Adaptation and Mitigation in the Energy and Infrastructure Sector (See **Section 4.5.7**). The strategy for the measures against the risks are summarized below,

1. Groundwater prioritization
   Large scale water source to meet the 2050 demand will be limited to surface water sources. However, in the intermediate years it is recommended to prioritize the groundwater sources because the risks on water quality deterioration are low compared to the surface water sources. This strategy will be further assessed from the cost aspects in the later chapter.

2. Energy reduction
   As the water supply system of the CoK consumes considerable ratio of total City's electricity demand, the energy reduction will impact all CoK resiliency. Two major approaches should be taken to reduce the energy; NRW reduction and appropriation of water transmission routes.
3. Flexible water supply system and periodical review of the demand
   The possible water demand increase through global warming should be considered as a part of the risks to water demand fluctuation by city's development. The water demand projection should be reviewed periodically in order that it fits the actual per capita consumption considering the global warming. The flexibility to follow the development change is the key measures against the demand increase locally.

The strategies are closely related to the strategies for water supply facilities: the Climate Change aspect will be integrated to the facility planning and set as an evaluation criteria for selecting the Master Scenario.

9.8 EXPECTED FINANCING

From the long list of projects identified under the Master Plan, the F/S projects are to be selected and studied in detail including the source of funding necessary for their implementation. At this moment, the expected funds are enumerated as follows. Particularly the government budget and international development partners' funds are expected to play a key role in financing the F/S projects.

- ✓ The WASAC own funds if operational cash flows are continuously predicted to be sufficiently positive
- ✓ The Rwanda Government budget
- ✓ The International Development Partners' financing

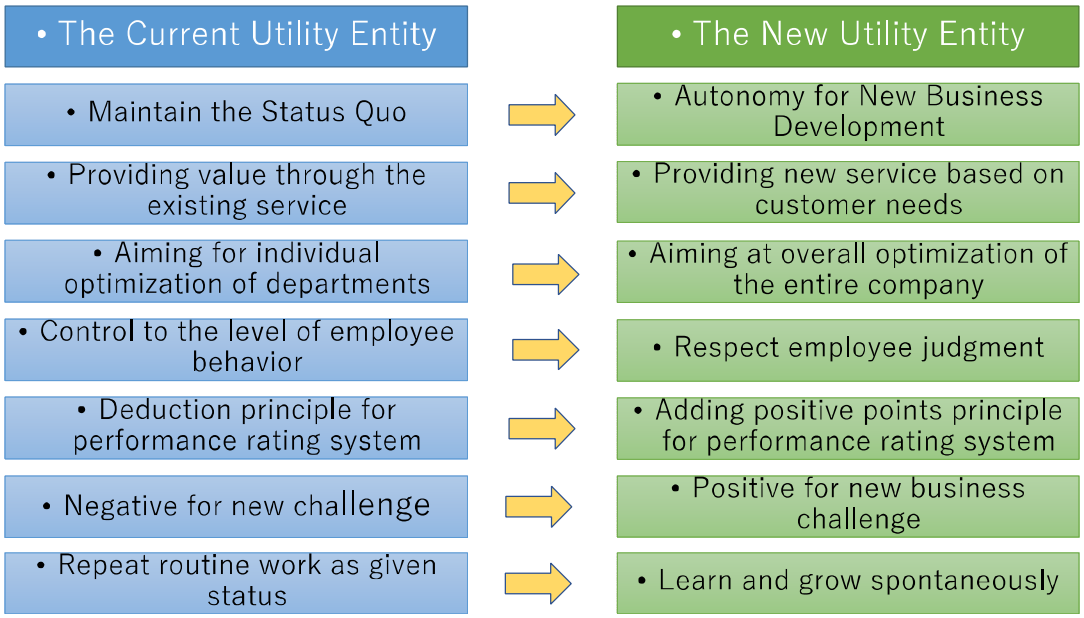
Simultaneously, other financial tools are to be considered.

- ✓ The possibility of private investors' participation such as BOT and PPP.

9.9 ORGANIZATIONAL DEVELOPMENT

9.9.1 Direction of Organizational Development as New Utility Business Entity

The direction of organizational change is presented in **Figure 9.9-1**. These changes are required within the WASAC as it aims to be not just a new government utility but an independent and autonomous business entity of utility.



Source: JST

Figure 9.9-1 Organizational Change for New Utility Business

9.9.2 Subjects Analyzed for Organizational Development

The organizational factors and dimensions to be analyzed are listed in the following **Table 9.9-1**. Target dimensions for this Project pertain to the entire WASAC's hierarchical Structure, Directorate and Section level. Targeted development factors are focused on Structure, Function, Human Resource and Culture.

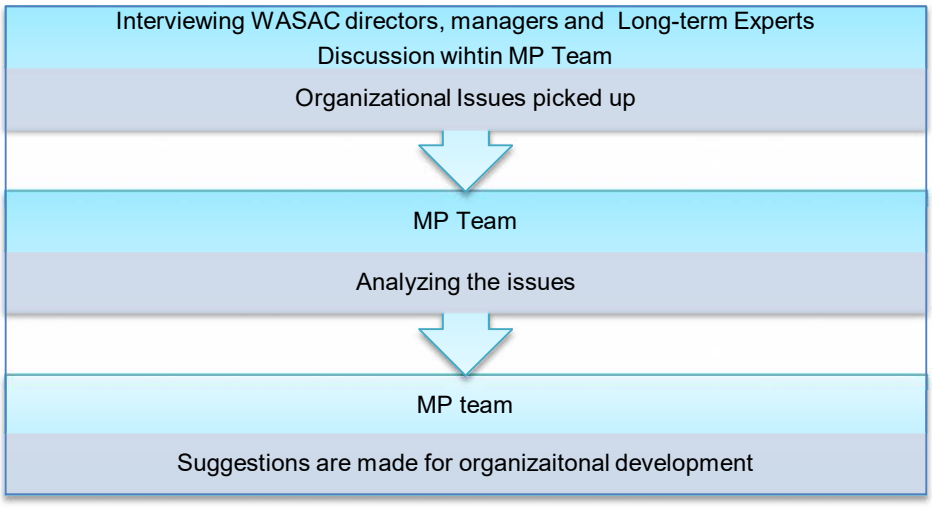
Table 9.9-1 Subjects to be Analyzed in Organizational Factors and Dimensions

		Organizational Development Factor			
Organizational Dimension		Structure	Function	Human Resource	Culture
	Corporate	*Corporate Organizational Structure (Business Division, Functional, Matrix) *Corporate Governance	*Decision Making and Management of Corporation *Management of Internal Management Accounting System	*Making Personnel Assessment Criteria *Making Employment Criteria *Deployment of Senior Manager	*Corporate Philosophy *Business Mission
	Directorate/ Department	*Department Design (Functional oriented, Business market oriented)	*Decision Making and Management of Department *Performance Management *Making Business Supply Chain	*Deployment of Officer/Staff *Training Professional	*Thinking and Behavior Habit
	Section	*Job Assignment for each Officer/Staff	*Sectional Business Decision Making *Making Process for Job Assignment *Handling Assignment	*Systematic Expertise/Skill Training *OJT *Mental Care	*Communication at Work Place

Source: JST

9.9.3 Organizational Development Issues of WASAC

Issues of organizational development are picked up based on analyzing subjects in **Table 9.8-1** through interviewing directors, managers of all departments and long-term experts by MP team. The procedure for analyzing issues and making suggestions is stated in **Figure 9.8-2.**



Source:JST

Figure 9.9-2 Procedure for Analyzing Organizational Issues and Making Suggestions

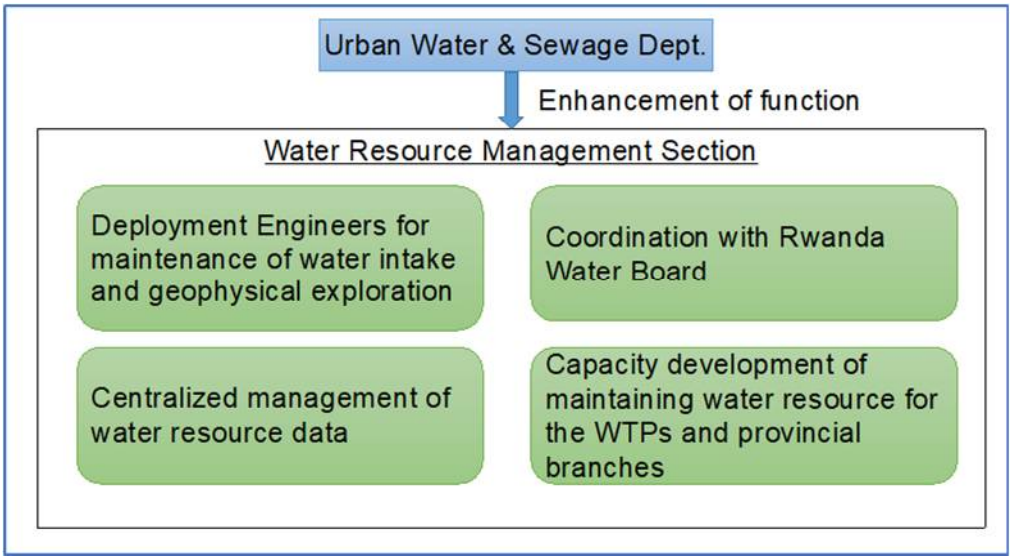
Detailed target activities for the organizational development are listed in **Appendix 19**.

9.9.3.1 Issues and Suggestions for the Head Office

(1) Enhancing the Sector Function of Water Resource Management

Operational management for sustainable water sources and water intake facilities to protect the production capacity and maintenance on water resources and well are not being implemented due to the lack of WASAC's engineers and officers having expertise in groundwater.

- Enhancing a function Water Resource Management Section by the following measures;
  - Deploy engineer for regular groundwater level observation and maintenance of water intake.
  - Deploy engineer of hydrogeological study for geophysical exploration.
  - Centralized management of design, construction, and maintenance information related to water sources (Including drawings, well core excavation results, pumping test records, etc.).
  - Coordinate with Rwanda Water Resource Board for strategic proposal of water resource development and water resource allocation.
  - Assist capacity development planning of water intake and well management for the WTPs and provincial branches.



Source: JST

Figure 9.9-3 Functional Enhancement of Water Resource Management Section

(2) Adding new Data Management Section under CEO Office

Setting up a section that manages documents, drawings and archive registration systems is necessary. Data pertaining to water purification plants, distribution reservoirs, pump stations, and completion drawings for water transmission and distribution pipelines are not properly maintained and are lost sometimes.

- Establish a Data Management Section that specializes in data management under the CEO Office.

(3) Enhancing Service Connection Work

The pipe material standards are not specified. As a result, inexpensive and low-quality pipes are installed.

It thus becomes much difficult to deal with the increase of water leakage without significantly improving material and service connection installations. Moreover, activities carried out during service pipe installations, such as location and earth cover, are not always appropriate.
The following activities are suggested;

- Creating a system for designated/ registered contractors for water service connection in order to respond to the dramatic increase in the number of service connections,
- Consider outsourcing of service connections by establishing a monitoring system for outsourced contractors. Using records from service connections are necessary as the status of current service connections is not available.
- Specify the standard of service connection materials to eliminate low quality materials.

(4) Enhancing Project Management and Supervision

Supervision on the design and construction of large-scale projects are facing challenges due to an enormous burden on design confirmation. The contractors usually lack incentives and capacities to prioritize the quality and efficiency of the water supply system. The number of personnel and technical capabilities involved on specific projects are insufficient to lead them on those aspects.

The following activities are suggested;

- WASAC needs to hire an experienced consultant for conducting F/S and D/D.
- Improve the ability to supervise/ monitor the consultant for conducting F/S, D/D, and supervising the contractor based on the design.
- Clarify the project approval procedure and create a manual.

(5) Enhancing Environmental and social considerations & public relations

It is necessary for the overall WASAC staff to enhance their understanding on the necessity of environmental and social considerations such as surrounding environment of WASAC. It is essential to conduct businesses with environmental and social considerations, even when competing with private companies for profits.

The following activities are suggested;

- Setting policy and manual for environmental and social considerations and manage and monitor the execution as a public utility organization.
- Increase the number of WASAC PR staff together with budget allocation for training and promotion of PR activities with corporate commitment and to the SDGs.

(6) Enhancing GIS Data Management

Data in the GIS are not regularly updated with customer meters and pipeline. The reason for stagnation is due to the lack of purpose-oriented operation of the GIS system.
The following activities are suggested;

- Establish **Pipeline Referencing System** in order that the Contractor for pipeline, city developers, road authority and local government agencies as well as NRW reduction team and all the WASAC's departments and branches can refer and utilize for the planning and coordination during design and construction.
- Increase the number of staff in the GIS department and regularly conduct GIS skill trainings. The GIS skill trainings also aim at accelerating communication between GIS section in HQs (for Rural Scheme and SPIU) and that in UWSSD.
- Set up the data updating Standard Operation Procedure involving branches and commercial department

(7) Financial & Accounting management

It is important for each department to recognize the entire costs related to water supply: separately at the water resource level, at the production level, at the distribution level, at the commercial level and at the administration level.

The following activities are suggested;

- Introduce a cost management system for monitoring cost reduction and financial performance.
- Recognize the importance of reconciliation between the register book and the ledger to avoid mismatching of assets.

(8) Reorganize Job Function

Job function is not clear as the responsible department that manages the customer meters among the commercial affairs section and the water distribution section are vague under the current branch structure. As a result, an accuracy of customer meters has not been confirmed on-site, and charges to customers are not properly billed sometimes.

- It is necessary to clarify the business structure of the branch office; which section is responsible for water charge billing, and management of the customer meter replacement / maintenance.

Responsibility for meter reading, maintenance and set-up are not clear among the job roles of the CACRO. As a result, reading index and maintenance of meter are not implemented properly.

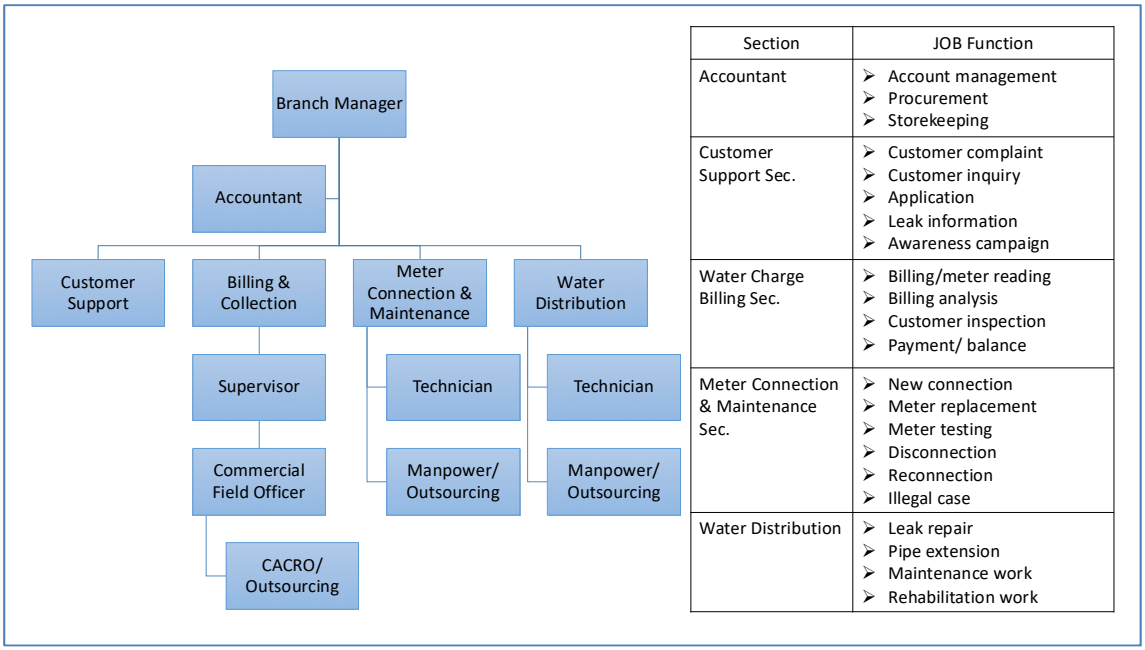
The following activities are suggested;

- Clarify working assignment for the CACRO and Manpower for proper job implementation pertaining to meter reading and maintenance.
- New branch structure that separates meter reading and meter maintenance function.

(9) Reorganize Branch Structure

The new organizational structure of the branch is depicted below which separates customer support section, meter connection & maintenance section, water charge billing section, and water distribution section. Furthermore, replacing the contract of the existing casual staff to outsourcing contracts will be an option

for ensuring effective branch business administration.



Section	JOB Function
Accountant	➢ Account management ➢ Procurement ➢ Storekeeping
Customer Support Sec.	➢ Customer complaint ➢ Customer inquiry ➢ Application ➢ Leak information ➢ Awareness campaign
Water Charge Billing Sec.	➢ Billing/meter reading ➢ Billing analysis ➢ Customer inspection ➢ Payment/ balance
Meter Connection & Maintenance Sec.	➢ New connection ➢ Meter replacement ➢ Meter testing ➢ Disconnection ➢ Reconnection ➢ Illegal case
Water Distribution	➢ Leak repair ➢ Pipe extension ➢ Maintenance work ➢ Rehabilitation work

Source: JST

Figure 9.9-4 New Branch Structure Suggested

(10) Set New Branch at East District of City

CoK plans more household and business development in the east district of Kigali. It better to set up new branch to cover these area instead of handling by an increase of the existing branch staff.

9.9.3.2 Issues and Suggestions for Water Treatment Plants (WTPs)

WASAC has a central laboratory in the CoK and a laboratory in each WTP. The inspectors in the laboratory inspect and monitor the water quality at each water treatment plant. The data examined by the simple laboratory are compiled in the central laboratory, and if any abnormalities are observed in the inspection results, the central laboratory conducts re-inspection and guidance.

There are 204 full-time staff and around 300 casual staff that are deployed. Chemist, Engineers, Biologists, Technician and Clerk are working as full-time base at WTP. They are duly supported by a team of short-term operators.

However, current quality assurance and quality control (QA / QC) procedures related to water quality testing are not well implemented at the individual level of WTP. Small water sources are at risk of pollution, but water quality tests are not properly conducted. The results of the water quality test of the distribution pipe network including the water quality at the terminal faucet are not properly reflected in the operation and maintenance at present.

Therefore, the following activity is suggested;

- Establishing a system with WASAC's Central Laboratory. This system controls each WTP's lab in terms of the QA / QC of Central Lab.
- Establish a sampling and testing implementation system for the purpose of water quality control for small-scale water sources.
- Establish a system for collecting, analyzing, and feeding back the water quality testing results of raw water, treated water, and distribution network including user's tap.

Issues and Suggestions: Water quality assurance and control (QA/QC)

The current quality assurance and quality control (QA / QC) procedures pertaining to water quality tests are not sufficiently implemented at the WTP level.

The following activity is suggested;

- Establishing a system with WASAC's Central Laboratory. This system controls each WTP's lab in terms of the QA / QC of Central Lab.

The water quality tests are not conducted properly at small-scale water sources, even though there are some places having potential risk for pollution.

The following activity is suggested;

- Establish a sampling and testing implementation system for the purpose of water quality control for small-scale water sources.

The current water quality testing results under the distribution system including user's taps are not always reflected during its operation and maintenance.

The following activity is suggested;

- Establish a system for collecting, analyzing, and feeding back the water quality testing results of raw water, treated water, and distribution network including user's tap.

9.9.3.3 Training for Human Resource Development

WASAC has organized human resource (HR) plan as a staff capacity development is a key factor for business growth and development.

Even though organized trainings were implemented in the past, a further capacity development of manager, engineer and staff are required for the business development. Such trainings that are required for capacity development are listed in the following **Table 9.9-2**.

The following activity is suggested;

- Conducting the suggested trainings with developing partners for enhancing job expertise.

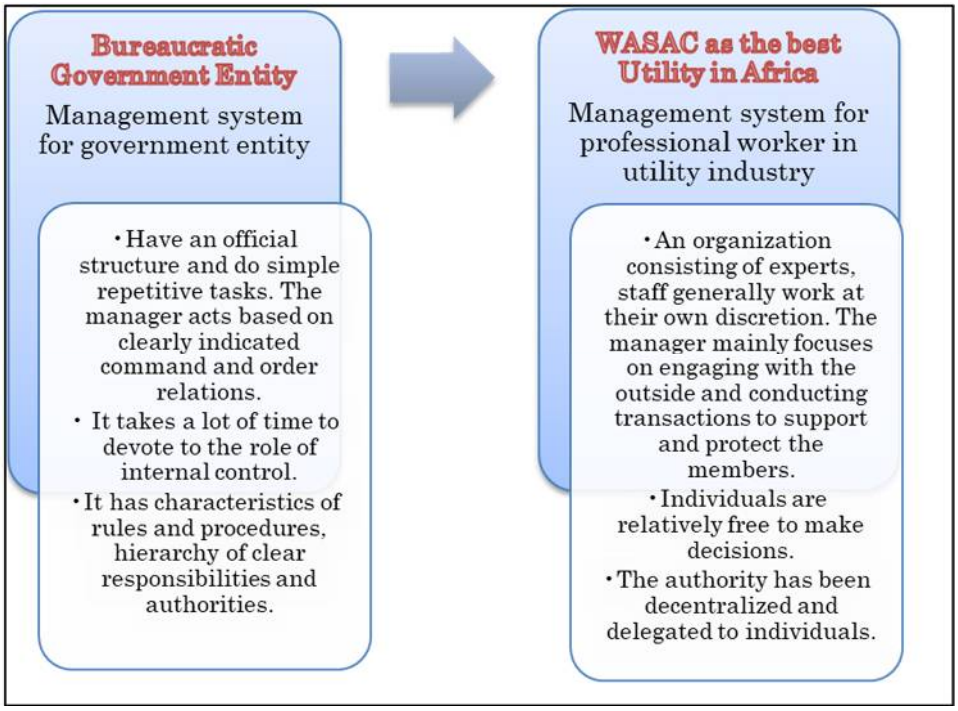
Table 9.9-2 Suggested Trainings for Capacity Development

Training Sector and issue	Training Module for development
Maintenance of water resources and wells	Acquire technology to improve the ability to maintain and manage water sources for the Surface water / groundwater monitoring and maintenance of well facilities (calculation of well efficiency, grasp of well interference, well rehabilitation method).
Service connection work	Training for; ・ Basic knowledge to be able to select / review standards for material of service connection. ・ Basic knowledge for designing and reviewing Plumber's qualification system and designing and reviewing the system of designated/registered contractors ・ Upgrade training of many Plumber qualification holders including contractors
Water quality control	Conduct training to draw WASAC's executives' attention to the issues on water quality control (e.g.,/ for WTP's managers / managers and their superior executives) with data sharing and effective data utilization.
Management and utilization of pipeline GIS data	Register GIS skill training regularly to understand how to use GIS and its value.
Environmental and social considerations	Conduct environmental and social consideration training to enhance understanding the necessity of environmental and social considerations
Empowerment	Organize a seminar for empowerment regularly and monitor an implementation of employee empowerment.

Source: JST

9.9.3.4 Development for Organizational Culture as a New Utility Business Entity

As a government-owned utility company controlled by the MININFRA, WASAC has a bureaucratic organizational system to run its entity. Although it is quite normal to have such a hierarchal order system to run a utility business, it still has more space to transfer decision-making to the staff at the site by empowering operational authority for the operation. To that end, the WASAC has a choice to adopt a management system that allows on-site decision-making by empowering more operational assignments. This new working procedure changes the mechanical and bureaucratic decision-making system to a management system for professional workers (**Figure 9.9-5**).



Source: JST

Figure 9.9-5 New Management System for WASAC as the Utility Business in New Business Environment

CHAPTER 10 WATER RESOURCES DEVELOPMENT PLAN

10.1 PRESENT AND FUTURE USE OF WATER RESOURCES

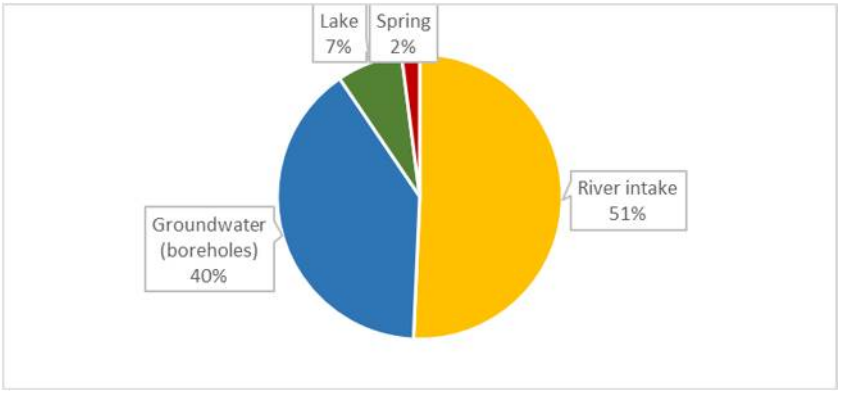
10.1.1 Present Water Source

Present available water supply sources are described in **Section 5.3**. The available amount of water is shown in **Table 10.1-1**. **Figure 10.1-1** shows the allocation of each water source. The river water is the main water source in the WASAC and it comprises for more than half (51%) of the total water use. Groundwater pumping by boreholes at flood plain of the Nyabarongo (Akagera) River contributes 40% of the total water use.

Table 10.1-1 Present Available Waters for Water Supply

Source	m^3/day	Area	Amount (m^3/day)	Remarks
River intake	102,000	Nzove	40,000	for Nzove 2
		Nzove	40,000	for new Nzove 1
		Yanze	22,000	for Kimisagara WTP
Groundwater (boreholes)	80,000	Nzove	40,000	for Nzove 1
		Kanzenze	40,000	for Kanzenze WTP by PPP
Lake	15,000	Mugesera	15,000	for Karenge WTP
Spring	4,133	22 spring sources	4,133	
		Total	**201,133**	

Source: JST



Source: JST

Figure 10.1-1 Water Allocation for Each Source

In addition to the amount of 201,133m^3/day, WASAC has already obtained the additional water permit to use for water supply by RWB (Rwanda Water Resources Board), former RWFA (Rwanda Water and Forest Authority). Total permitted waters for the study area's water supply (2020) is 237,350m^3/day.

Table 10.1-2 WASAC Permitted Waters for the Study Area's Water Supply by the RWB (2020)

Category at Hydrological Cycle	Source	Total Amount (m^3/day)	Permitted Amount of each Source (m^3/day)	Remarks
Surface water	Nyabarongo River	152,000	40,000	for Nzove 2 WTP
			40,000	for new Nzove 1 WTP
			(25,000)	for new Nzove 2 WTP (not yet used but WTP has license)
	Yanze River		24,000	for Kimisagara WTP
	Mugesera Lake		48,000	for Karenge WTP
	Muhazi Lake		(6,600)	for Eastern Province, not for Kigali
Groundwater (sub-surface water) -Development at floodplain)	Boreholes at floodplain of Nyabarongo River	80,000	40,000	for Nzove 1 WTP
	Boreholes at floodplain of Akagera River		40,000	for Kanzenze WTP
Groundwater (except floodplain)	Springs	5,350	4,450	
	Well		900	
Total		237,350		

Source: JST

Two types of groundwater are indicated, (1) Groundwater taken from floodplains of the Nyabarongo/ Akagera river by boreholes means that pumped water is a mixture of alluvium aquifer and river origin, Water taken from these boreholes is licensed as groundwater by the RWB. (2) Groundwater except floodplain means water that is extracted only from natural groundwater recharge.

* These amounts are not included the present available water source to use.

10.1.2 Future Water Resources to Water Demand

As explained in **Chapter 9** (Demand Projection), water supply capacity of about 335,000 m^3/day will be required to meet the water demand by 2035. From 2036 to 2050, extra 735,000 m^3/day will be needed. Present status and future usage of each water source is explained in the following section.

10.1.3 Water Balance of the Study Area

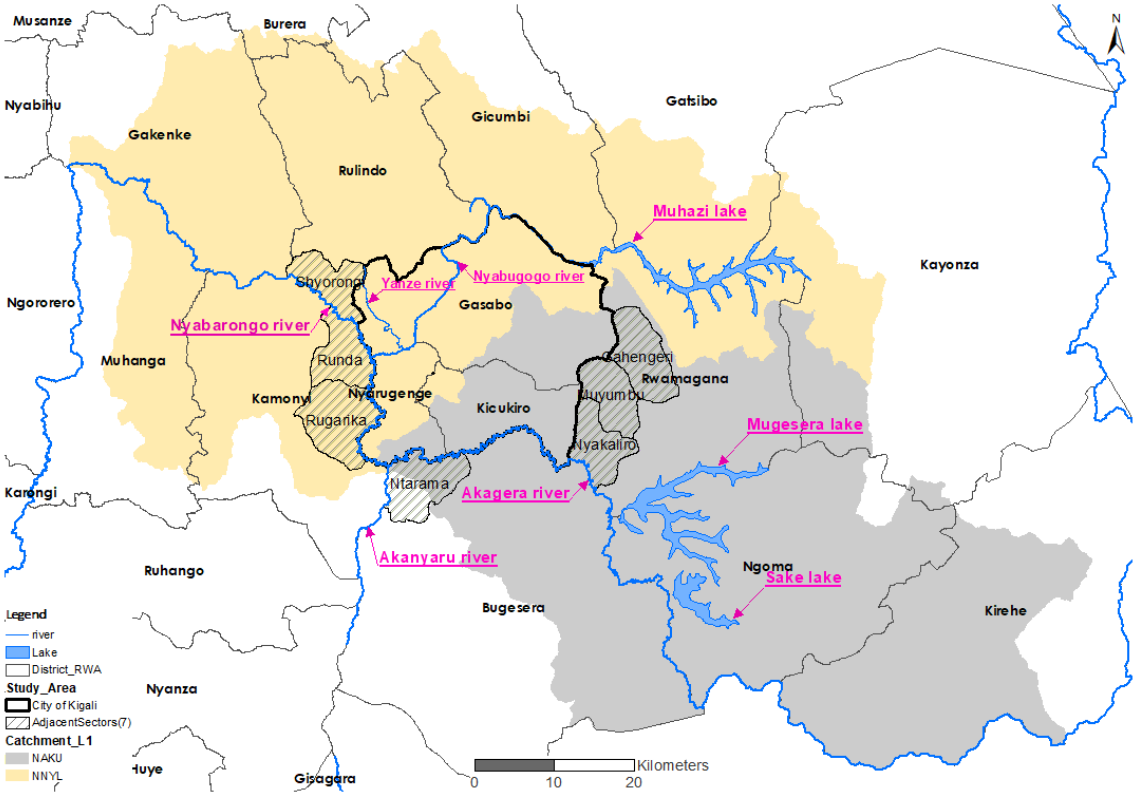
10.1.3.1 Introduction

The available water resources are being used by various sectors such as water supply, irrigation, coffee washing, mining, hydropower station and so on. Quantified information on current sector wise water resources utilization is limited due to unregulated and lack of the inventory of water use. In addition to the present water use, water demand projection by the above-mentioned sectors is also not studied well. In Kigali, studies were not conducted regarding sector wise water use and water demand projection. Water balance and future water demand of Level 1 catchments were studied and described under the National Water Resources Master Plan (NWRMP) (2015). A portion of those under Level 2 catchments are being studied by the Ministry of Environment (2018) and the RWB (2020 on going).

Thus, sector wise present and future water balance in the Study Area will be explained by using the available data. It should be noted that the results pertaining to water balance under a scale of L1 catchments as shown in the NWRMP (2015) and that under a scale of L2 catchments carried out recently do not match exactly. For example, water inventory carried out by the NWRMP can be regarded as outdated. On the other hand, the studies under L2 catchment management are being conducted recently (2019-on going). In addition, change of land use obviously affect water resources' generation and gives impact on the amount of renewable water resource at the catchment. This is also one of the reasons for discrepancy in the results between L1 and L2 catchment studies. Moreover, the water demand projection for the Study does not reflect the result of catchment studies.

10.1.3.2 Water Balance and Water Demand under L1 Catchment

Water Balance (water availability minus water use) of Level 1 catchments is included in the NWRMP. The Study Area comprises a part of the Nybarongo Lower Catchment (NNYL) and the Akagera Upper Catchment (NAKU).



Source: JST

Figure 10.1-2 Two Level 1 Catchments overlapping with the Study Area

At the NNYL, water use is just over 2% of the annual renewable sources. At the NAKU, it is about 5%, which is higher than that of the other catchments in Rwanda. At the NNYL, water supply use is more than irrigation use due to the water use in the Kigali city.

Table 10.1-3 Water Balance of Two Level 1 Catchments (2012)

Name of the catchment	Code	Renewable water source (m^3/year)	Water supply use (m^3/year)	Irrigation water use (m^3/year)	Total water use (m^3/year)	% of total water use over resource
Nyabarongo Lower	NNYL	899,000,000	11,983,000	7,983,000	19,966,000	2.22%
Akagera Upper	NAKU	504,000,000	9,776,000	16,034,000	25,810,000	5.12%

Source: NWRMP, Renewable water source means the average rainfall minus the volume of evaporation and plant transpiration in a catchment area.

Unadjusted and adjusted water demands by 2040 were also estimated under the NWRMP. In case of unadjusted demand, projected demand is based on population and indicators (irrigation area, energy production, number of cattle etc.) which are applied uniformly for all the catchments and no consideration is given to actual resource availability for this demand. On the other hand, water demand in each sector is reviewed and adjusted whenever necessary in case of adjusted water demand.

As seen in the following tables, amount of irrigation water has changed significantly after adjusting and is reduced to avoid the over exploitation of water resources. Considering adjusted water demand, total water consumption by all sectors in 2040 becomes 51% at the NNYL and 65% at the NAKU. This means that water resources will be consumed widely in future due to the high water demand.

Table 10.1-4 Water Balance Projection in 2040 at NNYL

	Nyabarongo Lower (NNYL)			
	Unadjusted water demand (m^3/year)	% of water use over renewable water source	Adjusted water demand (m^3/year)	% of water use over renewable water source
Water supply (Urban and Rural)	170,810,000	19	170,810,000	19
Irrigation	368,590,000	41	215,760,000	24
Industry	53,940,000	6	35,960,000	4
Mining	17,980,000	2	17,980,000	2
Livestock			8,990,000	1
Fish ponds			8,990,000	1
		68		**51**

Source: The NWRMP

Table 10.1-5 Water Balance Projection in 2040 at NAKU

	Akagera Upper (NAKU)			
	Unadjusted water demand (m^3/year)	% of water use over renewable water source	Adjusted water demand (m^3/year)	% of water use over renewable water source
Water supply (Urban and Rural)	90,720,000	18	90,720,000	18
Irrigation	463,680,000	92	196,560,000	39
Industry	25,200,000	5	15,120,000	3
Mining	10,080,000	2	10,080,000	2
Livestock	5,040,000	1	5,040,000	1
Fish ponds	10,080,000	2	10,080,000	2
		120		**65**

Source: The NWRMP

It is concluded under the NWRMP that the catchment's own renewable resources are sufficient to meet the water demand over the next thirty years or so at the scale of the Level 1. In addition, it is recommended under the NWRMP that comprehensive monitoring of actual water use and renewable resources are needed. Water source inventory and water demand projection were conducted in 2012. Therefore, this demand projection may not be valid under the present situation. It is obvious that water amount used by the Kigali water supply is underestimated.

10.1.3.3 Water Balance and Water Demand under L2 Catchment

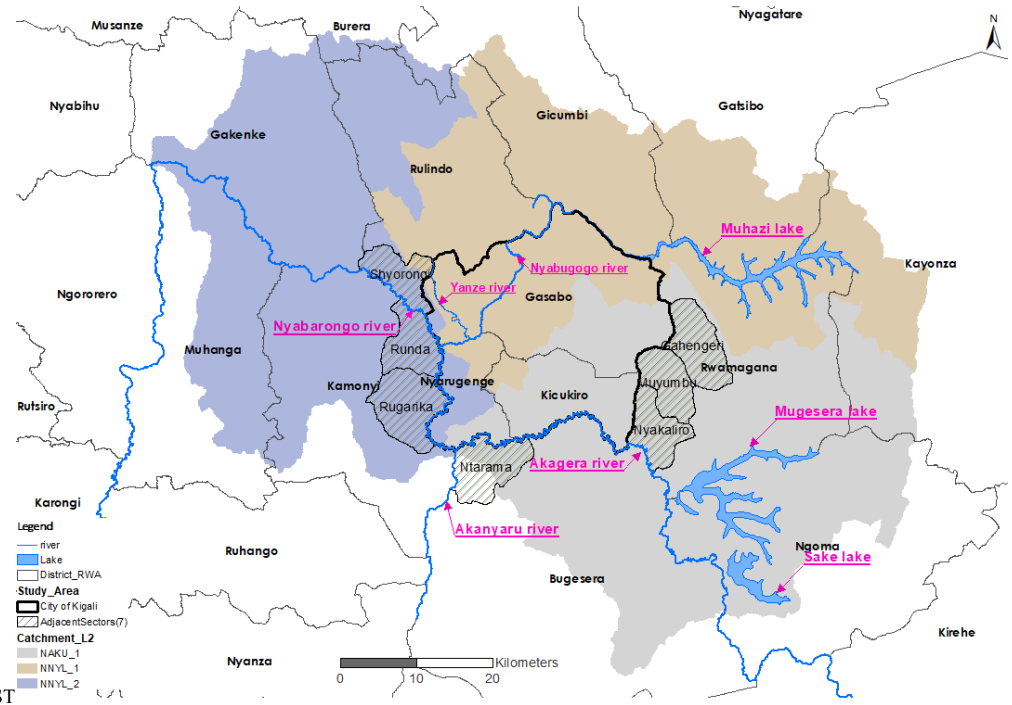
Level I catchments can be divided into Level 2 Catchments (Sub-Catchments). Two level 1 catchments in the Study Area have the following four (4) sub-catchments (Level 2 catchments).

Table 10.1-6 Name of Level 2 Catchments under NNYL and NAKU

Name of the level 1catchment	Code	Name of the level 2 catchment	Code	Area (km^2)
Nyabarongo Lower	NNYL	Nyabugogo	NNYL_1	1,540
		Mambu/ Base	NNYL_2	1764
Akagera Upper	NAKU	Mugesera/Sake	NAKU_1	1,888
		Rweru	NAKU_2	

Source: JST, Project area is 1,129 km^2

Within these four (4) catchments, three (3) catchments namely, NNYL_1, NNYL_2, and NAKU_1 cover the Study Area. The areas are shown in **Figure 10.1-3**.



Source: JST

Figure 10.1-3 Three Level 2 Sub-Catchments in the Study Area

At this moment, water balance study is carried out only at the Nyabugogo catchment (NNYL_1) and the Mugesera/ Sake catchment (NAKU_1).

(1) The Nyabugogo catchment (NNYL_1)

The Nybugogo catchment management plan (2018) was formulated by the Ministry of Environment. **Table 10.1-7** shows the sector wise water use. It shows that 8% of renewable water source is used at the catchment. This means that the Nyabugogo catchment is currently able to provide enough water to satisfy the demand. Its usage is more than the NNYL Level 1 catchment estimated under the NWRMP. Sector wise, irrigation has the highest water consumption and water supply comes second. Renewable water source is estimated to be 463 MCM/year. The catchment management plan mentioned that manageable water in surface water body and groundwater is very limited. Water balance projection in 2050 shows that 45% of renewable water source at the catchment would be used.

Table 10.1-7 Water Balance of the Nyabugogo Catchment

	2018		2035		2050	
	Water demand (m^3/year)	**% of water use over renewable water source**	**Water demand (m^3/year)**	**% of water use over renewable water source**	**Water demand (m^3/year)**	**% of water use over renewable water source**
Irrigation	18,493,500	4.0%	55,658,160	12.0%	117,795,032	25.4%
Water supply	9,276,360	2.0%	27,829,080	6.0%	51,395,886	11.1%
Industry	4,638,180	1.0%	13,914,540	3.0%	29,113,502	6.3%
Livestock	4,638,180	1.0%	6,493,452	1.4%	12,067,208	2.6%
		8.0%		**22.4%**		**45.4%**

Source: Nyabugogo catchment management plan, water balance projection in 2035 is not available in this study and estimated by JST using data of 2018 and 2050.

(2) The Mugesera / Sake catchment (NAKU_1)

The catchment study, carried out by the RWFA, is presently on-going. Renewable water source for this catchment is estimated to be 557 MCM/year. Water balance study shows that 8.8% of renewable water source in the catchment was used in 2019 (see **Table 10.1-8**).

Table 10.1-8 Water Balance of the Mugesera / Sake Catchment

	2019		2035		2050	
	Water demand (m^3/year)	% of water use over renewable water source	Water demand (m^3/year)	% of water use over renewable water source	Water demand (m^3/year)	% of water use over renewable water source
Irrigation	22,203,300	4.0%	83,529,000	15.0%	144,192,200	25.9%
Water supply	17,716,200	3.2%	38,980,200	7.0%	56,740,900	10.2%
Industry	36,000	0.01%	278,430	0.05%	684,000	0.1%
Fish ponds	351,600	0.1%	556,860	0.1%	448,000	0.1%
Livestock	8,514,200	1.5%	11,137,200	2.0%	16,273,900	2.9%
Mining	178,600	0.03%	167,058	0.03%	237,700	0.04%
Coffee washing	10,100	0.002%	16,706	0.003%	22,400	0.004%
		8.8%		**24.2%**		**39.3%**

Source: RWFA, water balance projection in 2035 is not available in the study and estimated by JST using data of 2019 and 2050.

Sector wise proportion of water consumption against renewable water source at this catchment is very much similar to that of the Nyabugogo catchment. This may indicate that these two catchments have similar natural and social environment for water consumption. Sector wise water use by 2050 is around 40% of renewable water source at this catchment. It is lower than that of the Nyabugogo catchment. Moreover, this value (40%) is relatively small when compared with that of the Level 1 catchment (NAKU) under the NWRMP. It also indicated that water consumption by irrigation will be a very large portion of renewable water source by 2050 and it is more than 6 times than the present use under the scale of the Level 2 catchments.

10.1.3.4 Comparison with Demand Projection by Kigali Water Supply Master Plan

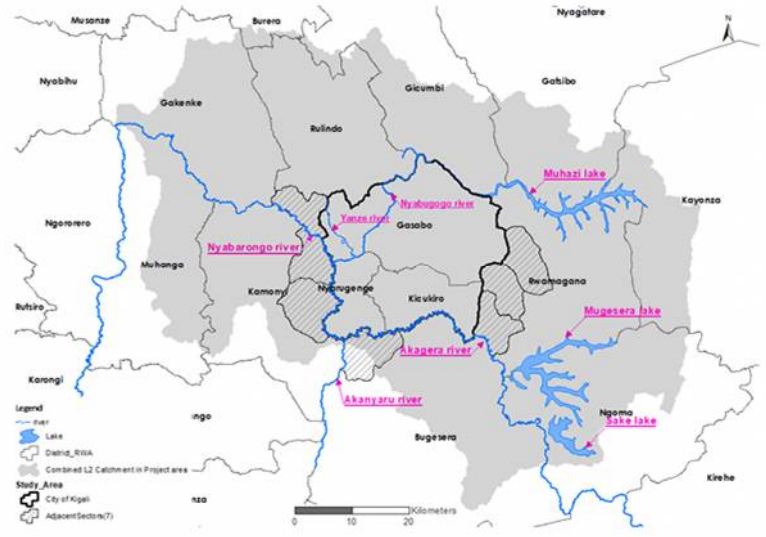
Water balance studies under the Level 2 catchment indicate that 22-24% of renewable water source at the catchment will be used by all sectors by 2035 and 40% to 45% by 2050. Water consumption by water supply (urban and rural) will be 6% to 7% of renewable water source by 2035 and 10% to 11% by 2050. However, these water demand prediction for water supply does not include the result of the Study. Water demand projection for water supply in Kigali indicated that the amount of 122,275,000 m^3/year (335,000 m^3/day) will be needed by 2035 and 390,550,000 m^3/year (1,070,000 m^3/day) by 2050 in order to meet the water demand. The water demand is compared with those in the three combined catchments.

Table 10.1-9 Comparison of Water Supply Demand by Catchment Study and Kigali Water Supply Master Plan Study

	2035	2050
Water demand by water supply (urban and rural) at three catchments (m^3/year) *	101,910,200	145,586,000
Water demand by water supply at Kigali estimated by Kigali Water Supply MP (m^3/year)	122,275,000	390,550,000
Proportion of amount of water needed in Kigali against total amount of water supply at three catchments	120%	268%

Source: JST,
* It is assumed 7% of renewable water source at three catchments in 2035 and 10% in 2050.Renewable water source of three catchment is estimated as 1,456 MCM/year in total which 463 MCM/year at Nyabugogo, 557 MCM/year at Mugesera / Sake., 436 MCM/year at Mambu / Base, Renewable water source of Mambu/ Base is not available then used that of Nybarongo Lower (L1) minus Nyabugogo (L2).

Table 10.1-9 shows that the amount of water supply estimated in the three catchments is much smaller than that in Kigali. This means that water demand projection for water supply is obviously underestimated under the Level 2 catchment studies. In order to adjust this, water balance at the three catchments by 2035 and 2050 are revised and shown in **Table 10.1-10**. It is assumed that 30% of total amount of water supply in the three catchments is derived from Kigali. It can be seen that total water use by 2035 at the three catchments is around 30% of renewable water source and water use by 2050 becomes 68%. Due to the high usage of water in Kigali, water demand by water supply (urban and rural) in the three catchment becomes higher than irrigation by 2035 and 2050. Revised amount of total water demand by 2035 and 2050 is still within the limitation of renewable water source. In other words, renewable source is sufficient to cater for the projected demand including Kigali water supply. However, in order to avoid the over exploitation of water resources in the catchments, efficiency of water use must be improved. Comprehensive monitoring of actual water use and renewable resources will be also required.



Source: JST

Figure 10.1-4 Area of combined three L2 Catchments

Table 10.1-10 Estimated Water Balance at combined three L2 catchments

	2035		2050	
	Water demand (m^3/year)	**% of water use over renewable water source**	**Water demand (m^3/year)**	**% of water use over renewable water source**
Irrigation	174,703,200	12.0%	378,523,600	26.0%
Water supply except Kigali	71,337,140	4.9%	101,910,200	7.0%
Kigali water supply	122,275,000	8.4%	390,550,000	26.8%
Industry	43,675,800	3.0%	87,351,600	6.0%
Livestock	14,558,600	1.0%	29,117,200	2.0%
Total	426,549,740	29.3%	987,452,600	67.8%

Source: JST, Renewable water source in three catchments is estimated 1,456 MCM/year

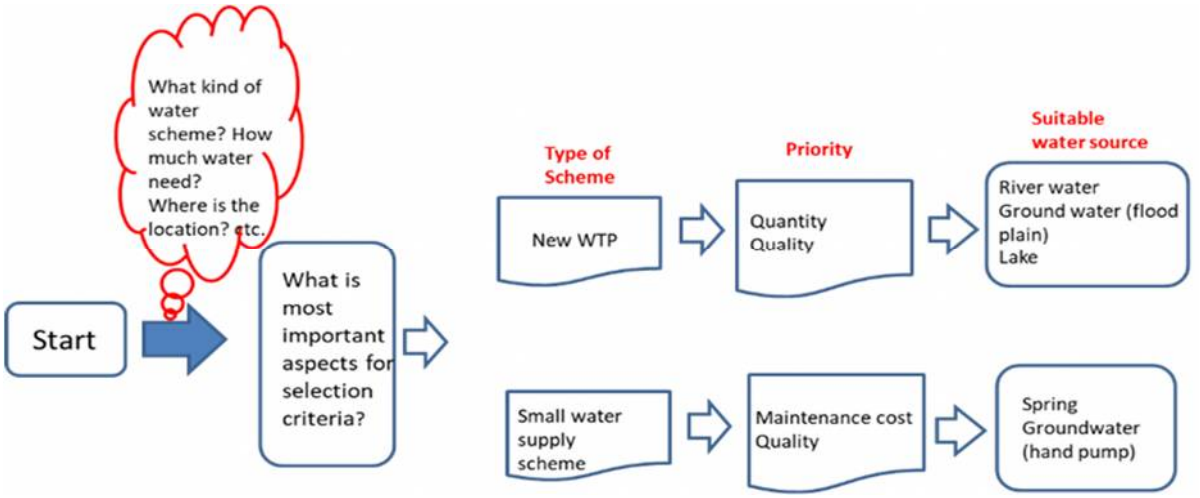
This is a very rough estimation since no study regarding the WRM in Kigali is conducted. However, this information is very useful and gives the degree of impact of Kigali water supply to the renewable water resource at the catchment level.

10.1.4 Water Source Selection for Future Water Supply

There are several water sources such as river, lake, groundwater and springs in the Study area. Following criteria will be considered in order to select the suitable water source which is available for water supply.

- ✓ Quantity
- ✓ Quality
- ✓ Sustainability (flood risk etc.)
- ✓ Development cost (drilling, distance from source to WTP)
- ✓ Maintenance cost (borehole rehabilitation etc.)

For example, river has high potential in terms of water quantity. On the other hand, spring gets the lowest. Each water source has advantage and disadvantage against key criteria for selection. Therefore, characteristic of water source has to be taken into account before the selection for the particular water scheme.



Source: JST

Figure 10.1-5 Water Sources Selection Process for Water Supply

10.2 WATER RECOURSES DEVELOPMENT AND MANAGEMENT FOR WATER SUPPLY

10.2.1 Literature Review Related to Water Allocation for Water Supply

Contents of a literature survey related to water resources in the Study Area is summarized as shown in **Table 10.2-1**.

Table 10.2-1 Contents of Literature Survey Related to Water Resources in the Study Area

Documents	Information regarding water resources for water supply
Rwanda National Water Resources Master Plan (2014)	Water Resources Management including present status of water balance, future prediction of water use of each industry was described based on the Level 1 catchment. The study area is included in NNYL (Lower Nyabarongo catchment). Characteristics of NNYL was explained as (1) Total water use of the catchment is only 2.22% of renewable water source, (2) Potable water supply use is the highest consumption compared with other catchments.
Nyabugogo Catchment Management Plan (2018)	Nyabugogo catchment is Level 2 catchment of NNYL. This report described water allocation policy and mentioned the importance for water use efficiency. It said that water allocation plan needs to enhance efficiency over time. By 2050, domestic water supply should increase the efficiency of 20% of water use. In addition, water allocation plan has been designed using the following priority. 1) Domestic water supply 2) Livestock 3) Environmental flow (to provide water to ecosystems and downstream stream users) 4) Industrial water demand, due to its very limited size and the fact that demand is constant throughout the year and independent of rainfall 5) Irrigation Highest priority was given to domestic water supply
Kigali Bulk Water Supply Project, Technical Feasibility Report (2014)	The report shows various water sources for water supply in Kigali. It includes intake from the Nybarongo River at Rutonde, Nzove and Kanzenze, groundwater development by well field in Nzove and Kanzenze. In addition to that, groundwater development in the Ruhengeri region was mentioned.
Pre-Feasibility Study Lake Muhazi Multipurpose Dam (2016)	Study was carried out by RWFA. The result of study showed that the present water balance of Muhazi Lake and possibility of increasing available water by construction of dam. It has been concluded by RWFA recently that they will rehabilitate the existing dam, but the dam is not increasing the level of the lake to avoid any environmental risk. It means that availability of lake water doesn't change after the construction of the dam.

Documents	Information regarding water resources for water supply
Feasibility Study for Nyabarongo II Multipurpose Development Project (2016)	Study included the construction of (1) Shyorongi dam for hydropower, (2) reservoirs by weirs to supply water of 130,000m^3/day and 42,300m^3/day. Construction of Shyorongi dam has been started in 2019. According to the schedule, those two weirs and water treatment plants using the water will be completed in 2039. However, the plan for the construction is still not yet decided.

Source: JST

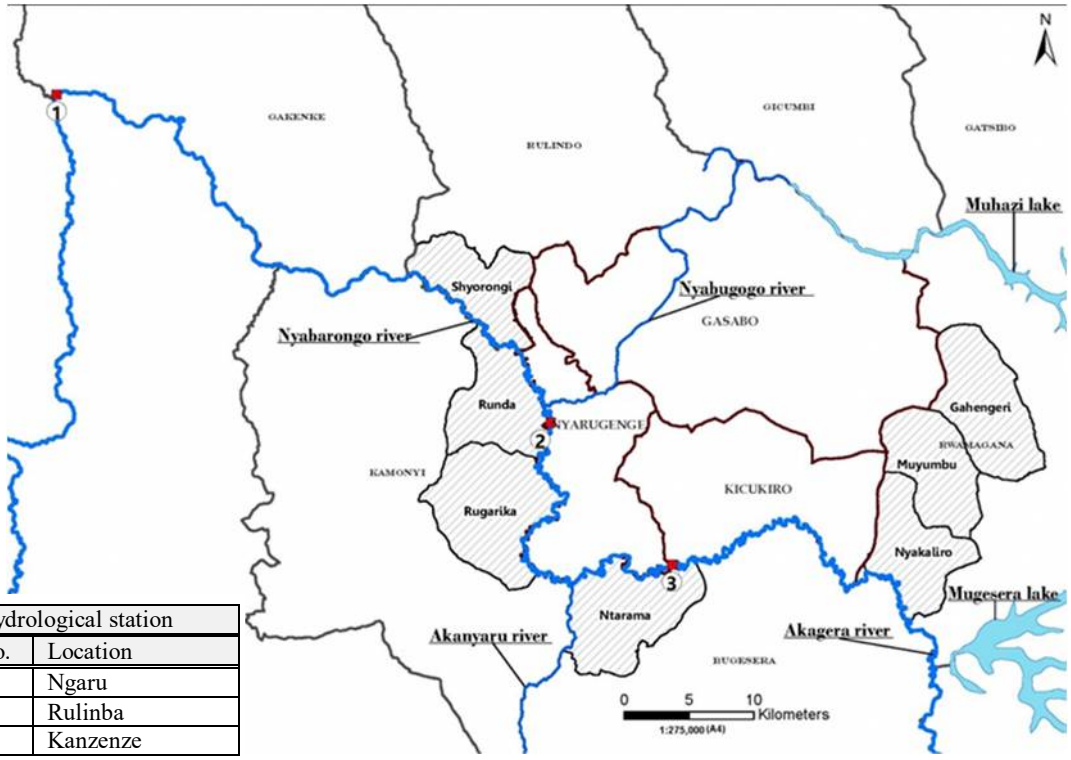
10.2.2 River Water

10.2.2.1 Present Usage of Nyabarongo, Akagera River

According to water permission records taken from the RWFA, the WASAC is a main water user of the Nybarongo River. A quantum of 105,000 m^3/day has been approved for water supply. At the moment, the quantum of 80,000m^3/day is being pumped up from the two intakes at the Nzove WTP. In addition to catering for domestic water supply, the Nyabarongo River is also being used for irrigation purposes. Due to the urbanization, the irrigation area is limited in the CoK and is concentrated along the downstream of the river. River intakes are located in the upstream of those irrigated areas, and do not overlap. These irrigation farms along the river haven't obtained the water permission to use. Previous study indicated that almost 50% percent of the total water users have no permit. At the moment, the WASAC is the main permitted water user of Nyabarongo River.

10.2.2.2 Future Use of the Nyabarongo, Akagera River

The discharge rate of the Nyabarongo River has been measured at three hydrological stations by RWB.

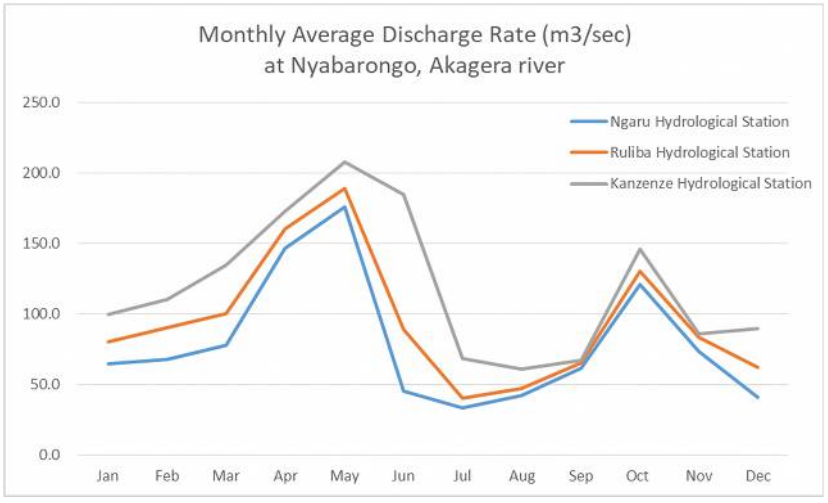


Hydrological station	
No.	Location
1	Ngaru
2	Rulinba
3	Kanzenze

Source: JST

Figure 10.2-1 Location of RWFA Hydrological Stations

The following **Figure 10.2-2** shows the average monthly discharge rate at three (3) hydrological stations.



Source: JST (Data taken from RWB)

Figure 10.2-2 Average Discharge Rate at Hydrological Stations

As inferred, the lowest discharge can be observed during the months of July and August, where the figure varies from 33.5 to 60.6m^3/s. The discharge rates at the three stations were monitored for over 50

years. The lowest observed flow rate (flow during the drought period) at the three stations is shown in the following **Table 10.2-2**.

Table 10.2-2 Lowest Flow Rate during Monitoring Period at RWB Hydrological Stations

	Hydrological station	Lowest flow rate (drought flow) m^3/s	Lowest observed date	Monitoring period
1	Ngaru	33.5	10-Aug-64	Jan 1960-Jun 2019 (59 years)
2	Rulinba	34.9	26-Jul-56	Apr 1955-Jun 2019 (64 years)
3	Kanzenze	28.7	8-Jun-72	Aug 1955-Jan 2019 (63 years)

Source: JST (Data from RWB)

JST conducted a preliminary discussion with RWFA (2019) assuming that extra water of 100,000 m^3/day will be needed from the Nyabarongo (Akagera) River to meet the water demand in 2035. As observed from the above table, the amount of 100,000 m^3/day is about 3% to 4% of the flow rate during the drought period. Therefore, it can be concluded that the extra intake of at least 100,000 m^3/day from the river is possible without causing much effect on the present river flow.

After 2035, river water from the Nybarongo River will continue to be used and possibly for an extra of 450,000 m^3/day. In addition, as described under the report of the Nyabarongo II Multipurpose Development Project, there is a plan to construct a new dam (weir) to supply water for 130,000 $m^{3/}$day from the river.

In addition to the Nyabarongo River, water from the Yanze River is used and the amount is 22,000 m^3/day. The Yanze River can produce more water if the dam (weir) is constructed at the upper stream of the river. However, the extra water produced by the dam may not be of a large quantity due to the size of the river.

10.2.2.3 Future Risk of Dam Construction at the Upstream of the Nyabarongo River

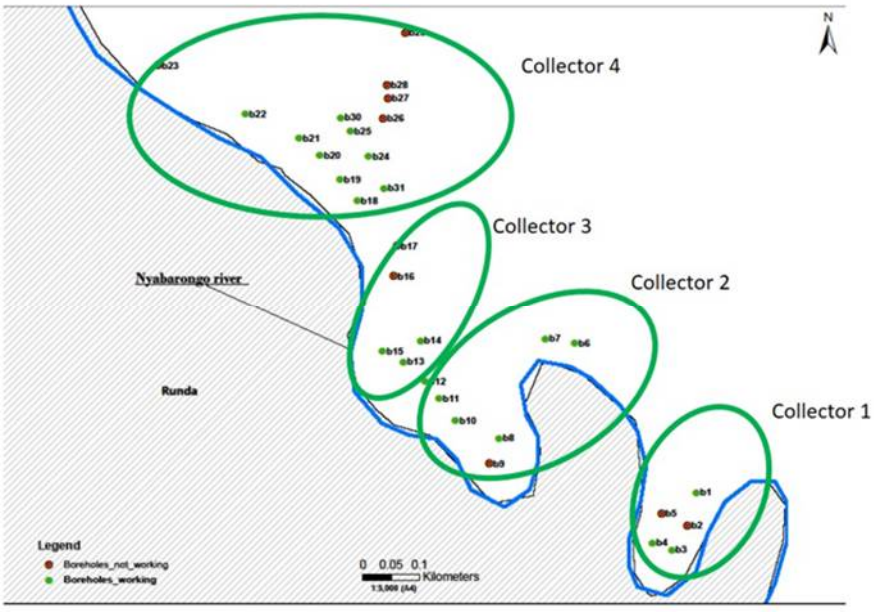
The Nybarongo II Hydropower Station (Shyorongi dam) will be constructed at upstream of the Nybarongo River. It is expected to be completed by 2024. During construction, it may cause a water quality problem and also reduce the flow rate of the river. Therefore, it is recommended to monitor river water quality and flow at the Nzove WTP. After completion of the dam, monitoring should be conducted on a regular basis.

10.2.3 Groundwater

10.2.3.1 Present Usage (Boreholes Abstraction from the Flood Plain of Nyabarongo River)

Boreholes were constructed in the flood plain of Nzove and Kanzene along the Nyabarongo/ Akagera River, an abstraction rate of 40,000 m^3/day at the Nzove well field was permitted by the RWB. In addition, the Kigali Bulk Water Project also has permission to abstract 40,000 m^3/day through 38 nos. of boreholes at Kanzenze. At Nzove well field, 31 nos. of boreholes were drilled for the supply of water to the Nzove WTP in 2006. The pumping test result shows that a total amount of about 30,000 m^3/day of groundwater could be extracted from the Nzove well fields consisting of four collectors and as shown in

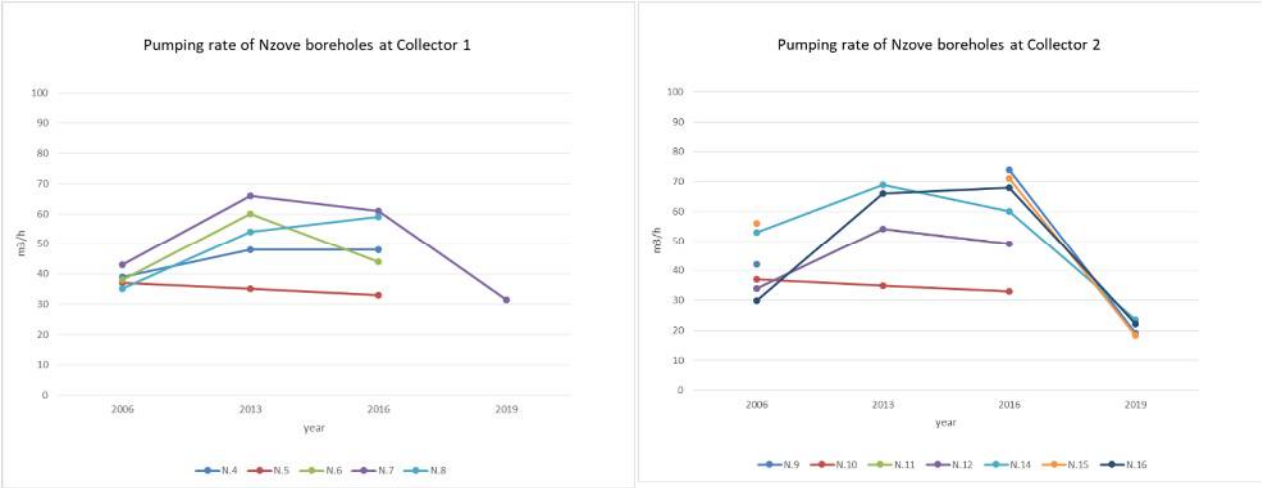
the following **Figure 10.2-3**.



Source: JST

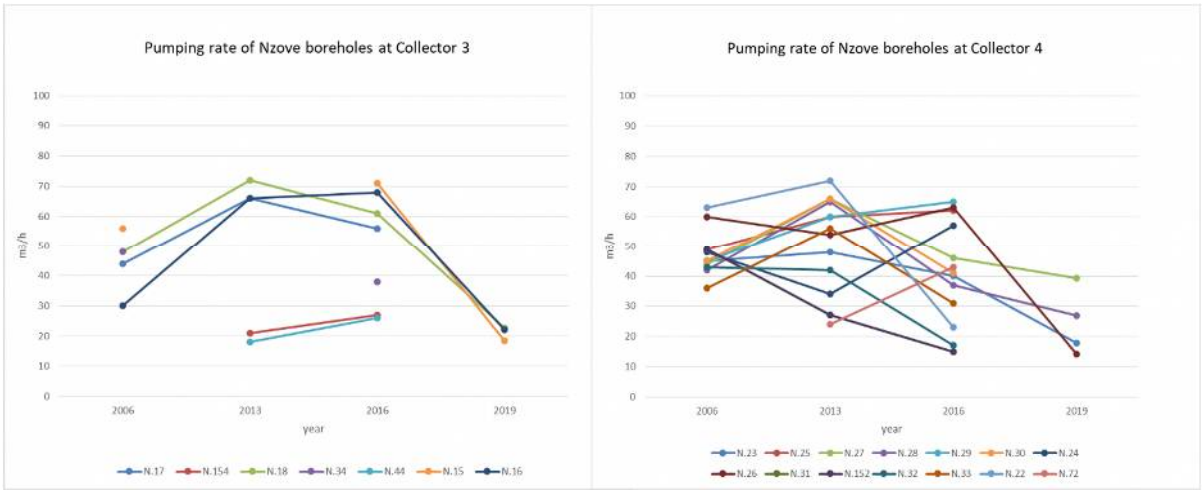
Figure 10.2-3 Nzove Well Field

The following **Figure 10.2-4** and **Figure 10.2-5** show the change of pumping rate at boreholes of each collector.



Source: JST

Figure 10.2-4 Pumping Rate at Boreholes in Collector 1 and 2



Source: JST

Figure 10.2-5 Pumping Rate at Boreholes in Collector 3 and 4

As inferred from the above figures, it is observed that following commencement of pumping in 2006, borehole yields have increased and it was beyond the safe yield (pumping rate in 2006), estimated at the pumping test conducted in 2006. As a result of over pumping, the borehole yield had decreased. The initial pumping rate in 2006 shows that groundwater development potential by each borehole is around 50 m^3/hour in the Nzove well field. However, adequate borehole management is needed in order to sustain the borehole yield.

Table 10.2-3 shows the result of pumping test carried out in Kanzenze.

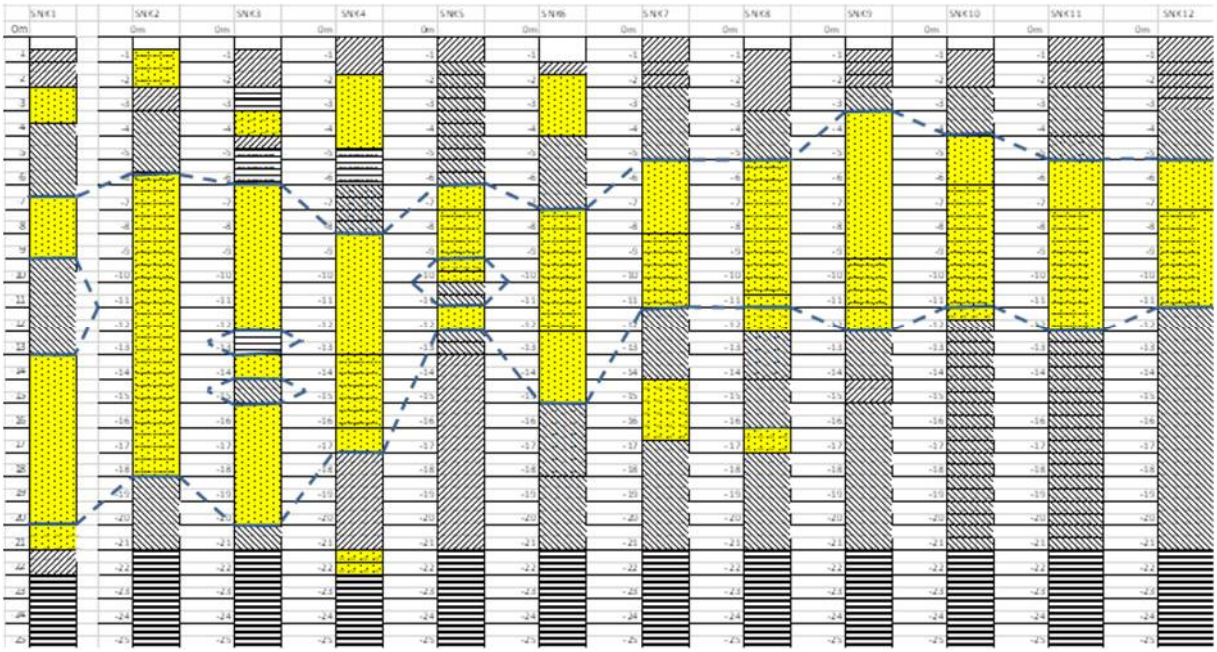
Table 10.2-3 Summary of pumping test result (step test) at Kanzenze boreholes

	Borehole depth (m)	Q1 (m^3/hour)	Drawdown by Q1(m)	Q2 (m^3/hour)	Drawdown by Q2 (m)	Q3 (m^3/hour)	Drawdown by Q3 (m)
1	21	30	6.06	48	9.04	**65**	**10.3**
2	19	38	3.33	48	4.14	62	5.5
3	18	30	2.57	48	4.59	62	6.58
4	15	34	2	51	2.64	62	3.24
5	15	31.8	2.79	43	3.72	61	5.05
6	15	35.4	2.5	52.2	4.01	65.4	5.35
7	18	35.4	1.54	55.4	2.51	80.5	3.54
8	15	42.6	1.23	55.8	1.68	**81.5**	**2.51**
9	15	39.6	1.04	58.2	1.54	81.3	2.19
10	15	32	1.24	48.6	2.01	81	3.41
11	15	30.6	6.51				
12	15	32	2.72	50.1	15	60	5.46

Source: Report prepared by Foraky Africa and WE Consultant (Nyabarongo Aquifer Test Pumping)

If it is assumed that the sustainable yield is 80% of Q3, the safe yield of the borehole could be from 48 to 65 m^3/hour. It is noted that the well efficiency or capacity varies depending on the borehole. For example, borehole No 1 has a 10.3 m drawdown due to pumping of 65 m^3/hour. On the contrary, borehole No 8 has only 2.51 m drawdown due to 81.5 m^3/hour pumping. It is thus observed that the aquifer in the flood plain has a wide variation of capacity. The core drilling result in the Kanzenze shows

the aquifer thickness is from 5 m to 10 m. This heterogeneity of thickness and distribution may cause the observed variation.



Source: Report prepared by Foraky Africa and WE Consultant (Nyabarongo Aquifer Test Pumping)

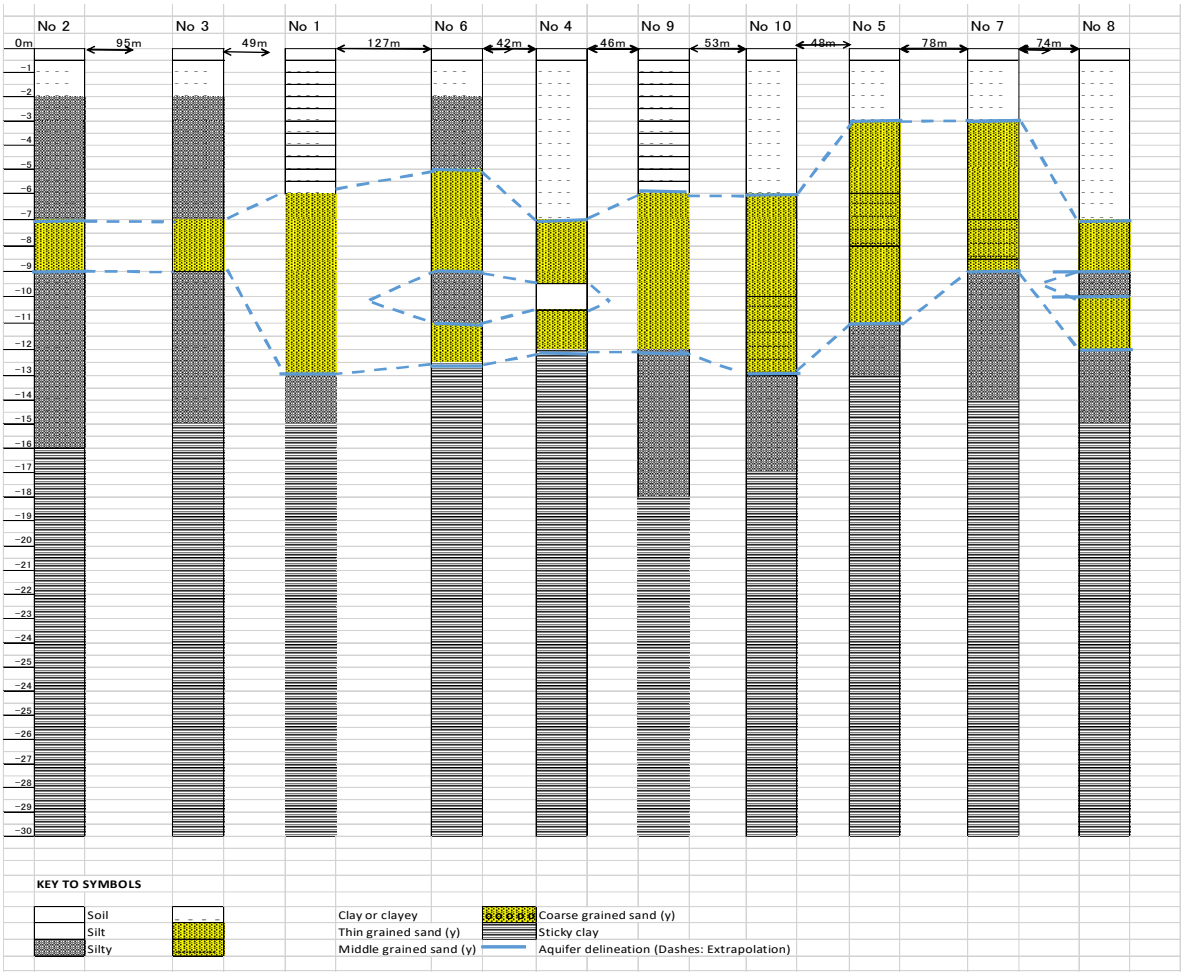
Figure 10.2-6 Thickness of Aquifer distribution at Kanzenze boreholes (yellow color indicate aquifer)

10.2.3.2 Groundwater development Potential at Masaka Area (Flood Plain of Akagera River)

In order to understand the aquifer property at flood plain of Akagera River around Masaka area, core drilling (10 core boreholes) and one water well drilling were carried out. Groundwater level measurement was also conducted by drilled boreholes.

✓ **Lithological data by core drilling at test site**

The core samples of each borehole were taken to 30m. The core samples shows that the study area is in sedimentary formation consisting of different layers, mainly clayey soil with thick layers of mainly fine sand at 7 to 11 m depths. There are one or two sand layers and have the thickness of 2 to 10m. Grain size of sand is fine to coarse sand. Data also shows the depth to sticky clay layer at the bottom of aquifer. Depth of clay layer at the bottom of aquifer of each borehole is shown in **Table 10.2-4**.



Source: JST

Figure 10.2-7 Thickness of Aquifer distribution at Masaka (yellow color indicate aquifer)

Table 10.2-4 Depth of Clay Layer at the Bottom of Aquifer and Aquifer Thickness

Borehole	Depth of clay layer (BGL) (m)	Total aquifer thickness(m)
No 2	16m	2m
No 3	15m	2m
No 1	15m	7m
No 6	12.6m	5.5m
No 4	12m	4m
No 9	18m	6m
No 10	17m	7m
No 5	13m	8m
No 7	14m	6m
No 8	15m	4m

Source: JST

✓ **Pumping Test Result in Masaka**

After the completion of test well at Masaka site, pumping test was conducted. The main objective of pumping test is to determine the safe yield and optimum installation depth of the pump. In addition, aquifer parameters such as transmissivity was estimated by pumping test result.



Source: JST

Figure 10.2-8 Pumping Test Layout

Table 10.2-5 Details of Pumping Test



Distance from pumping well

Monitoring well No10 (upstream)	27.9m
Monitoring well No5 (downstream)	27.1m
River(Akagera)	33.5m



1. Step test

Step	Yield (m3/hour)	Duration
1	54	180min
2	75	180min
3	80	180min

2. Constant test

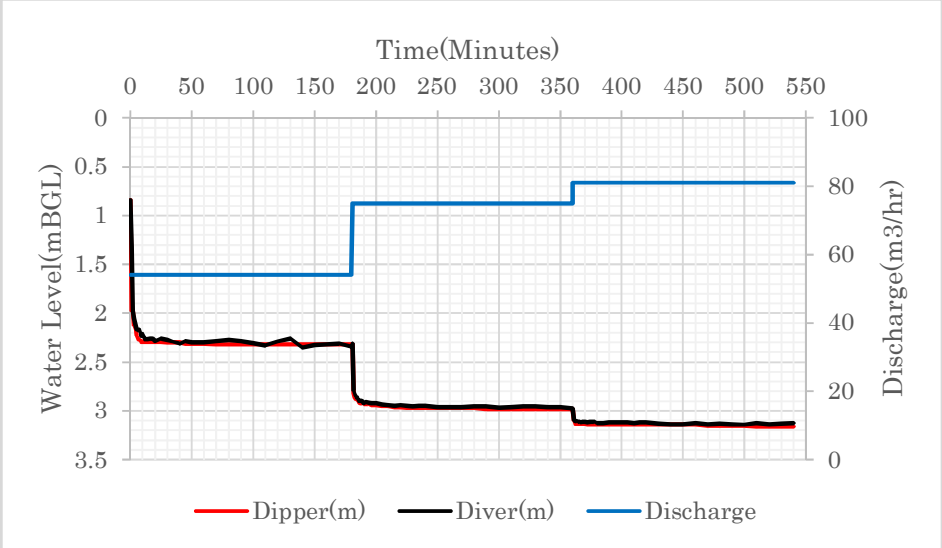
Yield (m3/hour)	Duration
81	24 hours

3. Recovery test

Source: JST

(1) **Step test**

Safe yield was calculated by the result of step test. Maximum yield (Qmax) of borehole was estimated 137 m^3/hour. Qmax is defined here as pumping rate which dynamic water level reach to pump setting depth. It is estimated by the Sw – Q curve of step test. Safe yield can be 95m3/hour (2,280 m^3/day) (70% of maximum yield). Steady state of drawdown was observed at third step (80 m^3/hour) after 130 min of pumping. Therefore, 80m^3/hour was adapted as pumping rate of constant test.



Source: JST

Figure 10.2-9 Result of Step Test

Table 10.2-6 Summary of Step Test

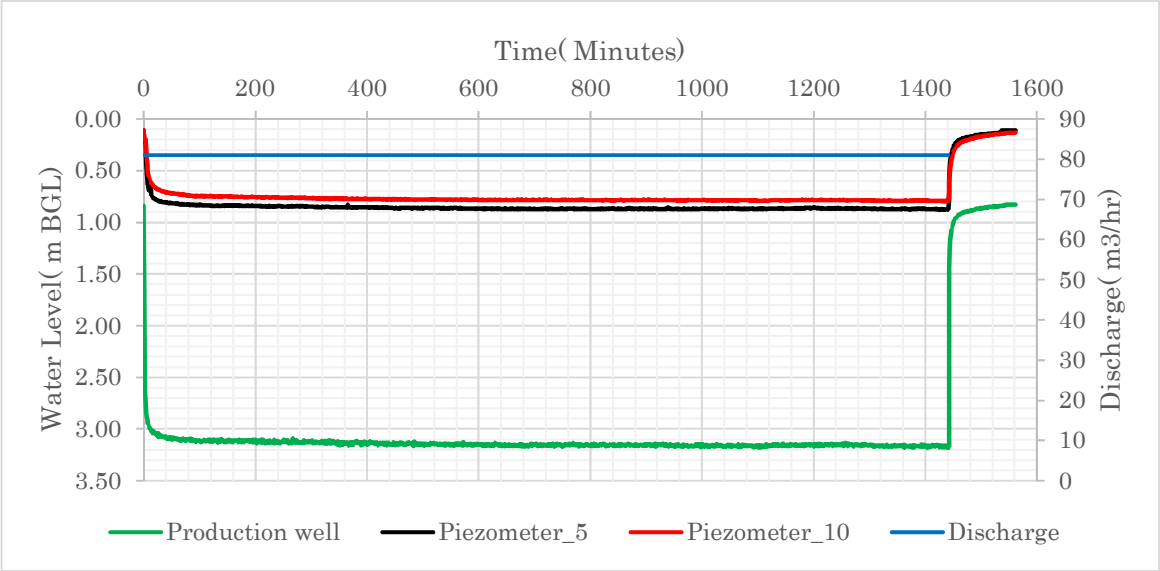
	Step 1	Step 2	Step 3
Initial water level (m bgl)	0.84	2.30	2.98
End water level (m bgl)	2.30	2.98	3.16
Discharge rate m^3/h	54	75	80
Pump installation depth(m bgl)	15m	15m	15m
Time when water level started to stabilize considering starting time of each step	70 minutes	110 minutes	130 minutes

Source: JST

(2) **Constant test**

The result shows that the water level of pumping well stabilized at 3.18 mbgl at the end of constant test (Q=80m^3/h) which falls within the fine sand alluvium formation according to stratigraphy. High sustainable aquifers are expected in coarse alluvium formation. If the water level does not stabilize during the test pumping exercise, or the drawdown is too high, then safe yield would be determined using the nearest yield to stability with a safety factor of 15 to 30 percent. Pump should not be installed adjacent to screened section. Normally, when the pump is placed adjacent to a plain casing and above the screen to minimize the risk of entry of small particles like silt and damage to the pump. Water level stabilized at 3.18mbgl in 24-hour constant discharge test is an indicator that the well has a higher

specific capacity with an available draw down from 3.68mbgl to 15.0mbgl (pump setting depth). The formation along this geology (3.2 to 15.7mbgl) is underlined with fine and coarse sand.



Source: JST

Figure 10.2-10 Result of Constant Test

Table 10.2-7 Summary of Constant Test

	Unit	Observations
Duration	Hours	24
Pumping rate	m^3/h	81
Initial static Water Level	mbgl	0.83
Dynamic water Level at end of the test	mbgl	3.18
Maximum drawdown	m	2.35
Pump installation depth	mbgl	15.0
Borehole depth	mbgl	30.0
Recovery period	minutes	130

Source: JST

(3) **Aquifer characters**

Transmissivity determines the rate at which groundwater will flow into a pumping borehole, measured as a unit rate of flow per unit aquifer thickness ($m^3/d/m$) and its unit is m^2/d. Transmissivity determines the borehole yield, hence its pumping rate. Transmissivity was determined for each borehole using the equation:

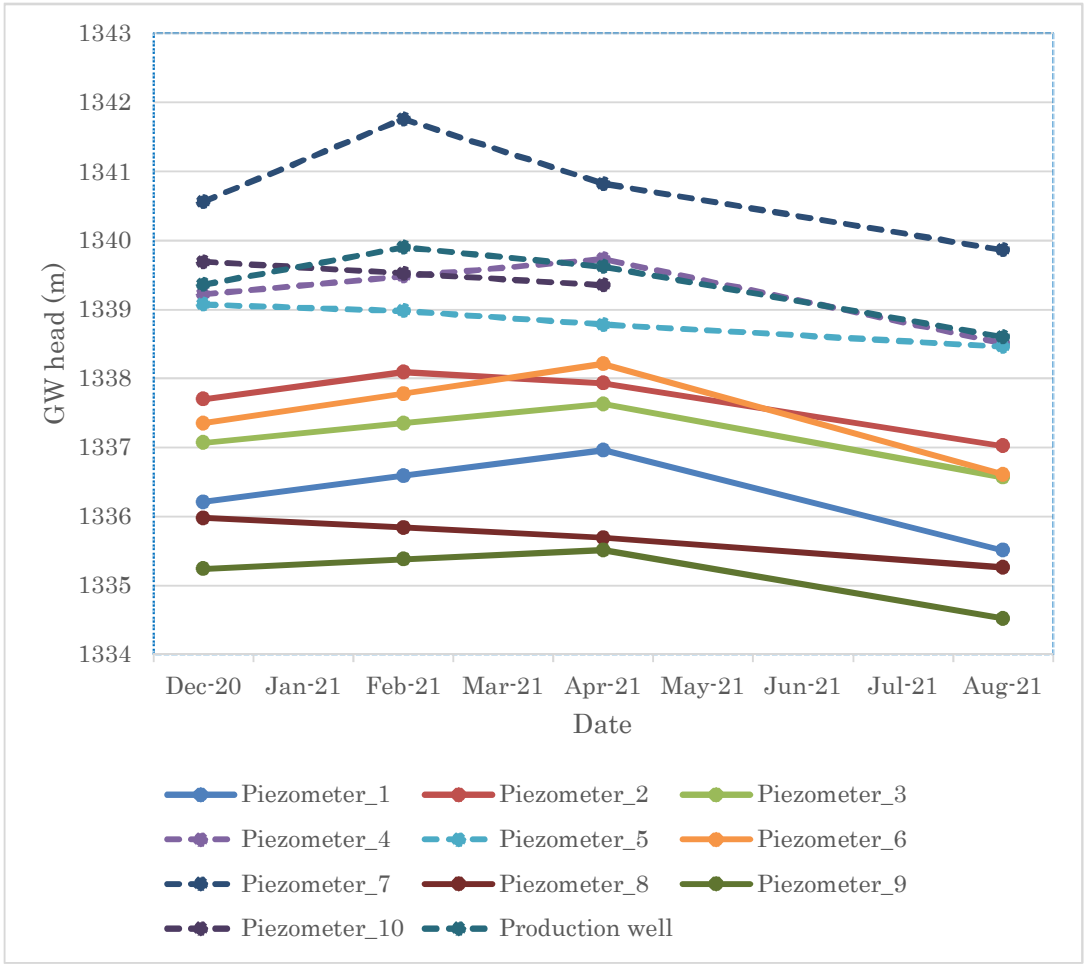
$T=2.3Q4\pi\Delta s$, where T is the transmissivity (m^2/d), Q is the borehole pumping rate (m^3/d), π (pi) = 3.142 and Δs is drawdown over a log-cycle of time.

Calculated transmissivity varies from $800m^2/d$ to $1,500m^2/d$ at the two monitoring boreholes. Assuming thickness of the aquifer is 10m, hydraulic conductivity is from 80m/d to 150m/d. High transmissivity values are typical of an alluvial aquifer and shows high groundwater potential. Inflow from River boundary can be observed during pumping.

(4) **Groundwater level measurement at Masaka test site**

Groundwater levels were also measured using boreholes of core drilling. After the core drilling, the PVC casing and screen was installed and converted to monitoring wells. Groundwater level monitoring was conducted by ten monitoring wells and one production well. Manual measurement of groundwater level of those monitoring wells was conducted four times, which was December 2020, February 2021, April 2021 and August 2021. **Figure 10.2-11** shows the result of manual measurement.

As shown in the result of drilling core analysis, the aquifers within the test site are not uniform. It means that groundwater heads measured at monitoring wells are not equal to the hydraulic head of same aquifer. Therefore, equipotential groundwater head contours couldn't be created by using individual groundwater head at monitoring wells. The result of measurement of groundwater head was only explained as comparison of groundwater head of each well.



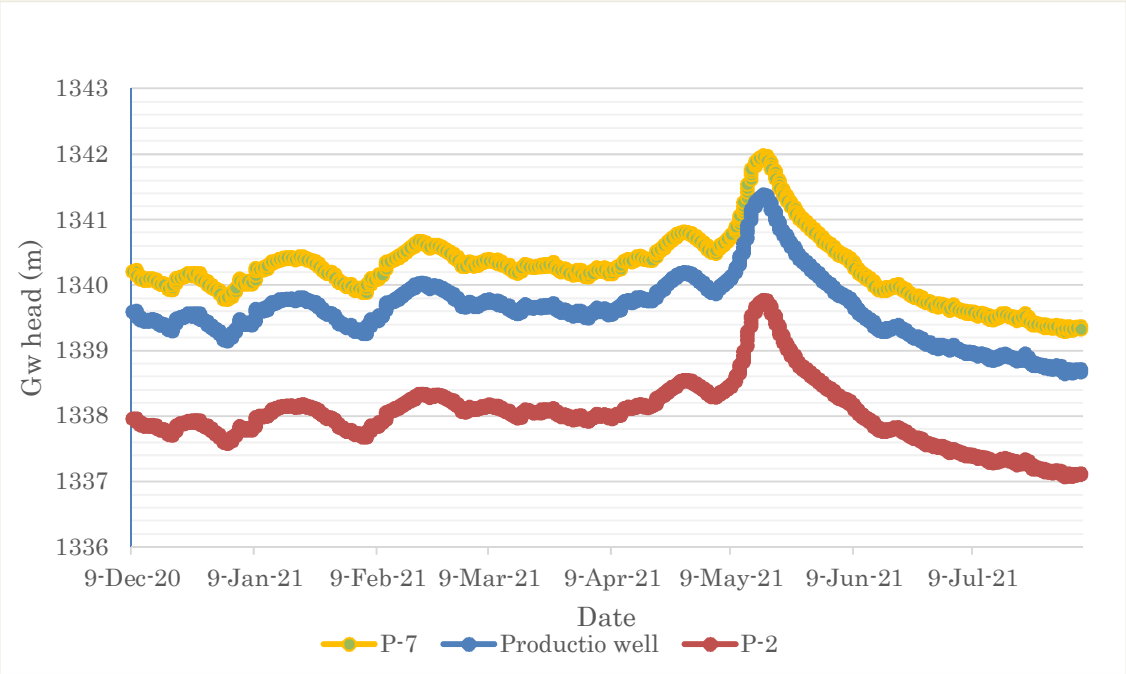
Source: JST

Groundwater head means ground elevation minus water level (bgl)

Figure 10.2-11 Groundwater Head by Manual Measurement

As shown on the figure above, groundwater head of all wells was low in August. In August, the lowest groundwater head was observed at P 9 well and highest was P-7. The head difference between two wells is 5.3m. It also noted that monitoring wells situated near Akagera River tend to have high groundwater head.

In addition to the manual measurement, continuous measurement was carried out from December 2020 to August 2021 at three wells (P-2, P-7 and production well).



Source: JST

Figure 10.2-12 Groundwater Head by Continuous Measurement

Fluctuation pattern of three wells is very similar. Highest groundwater head was observed in May and the lowest head was in August. The result shows the seasonal fluctuation was about 3m. It is also noted that monitoring wells situated near the Akagera River (p-7and production well) has high groundwater head.

(5) **Seasonal groundwater fluctuation and well yield**

Pumping test at test site was conducted in November 2021.It was observed that groundwater level was the lowest in August (dry period) in the test site. Statistic groundwater level difference between November and August was around 1.0m. Thus, dynamic water level caused by pumping in August can be lower than that in November. Qmax and safe yield of borehole estimated in November may not be same in August. Pumping rate of test well was considered the pumping in dry period and determined as 80m^3/hours and 65% of Qmax in November. Therefore, this value still be valid in dry season

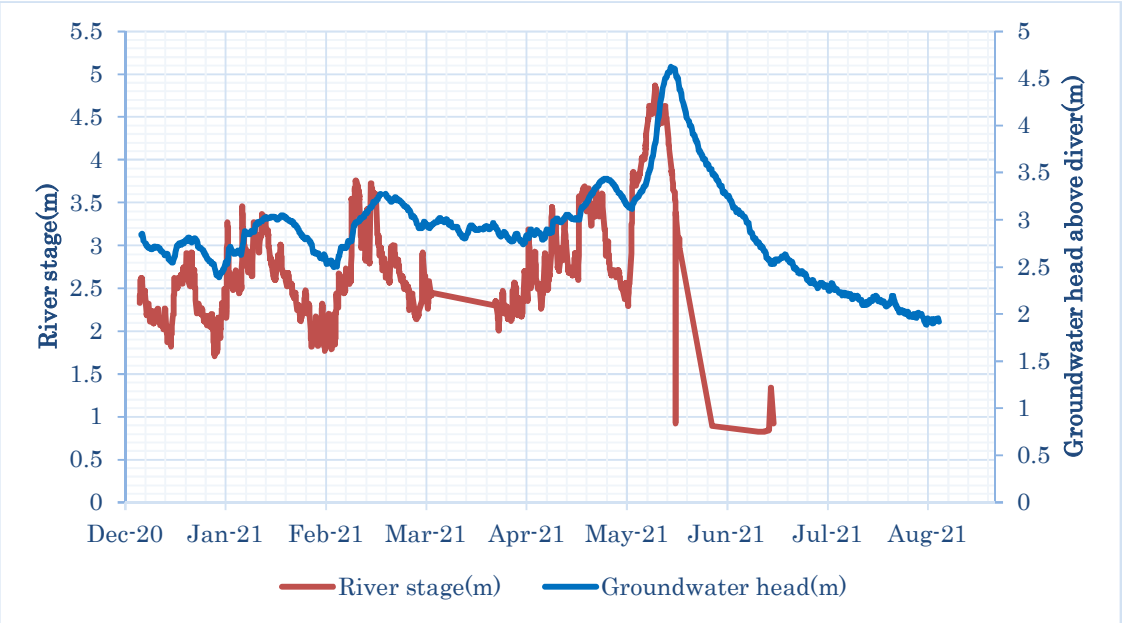
(6) **Relationship between river and groundwater at Masaka test site**

During pumping test, the extra water inflow from the river boundary was observed. Measured groundwater head was compared with the river stage data taken from RWB hydrological station near the test site. It can be seen from the graph (**Figure 10.2-13**) that it seems to be certain correlation between groundwater head and river stage at test site.

The interaction between river and groundwater takes place in three basic ways:

- streams gain water from inflow of groundwater through the streambed (gaining stream),
- streams lose water to groundwater by outflow through the streambed (losing stream), or
- both, gaining in some reaches and losing in other reaches.

Unfortunately, there is no river stage measurement station close to the observation wells. Therefore, it is difficult to judge the condition of interaction between groundwater and river.



Source: JST

Figure 10.2-13 Relationship between Groundwater Head and River Stage

10.2.3.3 Future Use of Groundwater

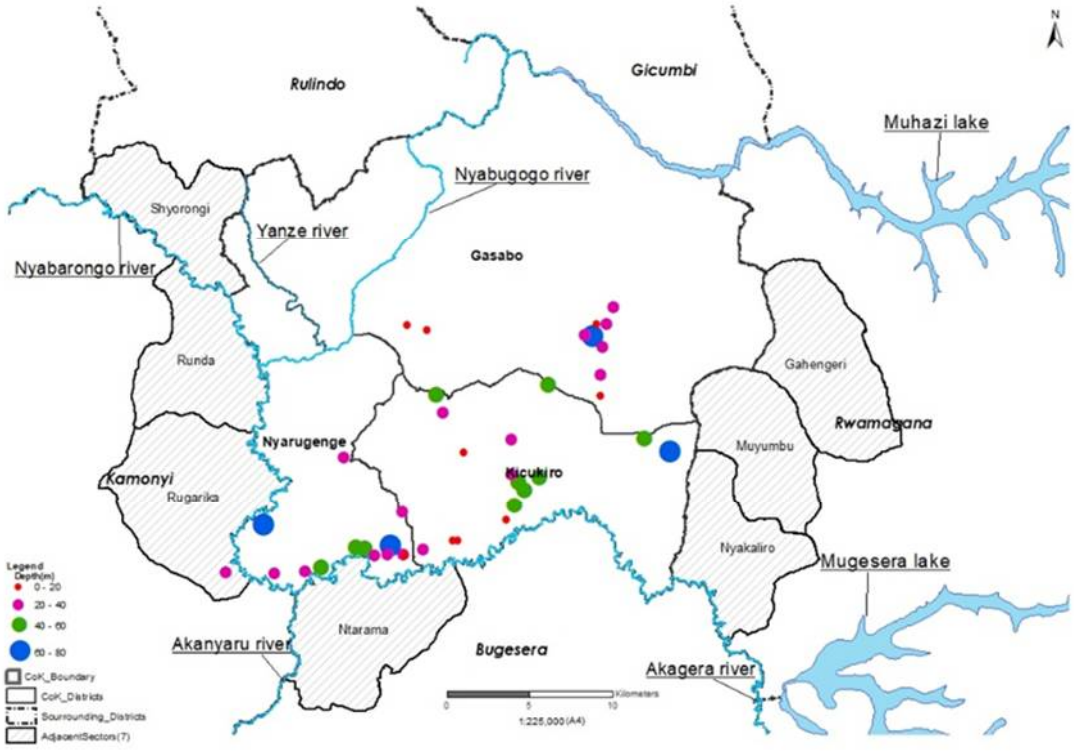
✓ **Groundwater in Flood Plain of the Nyabarongo, Akagera River**

According to the pumping test results taken from the Nzove and the Kanzenze well fields and Masaka test well, one borehole can produce >50-60 m^3/hour. One wellfield can be drilled up to 30-40 boreholes and the total production of wellfield could produce up to a 40,000 m^3/day. By 2035, extra 3 well fields will be constructed and would produce 120,000 m^3/day (e.g., Opposite side of Nzove, Kanzenze and Masaka). After that, groundwater development will be continued and by 2050, two extra wellfields can produce 80,000m^3/day (e.g., Rutonde). In total, seven (7) wellfields including Nzove and Kanzene could be constructed by 2050.

Pumping test results at the Kanzenze boreholes showed an increase in turbidity as time passes. This indicates the occurrence of direct recharge from river water. Groundwater in flood plain is likely to be a mixing of the recharge from rainfall, river and inflow from the upper boundary (e.g., groundwater divide). Therefore, it can be concluded that the amount of the total recharge is enough to cover the total present and future groundwater abstraction. It should be noted that available groundwater is not equal to the amount to be able to develop since it may cause serious depletion of groundwater level due to the pumping. Groundwater level monitoring has not been conducted properly in the study area and there is thus a need to establish the groundwater monitoring network in order to monitor the groundwater depletion in the area. In addition to Nybarongo, Akagera River, groundwater development at the flood plain of Akanyaru River would be possible if the potential can be confirmed.

✓ **Groundwater Development in the Fractured Zone around KIGALI**

Data on 40 Boreholes in the CoK was collected from the RWB. The average drilling depth was 33.6m and the average yield was 42L/min. The following figures show the distribution of those boreholes with depth and yield.

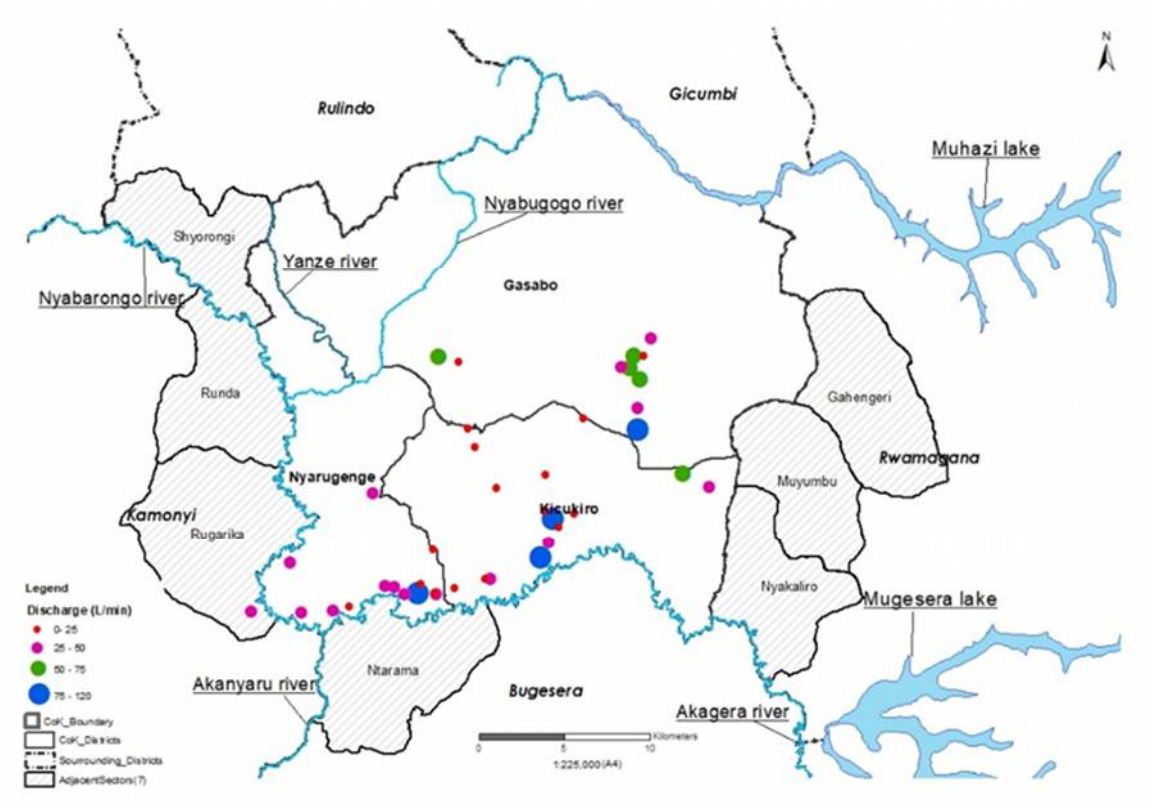


Source: JST

Figure 10.2-14 Distribution of Borehole with Drilling Depth

According to the result of pumping test, these boreholes can produce at 2,426 m^3/day in total and were drilled in the fractured formation with basement complex or granite, schist. Hand pumps (most of them

are Afridev pumps) are installed at those boreholes. Actual abstraction rate by hand pump is smaller than that of the pumping test result. These boreholes have been used for community and are not used as sources for the WASAC water supply. Since the yield is not adequate for urban water supply, the existing groundwater developments by hand pumps can be continued for community use.



Source: JST

Figure 10.2-15 Distribution of Borehole with Yield

✓ **Groundwater Development in the Volcanic Area around the Ruhengeri Region**

The previous study indicated a high groundwater development potential in the Ruhengeri region. From 2036 to 2050, it is expected to develop the groundwater in that area and the wellfield is estimated to produce 100,000 m^3/day. However, further study is needed to make sure the potential of groundwater development in the region. In addition to the development potential, the distribution cost to the CoK also has to be considered. Distance from CoK to Mutobo (Ruhengeri region) is more than 86km. If the available water sources around the City area are enough to satisfy the water demand, this development will be postponed.

10.2.4 Spring Water

10.2.4.1 Present Usage

Spring data collected from the Development of National Integrated Water Supply and Sanitation Master Plans for Rwanda (2019) shows the existence of 124 spring sources in the CoK and having a total

amount of 3,554 m^3/day discharge.

Table 10.2-8 Spring Data in Kigali

Number of springs	124	
Maximum discharge observed (m^3/day)	720 m^3/day (120 L/min)	
Minimum discharge (m^3/day)	0.0	Probable Seasonal springs or become dry due to less recharge
Average discharge (m^3/day)	120 m^3/day (20L/min)	Dominantly springs has low discharge

Source: Baseline report (Development of National Integrated Water Supply and Sanitation Master Plans in Rwanda)

In addition, the WASAC uses 22 springs water source for water supply and these springs produce 4,133m^3/day. Spring data is shown in the following **Table 10.2-9**. Discharge rate was estimated by the JST through the site survey.

Table 10.2-9 Spring Water Source for Water Supply by WASAC

Village	Discharge (m^3/day)	Number of spring sources in water tank
Akatabaro	1,200	6
Akinyana	300	3
Karambo		
Kabande		
Mpazi	648	3
Rwankuba	400	2
Bugarama		
Masizi	13,00	6
Munini		
Kiriza		
Kiriza		
Masizi		
Masizi		
Byimana	285	2
Total	**4,133**	**22**

Source: Hearing from WASAC and site survey by JST

Moreover, 20 nos. of springs are being used as water source in the surrounding sectors of the project area. The same is presented along with their discharge rate in the following **Table 10.2-10.** Discharge rate was confirmed by the water operator of each water scheme.

Table 10.2-10 Spring Water Source for Water Supply at in Surrounding Sectors

	Sector	Village	Discharge(m^3/day)
1	Gahengeri	Kiyovu	130
2		Rebero	190
3	Runda	Nyaruhoko	43
4		Nyaruhoko	43
5		Nyaruhoko	35
6		Nyaruhoko	35
7	Rugalika	Mibirizi	43
8		Ntebe	35

	Sector	Village	Discharge(m^3/day)
9	Shyorongi	Kirurumo	39
10		Kirurumo	39
11		Kirurumo	39
12		Rwintare	112
13		Kirurumo	86
14		Kirurumo	43
15		Mwagiro	130
16		Gatimba	108
17		Gatimba	86
18		Gatimba	86
19		Nyabyondo	345
20		Nyabyondo	691
	Total discharge		**2,358**

Source: Hearing from WASAC

10.2.4.2 Future Use of Spring Water

As mentioned previously, 42 nos. of springs (22 nos. in the CoK) are being used as water sources for water supply. Springs producing high discharge are already being used as a water supply source in the CoK. Springs located in the urban areas are difficult to protect due to human activates and their recharge area is being reduced due to urbanization. Therefore, it is difficult to develop more springs as water sources. On the other hand, springs in surrounding sectors will still serve to be an important water source and continue to be developed in the future.

10.2.5 Lake Water

10.2.5.1 Present Usage

The following two lakes are used as sources for water supply.

Table 10.2-11 Information about Muhazi and Mugesera Lake

Name of Lake	Surface area (km^2)	Volume (Mm^3)
Muhazi	34.45	454.25
Mugesera	21.23	253.19

Source: RWB

According to water permission records taken from the RWB, lake water has been used for various purposes which are shown in the following **Table 10.2-12** and **Table 10.12-13**.

Table 10.2-12 Usage of Muhazi Lake

Purpose	Amount (m^3/day)
Mining	1,000
Irrigation	8,185
Domestic water supply	6,600
Fish Farming	26 ha

Source: RWB

Table 10.2-13 Usage of Mugesera Lake

Purpose	Amount (m^3/day)
Irrigation	17.5
Domestic water supply	15,000

Source: RWB

10.2.5.2 Future Use of Lake Water

(1) Muhazi Lake

Available renewable water resources (precipitation minus evaporation and infiltration) of the Muhazi catchment were estimated by the RWFA. The average inflow into the Muhazi Lake is 110 M m^3/year with a variation between 38 and 147 M m^3/year. The total average amount of water available for use is 55 M m^3 per year (150,000 m^3/day). The average monthly water balance of the Muhazi Lake shows well-known seasonal patterns. From June to August, the inflow is very low and during those months water level in the lake is being depleted. However, given the relatively big storage capacity of the lake, there is no acute water shortage and the presently available water can fulfill the total demand for present water use (15,785 m^3/day).

Table 10.2-14 Available Water in Muhazi Lake

	Total inflow (m3)	Total outflow (m3)	Total available water (m3)
Jan	7,396,082	4,622,451	2,773,631
Feb	9,274,285	4,306,140	4,968,145
Mar	12,370,591	4,522,369	7,848,222
Apr	14,789,304	4,308,986	10,480,318
May	10,849,676	4,441,983	6,407,693
Jun	4,592,734	4,833,909	-241,175
Jul	3,885,057	5,137,986	-1,252,929
Aug	5,056,330	4,913,478	142,852
Sep	7,875,876	4,708,608	3,167,268
Oct	11,220,023	4,647,995	6,572,028
Nov	12,546,396	4,442,280	8,104,116
Dec	10,656,167	4,431,790	6,224,377
Annual	*110,512,521*	*55,317,975*	*55,194,546*

Source: RWFA

As mentioned above, there is enough water to cover all the current uses. However, it should be emphasized that demand is relatively low as the irrigated area is limited (480 ha marshland and 50 ha hillside) and domestic water supply is also low (Rwamagana: 3700 m^3/d; Kayonza: 2800 m^3/d). In addition, it is unclear to what extent additional water demands can be served and the impacts caused by water availability due to changes in climate. In order to meet the additional demands such as increasing domestic water supply and irrigated area, there may be a requirement to expand the reservoir capacity. The previous study conducted by the RWB (2019) indicated domestic water supply used by the Muhazi Lake to Rwamagana, Kayonza and Gatsibo will be increased by more than 50,000 m^3/day in future. This

means that additional water for domestic water supply can be used in those areas, but difficult to use in the CoK. At the discussion with the RWFA in November 2019, the RWFA mentioned that an additional 21,000 m^3/day of lake water can be used for domestic water supply. However, this amount of water will be used for the Eastern Province and cannot be used for the Kigali City

(2) Mugesera Lake

Mugesera Lake has not been studied well like Muhazi Lake. However, seasonal water level fluctuations were observed in 2016. There was a difference of 1.55 m between lowest and highest lake water levels. It means that at least 33 Mm^3 water from the Nyabarongo River flew into the lake at that time. Therefore, it can be concluded that there is still a capacity to utilize the lake water to provide extra water to use for water supply. At the moment, the WASAC obtained the water permission to utilize 48,000 m^3/day from the RWB. The Karenge WTP currently uses 15,000 m^3/day of lake water which can be extended to 48,000m^3/day. Due to the availability of limited monitoring data at lake and unknown inflow situation from the Akagera River in future,

10.2.6 Water Quality Survey for Water Resources

In order to confirm the suitability as drinking water sources and to decide the water treatment process, a series of water quality surveys have been conducted for potential water sources including surface water as well ground water both in the wet and dry season. The results are summarized in **Chapter 5**. As result of the water quality analysis, no harmful/ toxic substances are detected, and they can be used for drinking water purpose with having conventional treatment processes.

10.3 DEVELOPMENT POTENTIAL OF WATER SOURCES AND POLICY OF WATER SOURCE DEVELOPMENT

10.3.1 Available Water Sources for Future Demand by 2050

As mentioned under **Section 10.1.1**, present permitted amount of water used by water supply is 237,350 m^3/day (the RWB registered record in 2020). This amount can be used as water source for the Study Area.

Apparently, this amount can't satisfy the future demand of water supply in the Study Area. Therefore, extra water sources are needed for future water supply investment plan. Estimated additional water sources are shown in **Table 10.3-1**.

These amounts were decided by considering the result of water balance study and characteristics of each water source described previously. Impact of the development to each water source is explained in **section 10.3.2**. At the moment, only limited data is available, especially for floodplain development through boreholes. Therefore, the plan has to be revised if new data such as long-term groundwater level measurement data is available.

Table 10.3-1 New Water Sources to be developed by 2050

Category at Hydrological Cycle	Source	Location	Water Supply m^3/day	Raw Water Intake m^3/day	Amount to be Developed (m^3/day)		Remarks
					2035	2050	
Surface Water	River	Nyabarongo	25,000	25,000	25,000		Intake place is Nzove *
		Nyabarongo or Akagera (by 2035)	100,000	110,000	110,000		Contingency plan**
		Nyabarongo or Akagera (by 2050)	380,000	418,000		418,000	Intake points has not decided yet**
	(Dam)	Nyabarongo, Akanyaru	(200,000)				Sites has not decided yet, need further study**
		Nyabarongo (Butamwa)	(130,000)				Site was recommended by the Nyabarongo II Multi-purpose study***
	Lake	Mugesera	(33,000)	(36,000)			Intake facilities shall be expanded. Not included for water source development
		Mugesera	50,000	55,000		55,000	
Groundwater (sub-surface water) at floodplain)	Boreholes in the river flood plains	Floodplain (Akagera)	80,000	88,000	88,000		Assumed Masaka and Gahanga
		Floodplain (Nyabarongo)	40,000	44,000		44,000	Near Nzove
		Floodplain (Nyabarongo and Akagera)	160,000	176,000		176,000	Rutonde, Kanzenze and Gahanga
Groundwater except floodplain	Borehole and springs	Small scale WSS for remote area	5,000	5,000	5,000		Jali, Rutunga, Gikomero****
		Small scale WSS for remote area	10,000	10,000		10,000	
		Allocated amount(m^3/day)	850,000	931,000	228,000	703,000	

Source: JST,
The F/S for the Nyabarongo II Multipurpose Development Project, conducted by the EDCL (Energy Development Corporation Limited) refers to a plan of the Butamwa Dam that involves abstraction of 1.5 m3/d for the Butamwa WTP. However, the Butamwa WTP is purposely excluded from the Master Scenario 2050 due to its geographical disadvantage for transmission and distribution and concerns over uncert ain risk on future water quality. For this reason, this amount is being considered only as a provisional water source under this Water Resource D evelopment Plan.
* Amount based on the hearing from the RWFA (Permitted amount for abstraction).
** Contingency plan in case the water sources from sub-surface water are not capable. The amount shall be transferred to 2050 development if not used.
*** The amounts shown in the "Dam" are included in the amount shown in "Nyabarongo or Akagera (by 2050)" of "River" and deemed as possible sites of "Nyabarongo or Akagera (by 2050)".
*** Location of these area is explained in the Master Scenario of Chapter 13.

As can be inferred from the table, an amount of 228,000 m^3/day will be needed by 2035 in addition to the present water sources in order to meet the water demand and investment plan. It was suggested by the RWFA that the location of river intake should be at the downstream of the Nybarongo/Akagera River. In terms of groundwater extraction, the RWFA (2019) suggested that groundwater monitoring networks in the developed area must be established in order to confirm the sustainability of groundwater use. Furthermore, extra amount of 703,000 m^3/day will be needed to develop from 2035 to 2050 (15 years) to meet the water demand in the Study Area. It can be also seen from the table that extra water source to be used heavily depends on water from the Nyabarongo/ Akagera River, both directly and indirectly since there is no water resource which can contribute large amount of water around the Study Area.

10.3.2 Water Resources Development Potential for the Study Area's Water Supply by 2050

Water balance studies carried out during the preparation of the NWRMP (National Water Resources Masterplan) and the Catchment Management Plan by the RWB indicates that renewable water resources are available for all water users including the Study Area's water supply by 2050. **Table 10.3-2** shows the available water of each water source for the Study Area's water supply. Definitions of available water, which can be used of each water source are explained in **Table 10.3-3**. As observed, water resource at a scale of individual source is still available after the development in 2050. Water taken for development from the Nyabarongo / Akagera River by 2050 is around 27% of the total available amount at river flow and still 73% is available for further use. On the other hand, available water after development at the Yanze River is only 20%.

Table 10.3-2 Available Water of Each Water Source and its Consumption by 2050

Category at Hydrological Cycle	Source	Estimated available water (m^3/day) (a)	Present permitted amount of water for water supply (m^3/day) (b)	Amount needed by 2050 in addition to present permitted amount (m^3/day) (c)	Total needed by 2050 (b + c)	% used to (a)	Remarks
Surface Water	River including boreholes at floodplain (Nyabarongo/ Akagera) in the Grater Kigali	3,456,000	160,000	785,000	945,000	27%	It is assumed that majority of water abstracted from boreholes in floodplains (alluvium aquifer) is river origin.
	River (Yanze)	30,000	24,000	-	24,000	80%	It is difficult to collect more water from Yanze and need reservoir (dam) if need more water from Yanze***
	Lake (Muhazi)	32,000	-	-	-	-	This amount is for Eastern Province and not for the Study Area
	Lake (Mugesera)	N/A*	48,000	50,000	98,000**	N/A*	50,000 m3/day is needed in addition to present permitted amount at The Kigali water supply plan by 2050.
Groundwater	Boreholes for small scale WSS	119,656	900	10,000	20,350	17%	Average discharge 45 l/min of one borehole.
	Springs for small scale WSS		4,450	5,000			Average discharge 40 l/min per spring
	Total		237,350	850,000	1,087,350		

Source: JST
The amount is clear water basis. Extra amount is necessary for the loss in water treatment processes. Water abstraction appli cation (Daily Maximum) shall be submitted including the extra.
*The data will be available after the on-going study for the Mugesera-Sake Catchment by the RWB.
** Only for the demand in the Study Area. Additional amount should be considered for the demand in the other areas (e.g. the Rwamagana).
***Hydrograph of Yanze River is shown in Appendix 3. Further study is needed to verify the improving storage capacity by reservoir (dam).

Table 10.3-3: Definition of Available Water of Each Water Source

Category at Hydrological Cycle	Source	Methods of estimation of available water
Surface Water	River including boreholes at floodplain (Nyabarongo/ Akagera) in the Grater Kigali	Available water is assumed by the average long time dry flow rate of the Nyabarongo and the Akagera (50m^3/sec) in the Grater Kigali minus the environmental flow (20%)、Long time dry flow rates of the Nyabarongo and the Akagera are shown in the annual water status report published by the RWB. This amount can be extracted throughout the year without any damage to river environment.
	River (Yanze)	Available amount is estimated by dry flow rate minus environmental flow rate (20%). Dry flow rate is taken from hydrological station data of the Yanze river at the Rwanda Water Portal
	Lake (Muhazi)	The change in water storage with the lake is 11.6 million m3 per year. The total amount of water that can be abstracted is about 32,000m^3/day without impacting significantly the lake water level.
	Lake (Mugesera)	Catchment management plan including water balance study of the Mugesera lake has not been completed. Therefore, it is difficult to estimate available water (renewable water) of the Mugesera lake. Lake water level was measured before but only a limited data is available. It showed the inflow into the lake to be around 90,000m^3/day.
Groundwater	Boreholes for small scale WSS	Available groundwater to be able to use in the Study Area is difficult to estimate since no study related to recharge mechanism has been done yet. Available amount of groundwater here is assumed to be 10% of average groundwater recharge in the L2 catchments of the Study Area. Previous study (the Groundwater Recharge and Storage Enhancement in Eastern Province, 2019) concluded that around 10% of groundwater recharge is stored in the deep aquifer. Amount of aquifer storage depends on the aquifer type and recharge environment. The NWRMP study also indicated groundwater recharge is 60-70% of outflow at catchment scale Groundwater resource in the Study Area is difficult to develop due to its occurrence. Therefore, manageable amount of groundwater could be less than this amount.
	Springs for small scale WSS	

Source: JST

10.3.3 Characteristics of Water Sources and Issues on Development

Target water sources to be used for the Study Area's water supply will still be available to be utilized after the development in 2050. However, characteristic of each water source has to be considered before development. Otherwise, sustainable development of water sources cannot be achieved. The characteristics of each water source and development issues are explained in the following **Table 10.3-4**. It can be seen from the table that water source protection from flooding is a main problem pertaining to river water intake and boreholes at flood plain.

Table 10.3-4: Characteristic and Development Issues of Each Water Source

	Water Source	Characteristics of water source	Development Issues
Surface Water	River (Nybarongo/ Akagera)	High potential of development especially after the Kanzenze, Peak flows are observed during the periods of March to May and low flows are from June to August at hydrological station operated by the RWFA.	Relatively low cost for development. Protection of the facilities against flood is needed. In future, river intake facilities will be constructed in the downstream of the river,
	Boreholes at flood Plain along the river (Nyabarongo/A kagera)	Borehole data at the Nzove and the Kanzenze show development potential to be high. However due to complicated aquifer distribution, borehole yield is not uniform in the area.	High cost for development since there is a requirement for conducting geophysical survey to identify the aquifer and drilling for boreholes. Cost for rehabilitation of boreholes is also needed.
	River (Yanze)	Low development potential since river flow rate is small	70% of river water is already taken by the Kimisagara WTP. Therefore, it is difficult to collect more water. During peak flow, intake facility is often damaged.
	Lake (Muhazi)	Storage capacity of lakes is high. However, amount of renewable water source at lakes are small due to no inflow of rivers into lakes.	No water for the Study Area's water supply. Present allocated water for water supply is used for the Eastern Province.
	Lake (Mugesera)		It is not clear how much extra water can be used for water supply in addition to the present permitted amount since there is no data related to catchment management plan.
Ground water	Springs	Low potential for development, also difficult to protect the recharge area due to the urbanization in the Study Area	Low development cost, need pipelines from spring sources to reservoir tank
	Boreholes (Deep Groundwater)	Development potential depends on the aquifer capacity. Occurrence of groundwater is within the fractured or weathered zone. Therefore, it is suitable for small scale water supply	In order to develop groundwater, aquifer condition has to be investigated and also production boreholes have to be constructed to extract the groundwater. In addition, borehole maintenance cost is needed regularly.

Source: JST

10.4 POLICY OF WATER RESOURCE DEVELOPMENT FOR WATER SUPPLY

The main water sources during this period are (1) river water taken from the Nyabarongo and Akagera Rivers and (2) groundwater taken from the flood plain of the Nyabarongo River and Akagera River. Therefore, the development area is within Kigali. Groundwater is relatively easy for the treatment compared to river water. It may be able to extract more groundwater than the planned amount. Therefore, groundwater will be developed first to supply to the existing or new water treatment plants. However, there are some problems on the usage of groundwater such as accessibility during the rainy season, the change in river course and O&M of boreholes. Especially about the O&M of boreholes, it is necessary for the WASAC staff to carry out the training in order to ensure capacity development about the knowledge of hydrogeology, borehole hydraulics and groundwater investigation.

10.5 WATER RESOURCES MANAGEMENT FOR WATER SUPPLY

Various water sources such as river, lake and groundwater are being used for water supply in the Study Area. The management of water resources (implementation and exploitation of resources development works) are currently being conducted by several private users but implemented without considering other demand which may easily lead to conflicts and sub optimal use of scarce resources, both of which are largely preventable (NWRMP). Therefore, in order to maintain those sources, it is important to carry out a proper water resources management and monitoring both by the regulatory agency and by each water user including WASAC. **Table 10.5-1** shows the possible water resources management actions taken in catchment scale and water source scale.

Table 10.5-1 Water Resources Management Plan for Catchment and Source Scale

	Result of water use by the Study Area's water supply	**Management actions for sustainability of water resources**	
		Regulatory agency of WRM (RWB)	**Water users**
Catchment scale	27% of renewable water source will be used by water supply in 2050.and 68% will consumed by all water users in 2050	Monitoring of rainfall resource, surface water resource, groundwater resource, interventions in the natural hydrological cycle such as water abstraction by water users.	-
Individual source scale	Amount of water for individual water source used by water supply can sustain water resources after the development		Measurement of amount of water to extract (pumping rate), monitoring water quality

Source: JST

One of the obligations of water users is to inform the management (regulatory) authority at regular time interval on the user's intervention (volumes abstracted, released, water quality changes, etc.) **Table 10.5-2** shows the management plan of each water source.

Table 10.5-2 Water Resources Management Plan for each Source

Category at Hydrological Cycle	**Source**	**Management Tasks of Water User**	**Management Tasks of Regulatory Agency of WRM (RWB)**
Surface Water	River (the Nyabarongo/ Akagera)	Monitoring the abstraction rate and not to exceed the permitted amount, regular monitoring of water quality and river water level at intake place, inform the result to management authority	Monitoring water usage of all water users and check the flow rate and inform permitted users in the event of any change
	River (the Yanze)		
	Lake (the Muhazi)	Check pumping rate and not to exceed the permitted amount, regular monitoring of water level and water quality of lake, inform the result to management authority	Monitoring water usage of all water users, and water level
	Lake (the Mugesera)		Formulate catchment management plan for the Mugesera/ Sake and estimate amount of renewable water of the lake
Groundwater (sub-surface water)	Boreholes at the Nybarongo./ Akagera River	Monitoring pumping rate regularly and not to exceed safe yield of each borehole. Regular monitoring of water lever and quality and inform the result to management authority	Monitoring water usage of water users and groundwater level. If over extraction is observed, inform users to reduce the abstraction.
Groundwater	Boreholes for small scale WSS	Monitoring flow rate regularly and inform the RWFA in the event of any change, regular monitoring of water quality	Monitoring water usage of all water users.
	Springs for small scale WSS		

Source: JST

10.6 ADAPTATION MEASURES AGAINST CLIMATE CHANGE (FLOODING AND DROUGHTS)

Higher temperatures, prolonged droughts, and elevated rates of evapotranspiration have led to disturbances in the hydrologic cycle and altered river flows. Climate change-associated temperature increases, and precipitation variability may exacerbate negative impacts on lakes, rivers, and other important sources of water. This can have implications on the availability of water for distribution by utilities, such as those serving the Study Area, which are already struggling to meet user needs. Water sources for the Study Area are heavily depended on the Nyabarongo / Akagera River origin. It is known that the Nyabarongo River Flow is directly related to rainfall more than anthropogenic water abstractions and such conditions indicate that the Nyabarongo catchment's hydrology is vulnerable to any change in climate. It is characterized that very high peak flows during rainy days cause destructive flood followed by prolonged drought periods (REMA, 2018). **Table 10.6-1** shows the vulnerability and adaptation against flood and drought.

Table 10.6-1 Adaptation Measures of Water Resources against Flooding and Drought

Climate Indicator	Impacts & vulnerability	Actions to be taken
Warmer temperatures, prolonged droughts, and higher evapotranspiration.	Less renewable water resources cause reduced production of maize and beans, livestock losses, and shortage of water for water supply	Increase water efficiently, Promote rainwater harvesting at household level, Expansion of water storage and conservation technique
Changes in rainfall timing and amount	Increased flood and landslide frequency contributing to erosion, which can hamper agricultural production and destroy crops.	Flood protection improved by the construction of dikes and improving drainage. Construction of embankment along river banks.

Source: JST

CHAPTER 11 SOCIO-ECONOMIC SURVEY

11.1 OVERVIEW

This Study is trying to figure out customer's potential needs and implementation strategy for improving service level of the water supply service through a socio-economic survey. The target area was the CoK and its surrounding seven (7) sectors, namely Shyorongi (Rulindo District), Runda, and Rugarika (Kamonyi district), Natarama (Bugesera District), Muyumbu, Gahengeri, and Nyakaliro (Rwamagana district). To evaluate potential needs the survey focused on the following:

- To assess difference of socio-economic condition of the population between water-supply provisions are in existence and non-existence,
- To assess willingness to connect, willingness to pay, and customer satisfaction for the water-supply services,
- To identify and assess conditions of the existing water-supply service level including water quality

11.1.1 Socio-Economic Survey Implementation

The Study was implemented by the following steps:

1. Preparatory Works (Literature survey, Preparation of Questionnaire, and Sampling Plan)
2. Submission of Plan of Implementation (Application of visas required by NISR)
3. Actual Socio-economic Survey (Identification of water sources)
4. Water sampling and water quality survey

11.1.2 Preparatory Work

To carry out the socio-economic survey, JST had to acquire visas from NISR. The major portion of the preparatory work was to prepare the socio-economic survey's plan duly complying with requirements given by NISR. The major part of the consideration was to have consistency with the existing survey. For such purposes, JST had considered the Fifth Integrated Household Living Survey (hereafter EICV5) as a reference for the survey.

(1) Literature Survey

A literature survey was carried out to collect present baseline information on the socio-economic and social characteristics of the existing situation of the targeted population. The major part of the baseline information was referring to the EICV5 and the Fourth Population and Housing Census (hereafter PHC) as well.

(2) Making Questionnaire

The questionnaire was intended to figure out the following socio-economic characteristics of the population (difference of socio-economic conditions between water supply provision in existence area

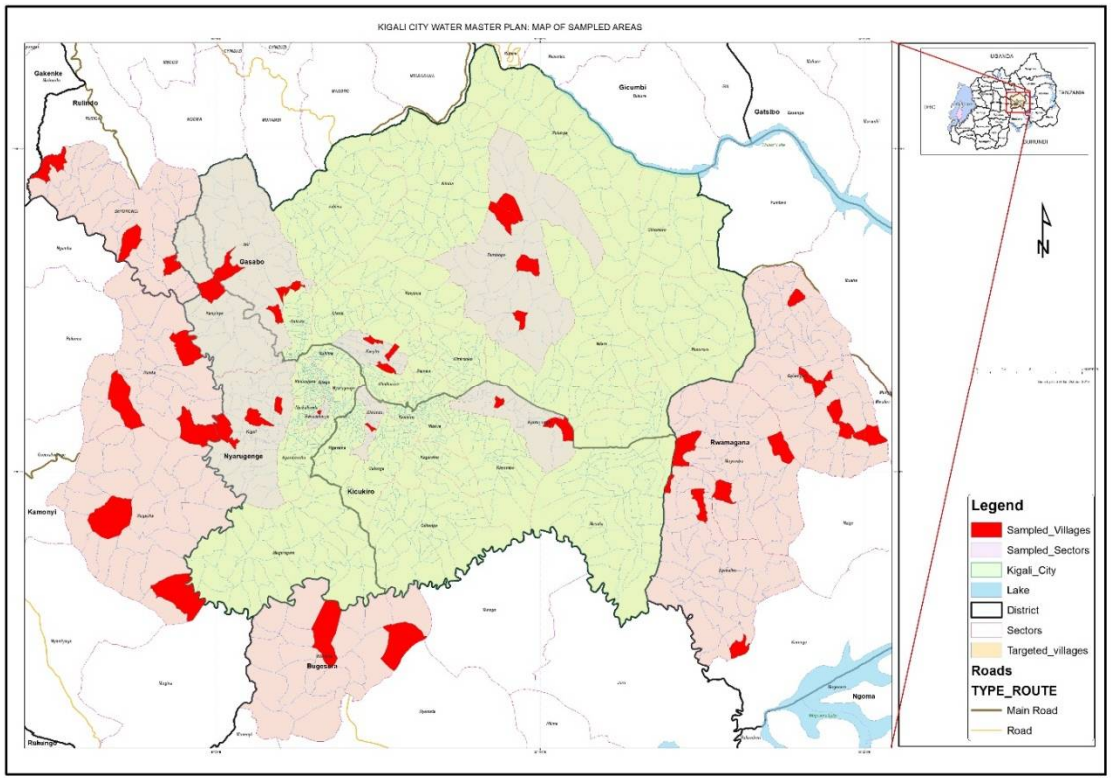
and non-existence area). In addition, it mostly followed questions used in the EICV5.

- Water usage (volume, distance to the water source, time consumption, water quality)
- Expenditures for water usage and other tariffs (drinking water source, water source for other usage, expenditures for water use, tariff for other utilities such as gas, electricity, communication)
- Economic conditions of households and their head (Occupation, income, side business, income from a side business, family member, the composition of household expenditure, education level, gender, water drawing labor (hours, times, and bearer))
- Health conditions (experience of health complaint, waterborne disease, nutritional deficiency)
- Willingness for water-supply service (willingness to connect, willingness to pay, satisfaction to the water-supply service, request)
- Condition of current water-supply service (water-supply non-existing area: water quality of water source, water-supply area: water pressure, restriction of water supply hours)

(3) Prepare Sampling Plan

In the urbanized area of the CoK, most of the households have access to improved water sources. Therefore, to capture households without access to improved water, households were sampled from sectors where access to the improved water sources is relatively low according to the PHC. The followings are the overall conditions for samplings.

- Around hundred twenty (120) samples were collected from lower access to improved water area in the CoK
- Around eighty (80) samples were collected from higher access to improved water area in the CoK, and
- Around thirty (30) samples were collected in each seven (7) surrounding sectors



Source: JST

Figure 11.1-1 Location of Sampled Sectors/Villages in the Study Area

Terms rural and urban used in the survey refers to the classification provided by the 4th General Population and Housing Census (2012) where classifying administrative area by village level. To be classified as urban, a village has to fulfil two main criteria of possessing: (1) an important built-up area and (2) Important infrastructures (education facilities, electricity, and water, markets, banks, and other financial institutions).

Table 11.1-1 Target Population (HHs) and Sample Size

Location	Access to Improved Water Sources	Sectors	Number of HHs	Sampled HHs	Number of Villages			Main source of water	
					Total	Urban	Rural	Improved water source %	Unimproved water source %
Kigali City	Ranked Higher Access to Improved Water Sources	Gikondo	4,227	10	19	19	0	92.2	8
		Kacyiru	9,095	30	32	32	0	96.6	3
		Nyarugunga	8,903	30	28	28	0	98.3	2
		Rwezamenyo	4,256	10	15	15	0	98.8	1
		Sub-Total	**26,481**	**80**	**94**	**94**	**0**	**96.5**	**3.5**
	Ranked Low Access to Improved Water Sources (Access to unproved Source of Water	Jali	6,065	30	33	4	29	47.2	53
		Kanyinya	5,760	10	20	0	20	58.3	42
		Bumbogo	9,624	40	43	3	40	68.5	32
		Kigali	8,116	40	48	2	46	78	22
		Sub-Total	**29,565**	**120**	**144**	**9**	**135**	**63.0**	**37.1**
	Total/Average		**56,046**	**200**	**238**	**103**	**135**	**79.7**	**20.3**
Sectors Surrounding Kigali City	Ranked Low Access to Improved Water Sources (Access to unproved Source of Water	Ntarama	4,827	20	22	0	22	26.5	73.5
		Gahengeri	5,575	40	47	0	47	40	60.1
		Shyorongi	5,774	40	40	5	35	63.2	36.7
		Rugarika	8,510	20	28	0	28	66.7	33.3
		Muyumbu	6,058	30	35	0	35	66.9	33
		Runda	8,272	30	26	7	19	67.7	32.4
		Nyakaliro	4,841	30	38	0	38	76.9	23.2
	Total/Average		**43,857**	**210**	**236**	**12**	**224**	**58.3**	**41.7**
Grand Total/Average			**99,903**	**410**	**474**	**115**	**359**	**69.0**	**31.0**

Source: 4th PHC 2012 (NISR, 2014);

(4) Interviewing and Water Quality Testing

As per the survey plan, data collection shall be carried out through the interview survey conducted in each sampled household. At each household, respondent sat together with the surveyor. The surveyor read and explained the questions. Respondent was verbally asked to answer which were duly filled out by the Surveyor in the questionnaire. In addition, the surveyor was asked to collect information regarding location of water source.

11.1.3 Socio-economic Survey in the CoK

In accordance with the survey plan, actual survey (interview survey) was carried out in the CoK and its surrounding 7 Sectors. Following **Table 11.1-2** shows detail of survey schedule.

Table 11.1-2 Overall Schedule

Date	Work Item	Remark
May 2019	Preparation (Sampling Plan etc.)	
June – July 2019	Visa Application	
August 2019	Survey	Interview survey
August 2019	Data Entry	
September 2019	Data Validation	
October - November 2019	Reporting	

Source: JST

11.1.4 Sampling of Water and Water Quality Survey

Following **Table 11.1-3** shows detail of survey schedule that was carried out in the CoK and its adjacent 7 Sectors.

Table 11.1-3 Schedule of Water Quality Survey

Date	Work Item	Remark
August 2019	Sampling Plan	Identify water source from interview
4th - 5th September 2019	Sampling	
September 2019	Testing	

Source: JST

11.2 RESULT OF SOCIO-ECONOMIC SURVEY

When the JST was preparing the sampling plan, it selectively chooses population who doesn't have access to an improved water source. Expected households' access to improved water was in between 69.0% from the 4th PHC 2012 (NISR, 2014) and 85.4% rural in the EICV5. The actual result survey (81.3%) matched with this expectation.

11.2.1 Status of the Population

Status of the household captured in this survey is summarized as follows;

- Population who has access to improved water are:
  - Urban area 98.0% while it was mentioned 95.8% in EICV5
  - Rural area 75.8% while it was mentioned 85.4% in EICV5
- Distribution of socio-economic categories (Ubudehe categories) are almost same in all areas, who has access to improved water, and who has not
  - Category 1: 8.3% Families who do not own a house and can hardly afford basic needs.
  - Category 2: 35.0% Those who have a dwelling of their own or are able to rent one but rarely get full time job.
  - Category 3: 53.6% Those who have a job and farmers who go beyond subsistence farming to produce a surplus which can be sold. In addition, small and medium enterprises who can provide employment to dozens of people.
  - Category 4: 1.5% Those who own large-scale business, individuals working with international organizations and industries as well as public servants.
- Mean size of households is bigger 5.2 compared with 4.0 EICV5 of Kigali City.
- Net attendance rate in Secondary School is 17.7% which is lower than 23.2% in EICV5. In addition, the rate for people who doesn't have access to improved water was 7.8% (12.2 point lower than those who does have access).
- Main income generating activities in Farming (Farming + Livestock) 50.0%. It is higher than 17.2% in EICV5 of Kigali City. It is higher 67.5% for who doesn't have access to improved water.

- Overall average household annual expense is 558 (Thousand RWFs) while EICV5 of the CoK was 597 (Thousand RWFs). Households that have access to improved water is 629 (thousand RWFs) and don't have access to improved water is 241 (thousand RWFs).
- Households type of habitat is 26.0% Isolated rural housing, unplanned clustered rural housing 43.0%, Unplanned urban housing 23.3%, other model villages, modern planned area, Umudugudu small settlement was 7.7%.

11.2.1.1 Access to Improved Water

By area, 98.0% of urban households have access to the improved drinking water source and they are mostly piped into dwelling/piped to yard/Plot (78.4%). However, EICV5 2016/2017 mentions the corresponding % of 95.9% and 34.0% respectively. Therefore, connection to dwelling/piped to yard/plot has shown rapid progress.

In peri-urban Area sectors, access to improved water is 78.0% and their main source of water is protected spring (26.3%) and public tap (25.8%). This is rather similar to the % mentioned in the EICV5 2016/2017 of the rural area which is 85.4%, 33.9% and 45.0% respectively. Each rate is lower, especially for the public tap. This gap may be caused due to a rapid increase in residential areas and delay of expansion of water supply service.

Under this survey, 77 nos. of households were found to have no access to improved water. They were getting water from unprotected springs (58.4%), surface water (31.2%), and 10.4% were getting water from unprotected wells.

Table 11.2-1 Percentage (%) of Households by Type Improved Drinking Source of Water

		Improved (include others)								Unimproved			
	% of HHs with access to Improved	Other (specify)	Piped into Dwelling/Piped to Yard/Plot	Protected Spring.	Protected Well	Public Tap/Standpipe	Tanker Truck	Tube Well /Borehole	Count Total HHs with access to Improved	Surface Water (River /Lake/Pond/Stream / Irrigation Channel).	Unprotected Spring	Unprotected Well.	Total Sample
All area	81.31	4.85	26.94	19.42	1.46	25.73	0.73	2.18	335	5.83	10.92	1.94	412
Urban/rural													
Rural	75.81	3.55	10.00	25.48	1.94	30.97	0.97	2.90	235	7.74	13.87	2.58	310
Urban	98.04	8.82	78.43	0.98	0.00	9.80	0.00	0.00	100	0.00	1.96	0.00	102
Sex HH Head													
Female	83.70	4.35	26.09	17.39	1.09	31.52	1.09	2.17	77	3.26	11.96	1.09	92
Kigali City/peri-urban area Kigali City/peri-urban area (sectors)													
CoK sectors	84.73	7.39	35.47	12.32	0.99	25.62	0.99	1.97	172	3.45	8.87	2.96	203
Peri-urban Area sectors	77.99	2.39	18.66	26.32	1.91	25.84	0.48	2.39	163	8.13	12.92	0.96	209
Quantiles													
Q1	66.67	9.20	11.49	26.44	1.15	18.39	0.00	0.00	58	13.79	16.09	3.45	87
Q2	67.50	5.00	12.50	22.50	0.00	27.50	0.00	0.00	54	10.00	18.75	3.75	80
Q3	87.36	3.45	20.69	20.69	3.45	33.33	1.15	4.60	76	1.15	10.34	1.15	87

	% of HHs with access to Improved	Improved (include others)								Unimproved			Total Sample
		Other (specify)	Piped into Dwelling/Piped to Yard/Plot	Protected Spring.	Protected Well	Public Tap/Standpipe	Tanker Truck	Tube Well /Borehole	Count Total HHs with access to Improved	Surface Water (River /Lake/Pond/Stream / Irrigation Channel).	Unprotected Spring	Unprotected Well.	
Q4	89.80	4.08	32.65	16.33	1.02	29.59	1.02	5.10	88	3.06	7.14	0.00	98
Q5	98.33	1.67	68.33	8.33	1.67	16.67	1.67	0.00	59	0.00	0.00	1.67	60
Source of Water (Drink)													
Improved	100.00	5.97	33.13	23.88	1.79	31.64	0.90	2.69	335	0.00	0.00	0.00	335
Not Improved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.17	58.44	10.39	77
Settlement													
Isolated rural housing	74.77	4.67	8.41	15.89	3.74	37.38	0.93	3.74	80	4.67	15.89	4.67	107
Model Village	100.00	0.00	100.00	0.00	0.00	0.00	0.00	0.00	14	0.00	0.00	0.00	14
Modern planned area	100.00	50.00	50.00	0.00	0.00	0.00	0.00	0.00	2.00	0.00	0.00	0.00	2
Umudugudu/ Small Settlement	93.75	0.00	25.00	18.75	0.00	37.50	6.25	6.25	15	0.00	6.25	0.00	16
Unplanned clusted rural housing	75.14	2.26	11.86	31.64	1.13	25.99	0.56	1.69	133	9.60	14.12	1.13	177
Unplanned urban housing	94.79	10.42	64.58	4.17	0.00	14.58	0.00	1.04	91	2.08	2.08	1.04	96

Source: Socio-economic survey, July 2019

11.2.1.2 Social Classification (Ubudehe Category)

Under this survey, households were classified according to their Ubudehe categories. The word Ubudehe refers to the long-standing Rwandan practice and culture of collective action and mutual support to solve problems within a community. Today, the concept has been translated into a home-grown development program whereby citizens are placed into different categories. These categories inform the level of support families receive through government social protection programs. In 2014, the Local Administrative Entities Development Agency created new Ubudehe categories. Under the program, households are put in categories based on their social-economic status, and their property – in terms of land and other belongings – and what the families' business to earn a living. The categories are as follows:

- Category 1: Families who do not own a house and can hardly afford basic needs.
- Category 2: Those who have a dwelling of their own or are able to rent one but rarely get full-time jobs.
- Category 3: Those who have a job and farmers who go beyond subsistence farming to produce a surplus that can be sold. The latter also includes those with small and medium enterprises who can provide employment to dozens of people.
- Category 4: Those who own large-scale businesses, individuals working with international organizations and industries as well as public servants.

Survey results show that, in terms of the Ubudehe category, 8.3% are in category1 socio-economic

categories (Ubudehe), 35.0% in category2, 53.6% category3, 1.5% category4, 1.2% do not know and 0.5% were not found on the list. This distribution can be evenly seen in most of the groups. However, category 4 households were only seen in the urban area or the CoK Sectors.

Table 11.2-2 Distribution of Households According to Their Location

	Sex of Household Head			Households Socio-economic categories							General %	Count Total Sample
	Female	Male	Total	Category 1	Category 2	Category 3	Category 4	Don't know	Not found on list	Total		
All area	**22.33**	**77.67**	**100.00**	**8.25**	**34.95**	**53.64**	**1.46**	**1.21**	**0.49**	**100.00**	**100.00**	**412**
Urban/Rural Area												
Rural	22.26	77.74	100.00	8.71	38.39	51.94	0.00	0.32	0.65	100.00	75.24	310
Urban	22.55	77.45	100.00	6.86	24.51	58.82	5.88	3.92	0.00	100.00	24.76	102
Kigali City/peri-urban area												
CoK sectors	23.15	76.85	100.00	10.84	38.42	46.31	2.96	0.99	0.49	100.00	49.27	203
Peri-urban Area sectors	21.53	78.47	100.00	5.74	31.58	60.77	0.00	1.44	0.48	100.00	50.73	209
Access to water (Drink)												
Improved	22.99	77.61	100.00	8.66	34.63	52.84	1.79	1.49	0.60	100.00	81.31	335
Not Improved	22.48	77.52	100.00	6.49	36.36	57.14	0.00	0.00	0.00	100.00	18.69	77

Source: Socio-economic survey, July 2019

11.2.1.3 Household Size

In this survey, the mean household size of the CoK is 5.4 persons per household. It is larger than 4.0 persons per household as mentioned in the CoK 's EICV5. In general, households in urban areas are relatively small. Especially for 1 person households, they can run the household by themselves which may be due to a higher income and better utility services.

In the EICV5 household's income become smaller and the size of the household become bigger. These overall trends were not seen in this survey. This may indicate that the survey captured relatively lower-income people while selectively choosing samples from lower water supplied areas.

When it comes to access to improved water, the mean household size is 5.2 while it is 5.0 for households with no access to improved water. However, the distribution of household size seems almost the same in both categories. Therefore, basically due to the selective sampling method, this survey result is considered as representing a relatively poor household.

Table 11.2-3 Size of Households in Project in the CoK and Surrounding Sectors

EICV5	Household Size						Total	Total Sample
	Mean	1	2-4	5-7	8-10	>11		
All Area	**5.19**	**2.43**	**37.86**	**45.39**	**13.59**	**0.73**	**100.00**	**412**
Urban/rural								
Urban	5.22	1.96	36.27	48.04	12.75	0.98	100.00	102
Rural	5.18	2.58	38.39	44.52	13.87	0.65	100.00	310
Kigali City/peri-urban area (Sectors)								
CoK sectors	5.37	1.97	32.51	49.75	14.78	0.99	100.00	203
Peri-urban Area sectors	5.02	2.87	43.06	41.15	12.44	0.48	100.00	209
Sex of HH Head								
Male	5.38	1.25	34.69	49.06	14.38	0.63	100.00	320
Female	4.54	6.52	48.91	32.61	10.87	1.09	100.00	92
Quintile								
Q1	4.74	3.45	45.98	37.93	12.64	0.00	100.00	87
Q2	4.61	5.00	40.00	47.50	7.50	0.00	100.00	80
Q3	5.17	2.30	37.93	47.13	12.64	0.00	100.00	87
Q4	5.47	1.02	40.82	38.78	17.35	2.04	100.00	98
Q5	6.20	0.00	18.33	61.67	18.33	1.67	100.00	60
Water Source								
Improved	5.24	2.39	38.21	45.37	12.24	1.79	100.00	335
Not Improved	4.99	2.60	36.36	45.45	15.58	0.00	100.00	77

Source: Socio-economic survey, July 2019

11.2.1.4 Education Level of Head of Household

The EICV5 results state that the net attendance rate of secondary school is 23.2%. Under this survey, it was observed that the rate was even lower (any University level and complete secondary) which was 17.7%. The rate becomes much lower when household doesn't have access to improved water (7.9%).

The TVET Programme (Technical and Vocational Education and Training Programme) is an education, training and learning activity leading to the acquisition of knowledge, understanding and skills which are relevant for employment or self-employment.

Table 11.2-4 Education Level of Head of Household

	Any University level	Complete Secondary	Incomplete secondary	Complete Primary	Incomplete primary	Non-Formal education	TVET	Total	Count (Total Sample)
All area	**8.98**	**8.74**	**8.74**	**33.98**	**23.54**	**14.08**	**1.94**	**100.00**	**412**
Rural/Urban									
Rural	2.58	5.81	8.39	40.32	25.16	15.81	1.94	100.00	310
Urban	28.43	17.65	9.80	14.71	18.63	8.82	1.96	100.00	102
Sex HH Head									
Female	3.26	10.87	5.43	35.87	21.74	19.57	3.26	100.00	92
Male	10.63	8.13	9.69	33.44	24.06	12.50	1.56	100.00	320
Kigali City/peri-urban area (Sectors)									
CoK sectors	13.30	10.84	10.34	30.54	18.23	13.79	2.96	100.00	203
Peri-urban Area sectors	4.78	6.70	7.18	37.32	28.71	14.35	0.96	100.00	209
Quantiles									
Q1	2.30	3.45	8.05	32.18	29.89	22.99	1.15	100.00	87
Q2	0.00	5.00	7.50	38.75	30.00	16.25	2.50	100.00	80
Q3	4.60	6.90	8.05	39.08	21.84	17.24	2.30	100.00	87
Q4	8.16	11.22	12.24	38.78	22.45	7.14	0.00	100.00	98
Q5	38.33	20.00	6.67	15.00	10.00	5.00	5.00	100.00	60
Source of Water (Drink)									
Improved	10.45	9.55	8.36	32.24	22.99	14.03	2.39	100.00	335
Not Improved	2.60	5.19	10.39	41.56	25.97	14.29	0.00	100.00	77

Source: Socio-economic study, July 2019

11.2.1.5 Main Source of Income

In Urban areas, the main income generating activity is full time employment (34.3%) while the same is only 11.3% in rural areas. In rural areas, the main income generating activity is farming which occupies 59.7% of rural sampled households. Farming occupies only 10.8% in urban areas. Further, results show that in per-urban area, farming is still the main income generating activity (56.5%).

On the other hand, the main income generating activity for households having no access to improved water is also farming (61.0%). Its distribution is basically same as in rural areas.

Table 11.2-5 Percentage of Households by Main Source of Income (%)

	Main Income generating activity								Count total Sample
	Employed (full time)	Employed (part time)	Farming Activities (Rice, fruits, vegetables, ,…..)	Livestock	Odd job	Others (specify)	Own business	Total	
All area	**16.99**	**0.49**	**47.57**	**2.43**	**17.96**	**5.10**	**9.47**	**100.00**	**412**
Urban/rural									
Rural	11.29	0.00	59.68	3.23	16.77	1.94	7.10	100.00	310
Urban	34.31	1.96	10.78	0.00	21.57	14.71	16.67	100.00	102
Sex HH Head									
Female	3.26	1.09	54.35	1.09	20.65	7.61	11.96	100.00	92
Male	20.94	0.31	45.63	2.81	17.19	4.38	8.75	100.00	320
Kigali City/peri-urban area (Sectors)									
CoK sectors	22.17	0.49	38.42	2.46	19.21	6.90	10.34	100.00	203
Peri-urban Area sectors	11.96	0.48	56.46	2.39	16.75	3.35	8.61	100.00	209
Quantiles									
Q1	4.60	0.00	70.11	1.15	17.24	2.30	4.60	100.00	87
Q2	3.75	0.00	63.75	5.00	21.25	2.50	3.75	100.00	80
Q3	14.94	0.00	50.57	1.15	24.14	2.30	6.90	100.00	87
Q4	19.39	2.04	34.69	4.08	15.31	9.18	15.31	100.00	98
Q5	51.67	0.00	10.00	0.00	10.00	10.00	18.33	100.00	60
Source of Water (Drink)									
Improved	17.91	0.60	44.48	1.49	19.10	6.27	10.15	100.00	335
Not Improved	12.99	0.00	61.04	6.49	12.99	0.00	6.49	100.00	77

Source: socio-economic survey, July 2019

11.2.1.6 Household Expenditure

The survey results show that the average monthly consumption in surveyed households is 46,474 Rwfs per month per household, which makes 557,688 per year. This is almost the same amount as mentioned in Kigali City EICV5 (597 thousand Rwfs per year)

In rural areas, average household consumption is 31,335 Rwfs per month compared to 93,255 Rwfs in urban areas. It is similar to access to improved water while households who don't have access earn 20,073 Rwfs per month but for who have access earn 52,403 Rwfs per month. Median of the monthly expenses is considered as in between 17,000 Rwf and 29,000 Rwf.

Table 11.2-6 Monthly Expenses of Households

	Average HH Monthly Expenses	Monthly Expenses							Count Total Sample
		0 - 30000	30000 - 50000	50000 - 80000	80000 - 160000	>=160000	Not Specified	Total	
All area	46,474	42.23	28.40	16.50	8.74	3.40	0.49	99.76	412
Urban/rural									
Rural	31,335	49.68	28.71	15.48	5.48	0.32	0.32	100.00	310
Urban	93,255	19.61	27.45	19.61	18.63	12.75	0.98	99.02	102
Sex HH Head									
Female	37,707	50.00	28.26	14.13	5.43	2.17	0.00	100.00	92
Male	49,019	40.00	28.44	17.19	9.69	3.75	0.63	99.69	320
Kigali City/peri-urban area (Sectors)									
CoK sectors	62,748	38.42	25.62	18.72	11.82	3.94	0.99	99.51	203
Peri-urban Area sectors	39,853	45.93	31.10	14.35	5.74	2.87	0.00	100.00	209
Quantiles									
Q1	6,199	96.55	0.00	0.00	0.00	0.00	2.30	98.85	87
Q2	16,928	100.00	0.00	0.00	0.00	0.00	0.00	100.00	80
Q3	29,609	11.49	88.51	0.00	0.00	0.00	0.00	100.00	87
Q4	50,888	0.00	40.82	59.18	0.00	0.00	0.00	100.00	98
Q5	159,500	0.00	0.00	16.67	60.00	23.33	0.00	100.00	60
Source of Water (Drink)									
Improved	52,403	34.93	31.04	18.51	10.45	4.18	0.60	99.70	335
Not Improved	20,073	74.03	16.88	7.79	1.30	0.00	0.00	100.00	77

Source: Socio-economic survey, July 2019

11.2.1.7 Type of Habitat

Results from the survey shows that 26.0% are living in isolated settlement, 3.4% in model village, 0.5% in modern planned area, 3.9% in Umudugudu/ small settlement, 43.0% in unplanned clustered rural housing and 23.3% are living in unplanned urban housing.

In urban areas, most households are living in unplanned urban housing (70.6%). While in rural areas, most of household are living in unplanned clustered rural housing (53.6%). A big share of households in the Sectors are living in unplanned urban housing (43.4%) compared to household in peri-urban sectors where a big share is living in unplanned clustered rural settlement.

In terms of improved water inaccessibility, 57.1% of household are living in unplanned clustered rural housing and 35.1% in isolated rural housing 35.1%.

Table 11.2-7 Distribution (%) of Households by Type of Habitat

	Isolated rural housing	Model Village	Modern planned area	Umudugudu/ Small Settlement	Unplanned clustered rural housing	Unplanned urban housing	Total	Total Sample
All area	**25.97**	**3.40**	**0.49**	**3.88**	**42.96**	**23.30**	**100.00**	**412**
Urban/rural								
Rural	34.52	0.00	0.32	3.87	53.55	7.74	100.00	310
Urban	0.00	13.73	0.98	3.92	10.78	70.59	100.00	102
Sex HH Head								
Female	26.09	1.09	0.00	7.61	38.04	27.17	100.00	92
Male	25.94	4.06	0.63	2.81	44.38	22.19	100.00	320
Kigali City/peri-urban area (Sectors)								
CoK sectors	22.66	5.91	0.99	3.94	23.15	43.35	100.00	203
Peri-urban Area sectors	29.19	0.96	0.00	3.83	62.20	3.83	100.00	209
Quantiles								
Q1	22.99	0.00	1.15	1.15	57.47	17.24	100.00	87
Q2	28.75	0.00	0.00	3.75	57.50	10.00	100.00	80
Q3	39.08	1.15	0.00	3.45	37.93	18.39	100.00	87
Q4	23.47	2.04	0.00	4.08	37.76	32.65	100.00	98
Q5	11.67	18.33	1.67	8.33	18.33	41.67	100.00	60
Source of Water (Drink)								
Improved	23.88	4.18	0.60	4.48	39.70	27.16	100.00	335
Not Improved	35.06	0.00	0.00	1.30	57.14	6.49	100.00	77

Source: Socio-economic survey, July 2019

According to the EICV5 results, single house dwelling comprises 88.9% and this type of dwelling is more common in rural areas (95.9%) than in urban areas (59.4%). Results from this survey shows that 14.3% of assessed households are living in shared dwelling and 85.7% are living in single occupied by one household dwelling.

Household in rural areas comprise of single occupied house (89.4%) and shared house (10.7%). In comparison, single occupied house in urban areas comprise of 74.5% and 25.5% as shared house. The survey results also show that 16.8% of households in the Sectors are living in shared house and 12.0% for peri-urban area sectors.

Households without access to improved drinking water source are mostly living in single house and only 15.6% of household are living in shared house.

Table 11.2-8 Dwelling Stand-Alone/Shared and Number of HH Shared

		A house occupied by multiple households							
	% of Single house occupied by one household dwelling	% of households living in a house occupied by multiple HHs	2-4	5-7	>7	Total	Count Total multiple HHs	Single house occupied by one household dwelling	Total Sample
All area	**85.68**	**14.32**	**77.97**	**15.25**	**6.78**	**100.00**	**59**	**353**	**412**
Urban/rural									
Rural	89.35	10.65	90.91	6.06	3.03	100.00	33	277	310
Urban	74.51	25.49	61.54	26.92	11.54	100.00	26	76	102
Sex HH Head									
Female	82.61	17.39	75.00	18.75	6.25	100.00	16	76	92
Male	86.56	13.44	79.07	13.95	6.98	100.00	43	277	320
Kigali City/peri-urban area (Sectors)									
CoK sectors	83.25	16.75	73.53	20.59	5.88	100.00	34	169	203
Peri-urban Area sectors	88.04	11.96	84.00	8.00	8.00	100.00	25	184	209
Quantiles									
Q1	96.55	3.45	100.00	0.00	0.00	100.00	3	84	87
Q2	81.25	18.75	86.67	0.00	13.33	100.00	15	65	80
Q3	86.21	13.79	75.00	25.00	0.00	100.00	12	75	87
Q4	81.63	18.37	61.11	27.78	11.11	100.00	18	80	98
Q5	81.67	18.33	90.91	9.09	0.00	100.00	11	49	60
Source of Water (Drink)									
Improved	78.51	21.49	55.56	12.50	4.17	100.00	72	263	335
Not Improved	84.42	15.58	50.00	0.00	8.33	100.00	12	65	77
Settlement									
Isolated rural housing	90.65	9.35	100.00	0.00	0.00	100.00	10	97	107
Model Village	92.86	7.14	100.00	0.00	0.00	100.00	1	13	14
Modern planned area	100.00	0.00	0.00	0.00	0.00	0.00	0	2	2
Umudugudu/ Small Settlement	81.25	18.75	100.00	0.00	0.00	100.00	3	13	16
Unplanned clusted rural housing	90.40	9.60	88.24	5.88	5.88	100.00	17	160	177
Unplanned urban housing	70.83	29.17	60.71	28.57	10.71	100.00	28	68	96

Source: socio-economic stud, July 2019

11.2.2 Accessibility and Service Level of Water Supply

Accessibility and service level of water supply is considered as following;

- Source of water is basically same for both drinking water and water for domestic use.
- Distance to fetch water
  - Urban area, available water source is very near (less than 100m).
  - Rural area, average household fetch water from almost 500m away.
  - Household who doesn't have access to improved water fetch water from 1,000m away.
- Alternative water sources are mostly available for urban areas (75.4%), and less for rural areas (49.6%), very rare for no accessibility areas (27.2%)

- To fetch water each household spend 60 min or less time per day. This is common for almost all categories
- Fetching activity
  - In rural areas, it is borne by family members and percentage of Wife is relatively high (20%)
  - In urban areas, it is borne by housekeeper and sellers (outsourced) - 48.5%
- Usage:
  - Drinking water is 20 – 60 liters per day in almost all categories
  - Domestic water for rural and no access areas is 20 – 60 liters per day
  - Domestic water for urban areas is 60 – 120 liters per day
- Urban areas experience frequent water fluctuation (76.5%)

11.2.2.1 Source of Drinking Water and Domestic Water

Compared to **Table 11.2-1**, source of domestic water does not differ much from the source of drinking water. It means same water is used for both domestic use and drinking.

Table 11.2-9 Percentage (%) of Households by Type Improved Domestic Water

	Improved (include others)							Unimproved			
	Other (specify)	Piped Into Dwelling/Piped to Yard/Plot	Protected Spring.	Protected Well	Public Tap/Standpipe	Tanker Truck	Tube Well /Borehole	Surface Water (River /Lake/Pond/Stream / Irrigation Channel).	Unprotected Spring	Unprotected Well.	Count Total Sample
All area	4.85	26.94	19.42	1.46	25.73	0.73	2.18	5.83	10.92	1.94	412
Urban/rural											
Rural	3.55	10.00	25.48	1.94	30.97	0.97	2.90	7.74	13.87	2.58	310
Urban	8.82	78.43	0.98	0.00	9.80	0.00	0.00	0.00	1.96	0.00	102
Sex HH Head											
Female	4.35	26.09	17.39	1.09	31.52	1.09	2.17	3.26	11.96	1.09	92
Male	5.00	27.19	20.00	1.56	24.06	0.63	2.19	6.56	10.63	2.19	320
Kigali City/peri-urban area											
CoK	7.39	35.47	12.32	0.99	25.62	0.99	1.97	3.45	8.87	2.96	203
Peri-urban Area	2.39	18.66	26.32	1.91	25.84	0.48	2.39	8.13	12.92	0.96	209
Quantiles											
Q1	9.20	11.49	26.44	1.15	18.39	0.00	0.00	13.79	16.09	3.45	87
Q2	5.00	12.50	22.50	0.00	27.50	0.00	0.00	10.00	18.75	3.75	80
Q3	3.45	20.69	20.69	3.45	33.33	1.15	4.60	1.15	10.34	1.15	87
Q4	4.08	32.65	16.33	1.02	29.59	1.02	5.10	3.06	7.14	0.00	98
Q5	1.67	68.33	8.33	1.67	16.67	1.67	0.00	0.00	0.00	1.67	60
Source of Water (Drink)											
Improved	5.97	33.13	23.88	1.79	31.64	0.90	2.69	0.00	0.00	0.00	335
Not Improved	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31.17	58.44	10.3	77

	Improved (include others)							Unimproved			
	Other (specify)	Piped Into Dwelling/Piped to Yard/Plot	Protected Spring.	Protected Well	Public Tap/Standpipe	Tanker Truck	Tube Well /Borehole	Surface Water (River /Lake/Pond/Stream / Irrigation Channel).	Unprotected Spring	Unprotected Well.	Count Total Sample
										9	
Settlement											
Isolated rural housing	4.67	8.41	15.89	3.74	37.38	0.93	3.74	4.67	15.89	4.67	107
Model Village	0.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14
Modern planned area	50.00	50.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2
Umudugudu/ Small Settlement	0.00	25.00	18.75	0.00	37.50	6.25	6.25	0.00	6.25	0.00	16
Unplanned clusted rural housing	2.26	11.86	31.64	1.13	25.99	0.56	1.69	9.60	14.12	1.13	177
Unplanned urban housing	10.42	64.58	4.17	0.00	14.58	0.00	1.04	2.08	2.08	1.04	96

Source: Socio-economic survey, July 2019

11.2.2.2 Distance from Nearest Water Source

This study results show that in urban areas 93.1% of households are living within 200 meters from the nearest source of drinking water compared to 35.8% in rural areas. In urban areas, according to **Table 11.2-1,** Piped into Dwelling/Piped to Yard/Plot is dominant (78.4%). However, average distance from a household to the nearest drinking water source is 57.03 meters in urban areas.

Households in the CoK are living at an average distance of 281.48 m compared to 1,037.90 m for sectors in peri-urban area sectors. In the Sectors, more households (71.4%) are living in distance less or equal to 200 m while in peri-urban sectors more households are in distance less or equal to 500 m from drinking water source nearest to the households.

Households with having access to improved drinking water source are mostly living in distance less or equal 200 m (57.0%) while those without access to improved drinking water source in the same category has to travel long distance more than 500 m (70.1%).

Table 11.2-10 Percentage (%) of Households with Distance from Nearest Drinking Water Source

	Average	Less or equal 200 m	Less or equal 500 m	Above 500 m	Total	Count Total Sample
All area	665.20	50.00	61.17	38.83	100.00	412
Urban/rural						
Rural	865.31	35.81	49.68	50.32	100.00	310
Urban	57.03	93.14	96.08	3.92	100.00	102
Sex HH Head						
Female	661.97	53.26	67.39	32.61	100.00	92
Male	666.13	49.06	59.38	40.63	100.00	320
Kigali City/peri-urban area (sectors)						
CoK sectors	281.48	71.43	79.80	20.20	100.00	203
Peri-urban Area sectors	1037.90	29.19	43.06	56.94	100.00	209
Quantiles						
Q1	818.36	32.18	51.72	48.28	100.00	87
Q2	847.40	45.00	51.25	48.75	100.00	80
Q3	721.49	44.83	59.77	40.23	100.00	87
Q4	555.79	56.12	66.33	33.67	100.00	98
Q5	297.28	80.00	81.67	18.33	100.00	60
Source of Water (Drink)						
Improved	575.68	57.01	68.36	31.64	100.00	335
Not Improved	1054.68	19.48	29.87	70.13	100.00	77

Source: Socio-economic survey, July 2019

11.2.2.3 Time spent from and to the nearest water source in Case of water unavailability

The water is not always available at the nearest water source. The data obtained from 412 assessed households indicate that 20.9% use 30 min per day to find alternative water source in case water is unavailable, 17.0% use between 30 min to 60 min or an hour and 18.2% are using more than one hour.

In urban areas, household looking for alternative water source is 75.5%. 40.2% out of 75.5% of the households may find water using 30 min or less. However, % of households in rural areas looking for alternative source is 49.7%. Only 14.5% out of 49.7% of the household find water within 30 minutes in case water is unavailable to the near source. Compared with rural areas, people living in urban area have a better chance to find alternative water source.

Households without access to improved drinking water source who look for an alternative water source is 27.3%. Only 9.1% out of 27.3% can find alternative water source.

Table 11.2-11 Time spent (%) to Go and Come Back from the Nearest Water Sources in Case of Water Unviability (in Minutes)

	less or 30 Min	Between 30 to 60 min	Above 60 Min	Not Identified	Total	Grand Total
All area	20.87	16.99	18.20	43.93	100.00	412
Urban/rural						
Rural	14.52	15.16	20.00	50.32	100.00	310
Urban	40.20	22.55	12.75	24.51	100.00	102
Sex HH Head						
Female	26.09	15.22	21.74	36.96	100.00	92
Male	19.38	17.50	17.19	45.94	100.00	320
Kigali City/peri-urban area (sectors)						
CoK sectors	23.65	22.66	23.65	30.05	100.00	203
Peri-urban Area sectors	18.18	11.48	12.92	57.42	100.00	209
Quantiles						
Q1	11.49	11.49	19.54	57.47	100.00	87
Q2	16.25	16.25	21.25	46.25	100.00	80
Q3	21.84	24.14	16.09	37.93	100.00	87
Q4	22.45	16.33	17.35	43.88	100.00	98
Q5	36.67	16.67	16.67	30.00	100.00	60
Source of Water (Drink)						
Improved	23.58	19.10	20.00	37.31	100.00	335
Not Improved	9.09	7.79	10.39	72.73	100.00	77

Source: Socio-economic survey, July 2019

11.2.2.4 Waiting time at water source (Domestic use and drinking water use)

Waiting time at water source is another indicator assessed to qualify the accessibility to water source and water service. Results show that generally waiting time is less than 60 minutes (55.3%). This is applicable for both domestic water (55.3%) and drinking water (54.1%).

In urban areas, most of households are piped into dwelling/piped to yard/plot (78.4%). Therefore, people who spend time for waiting is very limited (25.5%). However, % of households in rural areas who wait 60 min or less to domestic water source is 66.5% and the waiting time for the same period for drinking water is 63.2%.

Households without access to improved drinking water source have similar condition for both urban and rural areas. They spend less or 60 min for domestic water (70.1%) and drinking water (68.8%.)

Table 11.2-12 Waiting Time at Domestic/ Drinking Water Source

	Waiting Time Domestic Water Source				Waiting time Drinking Water Source			
	Less or 30 min	Less or 60 min	Above 60 min	Not Responded	Less or 30 min	Less or 60 min	Above 60 min	Not Responded
All area	38.59	55.34	19.17	25.49	34.95	54.13	21.36	24.51
Urban/rural								
Rural	46.77	66.45	24.19	9.35	39.68	63.23	27.10	9.68
Urban	13.73	21.57	3.92	74.51	20.59	26.47	3.92	69.61
Sex HH Head								
Female	43.48	59.78	17.39	22.83	41.30	55.43	20.65	23.91
Male	37.19	54.06	19.69	26.25	33.13	53.75	21.56	24.69
Kigali City/peri-urban area (sectors)								
CoK sectors	32.51	46.80	11.82	41.38	35.96	47.78	13.30	38.92
Peri-urban Area sectors	44.50	63.64	26.32	10.05	33.97	60.29	29.19	10.53
Quantiles								
Q1	43.68	70.11	19.54	10.34	39.08	66.67	21.84	11.49
Q2	46.25	65.00	23.75	11.25	43.75	65.00	23.75	11.25
Q3	43.68	59.77	19.54	20.69	35.63	56.32	22.99	20.69
Q4	33.67	46.94	22.45	30.61	30.61	46.94	25.51	27.55
Q5	21.67	28.33	6.67	65.00	23.33	30.00	8.33	61.67
Source of Water (Drink)								
Improved	38.21	51.94	16.72	31.34	34.33	50.75	19.40	29.85
Not Improved	40.26	70.13	29.87	0.00	37.66	68.83	29.87	1.30
Settlement								
Isolated rural housing	46.73	61.68	30.84	7.48	42.99	61.68	30.84	7.48
Model Village	0.00	0.00	7.14	92.86	7.14	7.14	7.14	85.71
Modern planned area	50.00	50.00	0.00	50.00	50.00	50.00	0.00	50.00
Umudugudu/ Small Settlement	56.25	75.00	0.00	25.00	37.50	50.00	18.75	31.25
Unplanned clusted rural housing	45.20	68.36	20.90	10.73	36.72	64.97	24.29	10.73
Unplanned urban housing	19.79	29.17	8.33	62.50	26.04	33.33	8.33	58.33

Source: Socio-economic survey, July 2019

11.2.2.5 Responsibility of Fetching Water

In urban areas, almost half of households outsource the works for fetching water (house keepers and sellers) which comprise of 48.5%. While in rural areas, family members (All-family, Children, Daughter, Husband, Son, and Wife) are mobilized for fetching water. In addition, among family members, percentage of Children and Wife are relatively higher.

For households who don't have access to improved water, the conditions in both urban as well as rural areas are same. But percentage of wife fetching water is relatively higher than other family members.

Table 11.2-13 Responsibility of Fetching Water among Household's Members (%)

	Who Fetch water in HHs											Total Sample
	All families	Children	Daughter	House keepers	Husband	Husband and children	Sellers	Son	Wife	Wife and children	Total	
All area	19.70	16.20	4.90	16.70	7.90	0.50	9.30	6.10	18.40	0.20	100.00	412
Urban/rural												
Rural	21.30	17.40	5.50	11.60	10.00	0.60	7.40	5.80	20.00	0.30	100.00	310
Urban	14.40	12.40	3.10	33.00	1.00	0.00	15.50	7.20	13.40	0.00	100.00	102
Sex HH Head												
Female	13.00	21.70	8.70	14.10	0.00	0.00	6.50	9.80	26.10	0.00	100.00	92
Male	21.60	14.60	3.80	17.50	10.20	0.60	10.20	5.10	16.20	0.30	100.00	320
Kigali City/peri-urban area (sectors)												
CoK sectors	19.20	17.70	4.50	22.70	4.50	0.50	10.60	6.10	13.60	0.50	100.00	203
Peri-urban Area sectors	20.10	14.80	5.30	11.00	11.00	0.50	8.10	6.20	23.00	0.00	100.00	209
Quantiles												
Q1	23.30	15.10	5.80	8.10	11.60	0.00	3.50	10.50	22.10	0.00	100.00	87
Q2	20.00	13.80	7.50	6.30	15.00	1.30	6.30	6.30	23.80	0.00	100.00	80
Q3	24.40	18.60	8.10	7.00	7.00	0.00	9.30	7.00	18.60	0.00	100.00	87
Q4	16.70	18.80	2.10	24.00	4.20	1.00	7.30	4.20	20.80	1.00	100.00	98
Q5	11.90	13.60	0.00	45.80	0.00	0.00	25.40	1.70	1.70	0.00	100.00	60
Source of Water (Drink)												
Improved	19.10	15.50	5.20	17.90	7.00	0.60	10.00	6.70	17.90	0.30	100.00	335
Not Improved	22.10	19.50	3.90	11.70	11.70	0.00	6.50	3.90	20.80	0.00	100.00	77

Source: socio-economic survey, June-July 2019

11.2.2.6 Quantity of Water Used (Drinking and Domestic Use)

The National Policy indicates that the water supplied should provide an adequate quantity (minimum 20 litres/person/day in rural areas and 80 litres/person/day in urban areas) within a reasonable amount of time. Based on this indicator, the survey results indicate that, in rural areas, most of the households are still using 1-3 nos. of jerrican (20 litter per jerrican) per day. In urban areas, usage of the domestic water has relatively increased compared to rural area. The majority of usage has moved to 4-6 nos. of jerrican per day (47.1%).

For households having no access to improved water, the condition is basically the same in case of rural areas. Their average usage of the water is 1-3 nos. of jerrican per day (67.5%).

Table 11.2-14 Quantity (%) of Drinking Water and Domestic Use by Household

	Quantity of water Drink (Jerrican[1] per Day)			Quantity of water Domestic (Jerrican per Day)			Total	Total Sample
	1-3	4-6	7+	1-3	4-6	7+		
All area	51.21	38.83	9.95	52.18	35.92	11.89	100.00	412
Urban/rural								
Rural	53.23	36.13	10.65	58.71	32.26	9.03	100.00	310
Urban	45.10	47.06	7.84	32.35	47.06	20.59	100.00	102
Sex HH Head								
Female	57.61	35.87	6.52	59.78	31.52	8.70	100.00	92
Male	49.38	39.69	10.94	50.00	37.19	12.81	100.00	320
Kigali City/peri-urban area (sectors)								
CoK sectors	51.72	39.90	8.37	39.90	43.84	16.26	100.00	203
Peri-urban Area sectors	50.72	37.80	11.48	64.11	28.23	7.66	100.00	209
Quantiles								
Q1	58.62	31.03	10.34	62.07	32.18	5.75	100.00	87
Q2	55.00	35.00	10.00	66.25	30.00	3.75	100.00	80
Q3	51.72	41.38	6.90	65.52	27.59	6.90	100.00	87
Q4	48.98	41.84	9.18	46.94	39.80	13.27	100.00	98
Q5	38.33	46.67	15.00	8.33	55.00	36.67	100.00	60
Source of Water (Drink)								
Improved	51.34	39.10	9.55	48.66	38.81	12.54	100.00	335
Not Improved	50.65	37.66	11.69	67.53	23.38	9.09	100.00	77

Source: Socio-economic survey, July 2019

11.2.2.7 Reliability Water Service and Water Availability

Another indicator assessed is reliability of water services or availability of water especially for those households who are connected or who get water from public taps. This was assessed through frequency of water availability over one month. Results reveal that 28.6% of interviewed households faced water fluctuation during the last 7 days preceding the survey. Further, 26.3% had faced water fluctuation ranging 1-2 times a week, 35.6% 3-5 times a week and 38.1% more than 6 times a week. Water fluctuation is fluent in urban areas (76.5%) compared to 12.9% in rural areas. The next table presents the water fluctuation over 7 days preceding the survey.

In this regard, households who don't have access to improved water experience almost no fluctuation (1.3%). Compared with urban areas, reliability of the water source is better for them.

[1] 1 Jerrican=20liters

Table 11.2-15 Distribution of Households According to Water Unavailability in Last 7 Days

	% faced water fluctuation	1-2	3-5	6+	Total	Total Faced water fluctuation	Total Sample
All area	28.64	26.27	35.59	38.14	100.00	118	412
Urban/rural							
Rural	12.90	17.50	57.50	25.00	100.00	40	310
Urban	76.47	30.77	24.36	44.87	100.00	78	102
Sex HH Head							
Female	32.61	33.33	43.33	23.33	100.00	30	92
Male	27.50	23.86	32.95	43.18	100.00	88	320
Kigali City/peri-urban area (sectors)							
CoK sectors	48.77	27.27	36.36	36.36	100.00	99	203
Peri-urban Area sectors	9.09	21.05	31.58	47.37	100.00	19	209
Quantiles							
Q1	14.94	23.08	53.85	23.08	100.00	13	87
Q2	16.25	23.08	38.46	38.46	100.00	13	80
Q3	22.99	35.00	25.00	40.00	100.00	20	87
Q4	31.63	25.81	29.03	45.16	100.00	31	98
Q5	68.33	24.39	39.02	36.59	100.00	41	60
Source of Water (Drink)							
Improved	34.93	26.50	35.04	38.46	100.00	117	335
Not Improved	1.30	0.00	100.00	0.00	100.00	1	77
Settlement							
Isolated rural housing	12.15	15.38	69.23	15.38	100.00	13	107
Model Village	92.86	30.77	23.08	46.15	100.00	13	14
Modern planned area	0.00	0.00	0.00	0.00	0.00	0	2
Umudugudu/ Small Settlement	43.75	28.57	57.14	14.29	100.00	7	16
Unplanned clusted rural housing	13.56	20.83	37.50	41.67	100.00	24	177
Unplanned urban housing	63.54	29.51	27.87	42.62	100.00	61	96

Source: socio-economic survey, July 2019

11.2.3 Expenditure for Water Supply and Willingness to Pay

Current expenditure for water supply service and willingness to pay is considered as follows;

- Payment to distributor (the WASAC) is indirectly done (81.8%)
- Direct payment for water distributor is mostly within 10,000 Rwf per month
- For private transporter, range of payment is also within 10,000 Rwf per month
- Except already connected households, 92.3% has willingness to connect
- Loyalty (preference) to paying water supply service is 17.7% in urban areas, 7.6% in rural areas, and no access areas 2.6%

11.2.3.1 Monthly Expenditures for Water Services from WASAC

This section assesses the average amount paid to the WASAC for water service during the previous month. Only around 20% of households responded to the question related to monthly expenditure given that the number of people that pays water bill is different from people having water access.

Survey results show that 14.6% of respondents paid a bill equal to or less than 10,000 Rwfs during last month of the survey (counting before the day of interview) and only 3.6% paid between 10,001-43,000 Rwfs. Urban households pay more money. In fact, 35.3% of urban households paid less than or equal to 10,000 Rwfs compared to 7.7% of households in rural areas.

Table 11.2-16 Payment of Water for a Month Preceding the Period of the Study
DISTRIBUTOR: WASAC

	0-10,000	10,001-43,000	Not paying WASAC Bill	Total	Count Total Sample
All area	14.56	3.64	81.80	100.00	412
Urban/rural					
Rural	7.74	1.29	90.97	100.00	310
Urban	35.29	10.78	53.92	100.00	102
Sex HH Head					
Female	11.96	4.35	83.70	100.00	92
Male	15.31	3.44	81.25	100.00	320
Kigali City/peri-urban area					
CoK	23.15	6.40	70.44	100.00	203
Peri-urban Area	6.22	0.96	92.82	100.00	209
Quantiles					
Q1	6.90	1.15	91.95	100.00	87
Q2	11.25	0.00	88.75	100.00	80
Q3	14.94	2.30	82.76	100.00	87
Q4	19.39	3.06	77.55	100.00	98
Q5	21.67	15.00	63.33	100.00	60
Source of Water (Drink)					
Improved	17.91	4.48	77.61	100.00	335
Not Improved	0.00	0.00	100.00	100.00	77

Source: socio-economic survey, July 2019

11.2.3.2 Willingness to Pay and Expenses on Water

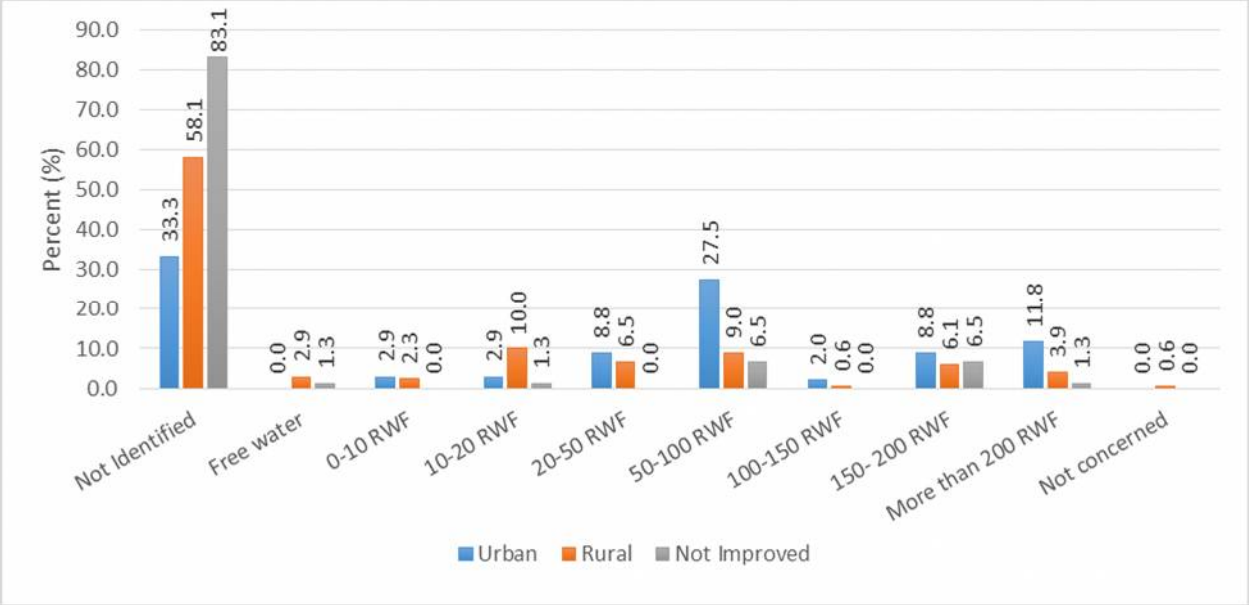
In case of water unavailability, households buy water from alternative water sources or fetch water from free source. This amount of "expense on 20l jerrican of water" can be considered as a willingness to pay and the amount of money willing to pay per water consumption. It turns out, most of the households did not identify the price or goes to free water.

- Willingness to pay is very little (51.9% not identified, and 2.2% goes to free water)

In urban area, one third (1/3) of household did not identify amount but half of the remaining households may pay 50 – 100 RWF per jerrican of water. In rural area, two third (2/3) of households didn't identify amount but half of remaining households may pay 20-50 RWF per jerrican.

From **Table 11.2-3**, it was observed that average household size in rural and urban group was 5.2 persons. Therefore, by referring minimum usage of water consumption 20 litter/person/day followings amount can be considered as willingness to pay for water usage per month.

- Urban area: 10,400 (*Rwf per month*) = 100 (*Rwf per jerrycan*) × 5.2 (*HH size*) × 20 (*litter per day per person*)
- Rural area: 5,200 (*Rwf per month*) = 50 (*Rwf per jerrycan*) × 5.2 (*HH size*) × 20 (*litter per day per person*)



Source: JST

Figure 11.2-1 Distribution of Willingness to Pay to Water (by Alternative Service Provider)

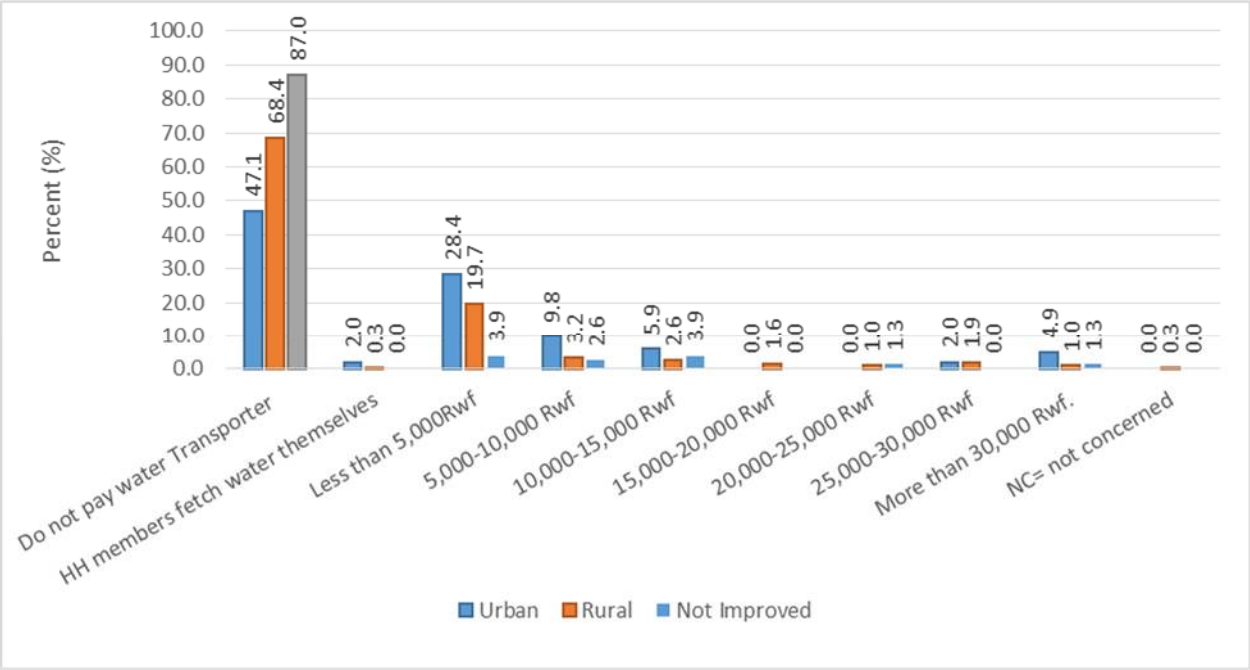
Table 11.2-17 Expenses on 20l Jerrican of Water in Case Water Unavailable (%s)

	Not Identified	Free water	0-10 Rwf	10-20 Rwf	20-50 Rwf	50-100 Rwf	100-150 Rwf	150- 200 Rwf.	More than 200 Rwf	NC= Not concerned	Total	Grand Total
All area	51.9	2.2	2.4	8.3	7.0	13.6	1.0	6.8	5.8	0.9	100.0	412
Urban/rural												
Rural	58.1	2.9	2.3	10.0	6.5	9.0	0.6	6.1	3.9	0.6	100.0	310
Urban	33.3	0.0	2.9	2.9	8.8	27.5	2.0	8.8	11.8	0.0	100.0	102
Sex HH Head												
Female	54.3	1.1	2.2	8.7	5.4	14.1	0.0	7.6	6.5	0.0	100.0	92
Male	51.3	2.5	2.5	8.1	7.5	13.4	1.3	6.6	5.6	1.2	100.0	320
Kigali City/peri-urban area (sectors)												
CoK sectors	38.9	1.0	3.0	11.8	7.4	19.2	2.0	7.9	8.4	0.5	100.0	203
Peri-urban Area sectors	64.6	3.3	1.9	4.8	6.7	8.1	0.0	5.7	3.3	1.5	100.0	209
Quantiles												
Q1	65.5	3.4	2.3	1.1	11.5	6.9	0.0	4.6	3.4	1.1	100.0	87
Q2	60.0	2.5	0.0	8.8	7.5	7.5	2.5	3.8	7.5	0.0	100.0	80
Q3	52.9	2.3	3.4	8.0	4.6	9.2	1.1	12.6	5.7	0.0	100.0	87

	Not Identified	Free water	0-10 Rwf	10-20 Rwf	20-50 Rwf	50-100 Rwf	100-150 Rwf	150- 200 Rwf.	More than 200 Rwf	NC= Not concerned	Total	Grand Total
Q4	42.9	0.0	5.1	11.2	4.1	23.5	0.0	5.1	6.1	2.0	100.0	98
Q5	35.0	3.3	0.0	13.3	8.3	21.7	1.7	8.3	6.7	1.7	100.0	60
Source of Water (Drink)												
Improved	44.8	2.4	3.0	9.9	8.7	15.2	1.2	6.9	6.9	1.2	100.0	335
Not Improved	83.1	1.3	0.0	1.3	0.0	6.5	0.0	6.5	1.3	0.0	100.0	77

Source: Socio-economic survey, July 2019

The survey further reveals that there are some households who receive water from private transporters who in turn fetch water from various sources and sell it to households when the primary source of water is unavailable. Results show that 3.40% pay to transporters costs between 10-15 thousand Rwfs, 1.21% between 15-20 thousand Rwfs, 0.73% between 20-25 thousand Rwfs, 1.94% between 25-30 thousand Rwfs, 4.85% between 5-10 thousand Rwfs, 21.84% less 5 thousand Rwfs, 1.94% more than 30 thousand Rwfs and 0.73% don't pay at all and sent household member(s) to fetch water. Households in rural areas fetch water by themselves and spend less for water transport.



Source: JST

Figure 11.2-2 Distribution of Willingness to Pay to Transportation Service

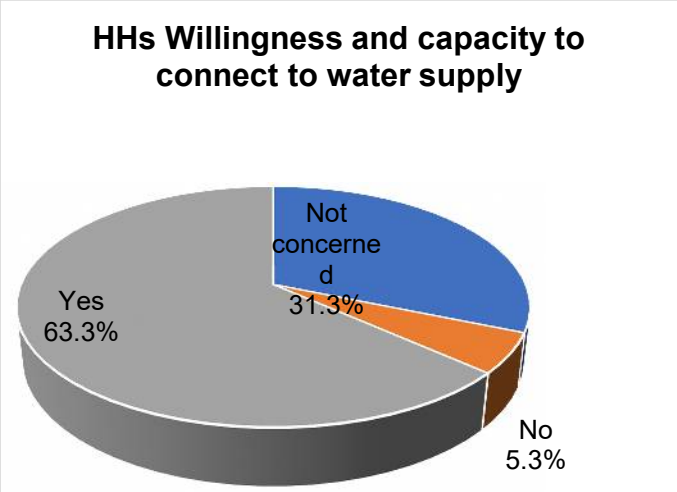
Table 11.2-18 Expenses for Water Transport in Case Water Unavailability (%)

	Do not pay water Transporter	HH members fetch water themselves	Less than 5,000Rwf	5,000-10,000 Rwf	10,000-15,000 Rwf	15,000-20,000 Rwf	20,000-25,000 Rwf	25,000-30,000 Rwf	More than 30,000 Rwf.	NC= not concerned	Total	Grand Total
All area	63.11	0.73	21.84	4.85	3.40	1.21	0.73	1.94	1.94	0.24	100.00	412
Urban/rural												
Rural	68.39	0.32	19.68	3.23	2.58	1.61	0.97	1.94	0.97	0.32	100.00	310
Urban	47.06	1.96	28.43	9.80	5.88	0.00	0.00	1.96	4.90	0.00	100.00	102
Sex HH Head												
Female	66.30	0.00	22.83	3.26	2.17	0.00	0.00	3.26	2.17	0.00	100.00	92
Male	62.19	0.94	21.56	5.31	3.75	1.56	0.94	1.56	1.88	0.31	100.00	320
Kigali City/Peri-urban area (sectors												
CoK sectors	51.72	1.48	31.03	6.90	3.45	0.49	0.00	1.97	2.96	0.00	100.00	203
Peri-urban Area sectors	74.16	0.00	12.92	2.87	3.35	1.91	1.44	1.91	0.96	0.48	100.00	209
Quantiles												
Q1	79.31	1.15	11.49	2.30	2.30	0.00	0.00	1.15	1.15	1.15	100.00	87
Q2	72.50	0.00	15.00	5.00	3.75	0.00	0.00	1.25	2.50	0.00	100.00	80
Q3	64.37	1.15	20.69	5.75	4.60	1.15	1.15	0.00	1.15	0.00	100.00	87
Q4	53.06	1.02	29.59	5.10	3.06	3.06	2.04	3.06	0.00	0.00	100.00	98
Q5	41.67	0.00	35.00	6.67	3.33	1.67	0.00	5.00	6.67	0.00	100.00	60
Source of Water (Drink)												
Improved	57.61	0.90	25.97	5.37	3.28	1.49	0.60	2.39	2.09	0.30	100.00	335
Not Improved	87.01	0.00	3.90	2.60	3.90	0.00	1.30	0.00	1.30	0.00	100.00	77

Source: Socio-economic survey, July 2019

11.2.3.3 Willingness to Connect for Water-Supply Service

Connection to the channel or water distribution system in the area or in Rwanda in general is currently an initiative from the water distributing companies or institutions, Development Partners and households itself. From assessed households, it was observed that 63.3% are willing to connect and thereby contribute for this connection while 5.3% are not willing to connect. Results show that 31.3% of assessed households did not respond to this question as they were already connected.



Source: Socio-economic survey, July 2019

Figure 11.2-3 Distribution of Households According to Their Willing to Connect to Water Services

11.2.3.4 Loyalty for Water Supply Service

The survey tries to understand how people get water when they are not connected and do not have money to buy water. Furthermore, especially for urban areas, the survey identified how much each household is loyal to the water supply service, which is 17.7%. (borrow money to buy -5.9% and get water from neighbors -11.8%) However, most of the households fetch free water from river water/lake (77.7%)

Table 11.2-19 Alternative Solution for Getting Water When There is No Money

	When there is no money to buy water in case unavailable						
	Not Concerned or attended	Borrow money to buy	Get water from neighbors	Go for river water/ lake	Prefer to stay disconnected	Water is always available	Total
All area	8.00	3.90	6.10	77.70	0.70	3.60	100.00
Urban/rural							
Rural	6.10	3.20	4.20	82.90	1.00	2.60	100.00
Urban	13.70	5.90	11.80	61.80	0.00	6.90	100.00
Sex HH Head							
Female	5.40	1.10	6.50	84.80	0.00	2.20	100.00
Male	8.80	4.70	5.90	75.60	0.90	4.10	100.00
Kigali City/Peri-urban area (sectors)							
CoK sectors	8.90	5.40	8.40	72.90	0.00	4.40	100.00
Peri-urban Area sectors	7.20	2.40	3.80	82.30	1.40	2.90	100.00

	When there is no money to buy water in case unavailable						
	Not Concerned or attended	Borrow money to buy	Get water from neighbors	Go for river water/ lake	Prefer to stay disconnected	Water is always available	Total
Quantiles							
Q1	3.40	4.60	3.40	87.40	0.00	1.10	100.00
Q2	5.00	3.80	3.80	83.80	1.30	2.50	100.00
Q3	6.90	5.70	3.40	78.20	1.10	4.60	100.00
Q4	9.20	2.00	11.20	74.50	1.00	2.00	100.00
Q5	18.30	3.30	8.30	60.00	0.00	10.00	100.00
Source of Water (Drink)							
Improved	9.00	4.20	7.50	75.80	0.30	3.30	100.00
Not Improved	3.90	2.60	0.00	85.70	2.60	5.20	100.00

Source: socio-economic survey, July 2019

11.2.4 Benefit of the Water Supply Service

Major benefit that is derived from water supply service is observed through the improvement of the health conditions. In terms of medical consultation, urban areas have less chance to get sick. It is considered as follows:

- Households in an urban area has less risk to make medical consultation compared with households with no access to improved water (16.8%)
- Households in an urban area has less risk to suffer water borne diseases compared with households with rural area (19.1%) and no access to improved water (35.3%)

11.2.4.1 Health Condition of Households

The EICV5 states that around 20% of the total Rwandan population had medical consultation during the four weeks preceding the survey. Sickness was the major reason for medical consultation in both urban and rural areas. Aside from sickness, the most common reasons for medical consultation were vaccination and general visit/preventive healthcare in urban areas, and in rural areas.

From this survey it was inferred that 58.7% of assessed households had at least one member who made a medical consultation and the main reason for this was sickness. A large share of households who were making medical consultation is in rural areas (61.0%). The households who made medical consultation and having without access to improved drinking water was 68.8%, which when compared with urban areas (52.0%), the rates are almost 10% or much higher.

Table 11.2-20 Percentage (%) of Population Making a Medical Consultation in Last Four Weeks

Row Labels	% making medical consultation within last 4 weeks	Reason for Consultation									Number of households with member making medical consultation	Total Sample
		General visit or preventive	Injury	Other (specify)	Postnatal care	Prenatal care	Sickness and injury	Sickness.	Vaccination	Total		
All area	**58.74**	**1.24**	**3.31**	**0.41**	**4.13**	**5.37**	**0.41**	**84.71**	**0.41**	**100**	**242**	**412**
Urban/Rural Area												
Rural	60.97	0.53	3.7	0.53	5.29	6.35	0.00	83.07	0.53	100	189	310
Urban	51.96	3.77	1.89	0.00	0.00	1.89	1.89	90.57	0.00	100	53	102
Kigali City/peri-urban area (Sectors)												
CoK sectors	55.17	0.89	2.68	0.00	3.57	3.57	0.89	87.5	0.89	100	112	203
Peri-urban Area sectors	62.2	1.54	3.85	0.77	4.62	6.92	0.00	82.31	0.00	100	130	209
Sex of respondent												
Male	56.25	1.11	3.33	0.56	3.89	6.67	0.00	83.89	0.56	100	180	320
Female	67.39	1.61	3.23	0.00	4.84	1.61	1.61	87.1	0.00	100	62	92
Quintile												
Q1	57.47	0.00	6.00	0.00	6.00	2.00	0.00	86	0.00	100	50	87
Q2	66.25	1.89	3.77	0.00	5.66	3.77	0.00	84.91	0.00	100	53	80
Q3	56.32	4.08	4.08	0.00	6.12	4.08	0.00	81.63	0.00	100	49	87
Q4	57.14	0.00	1.79	0.00	0.00	7.14	1.79	89.29	0.00	100	56	98
Q5	56.67	0.00	0.00	2.94	2.94	11.76	0.00	79.41	2.94	100	34	60
Water Source (Drink)												
Improved	56.42	1.59	2.65	0.53	3.70	5.82	0.53	84.66	0.53	100	189	335
Not Improved	68.83	0.00	5.66	0.00	5.66	3.77	0.00	84.91	0.00	100	53	77

Source: Socio-economic survey, July 2019

The survey results show that 31.1% of households reported at least one member who suffered from water borne diseases and the main cause of disease was intestinal worm. This was also common for all household defined categories (by location, area, sex of household's heads, consumption quantiles and access to improved or not improved drinking water source). At all levels, intestinal worm took a greater share (72%) except for urban households where it was 58.8% and replaced by diarrhea 29.4%.

People without access to improved drinking water source are these who suffer a lot with diseases caused by poor quality water (52.0%). This indicates that the provision of improved water plays an important role on reducing diseases related to poor water quality.

Table 11.2-21 Water Borne Diseases in last three months (%)

	% of HHs suffered any sickness resulted by Poor water quality in Last 3 months	Diarrhea	Hepatitis A or E	Intestinal (beaver fever)	Intestinal worm	Other (Specify)	Typhoid fever	Total	Count HHs member suffered any Sickness	Total Sample
All Area	**31.07**	**19.53**	**0.78**	**0.78**	**76.56**	**1.56**	**0.78**	**100.00**	128	**412**
Urban/rural										
Rural	35.81	18.02	0.90	0.90	79.28	0.00	0.90	100.00	111	310
Urban	16.67	29.41	0.00	0.00	58.82	11.76	0.00	100.00	17	102
Kigali City/peri-urban area (Sectors)										
CoK sectors	26.11	13.21	0.00	1.89	79.25	3.77	1.89	100.00	53	203
Peri-urban Area sectors	35.89	24.00	1.33	0.00	74.67	0.00	0.00	100.00	75	209
Sex of HH Head										
Female	23.91	18.18	4.55	0.00	72.73	4.55	0.00	100.00	22	92
Male	33.13	19.81	0.00	0.94	77.36	0.94	0.94	100.00	106	320
Quintile										
Q1	34.48	16.67	3.33	0.00	80.00	0.00	0.00	100.00	30	87
Q2	23.75	5.26	0.00	5.26	89.47	0.00	0.00	100.00	19	80
Q3	33.33	13.79	0.00	0.00	79.31	3.45	3.45	100.00	29	87
Q4	39.80	20.51	0.00	0.00	76.92	2.56	0.00	100.00	39	98
Q5	18.33	63.64	0.00	0.00	36.36	0.00	0.00	100.00	11	60
Water Source Drink										
Improved	26.27	19.32	0.00	0.00	77.27	2.27	1.14	100.00	88	335
Not Improved	51.95	20.00	2.50	2.50	75.00	0.00	0.00	100.00	40	77

Source: Socio-economic survey, July 2019

11.3 WATER QUALITY SURVEY

11.3.1 Survey Parameters

Following **Table 11.3-1** shows the analysis parameters and analysis methods for water quality survey.

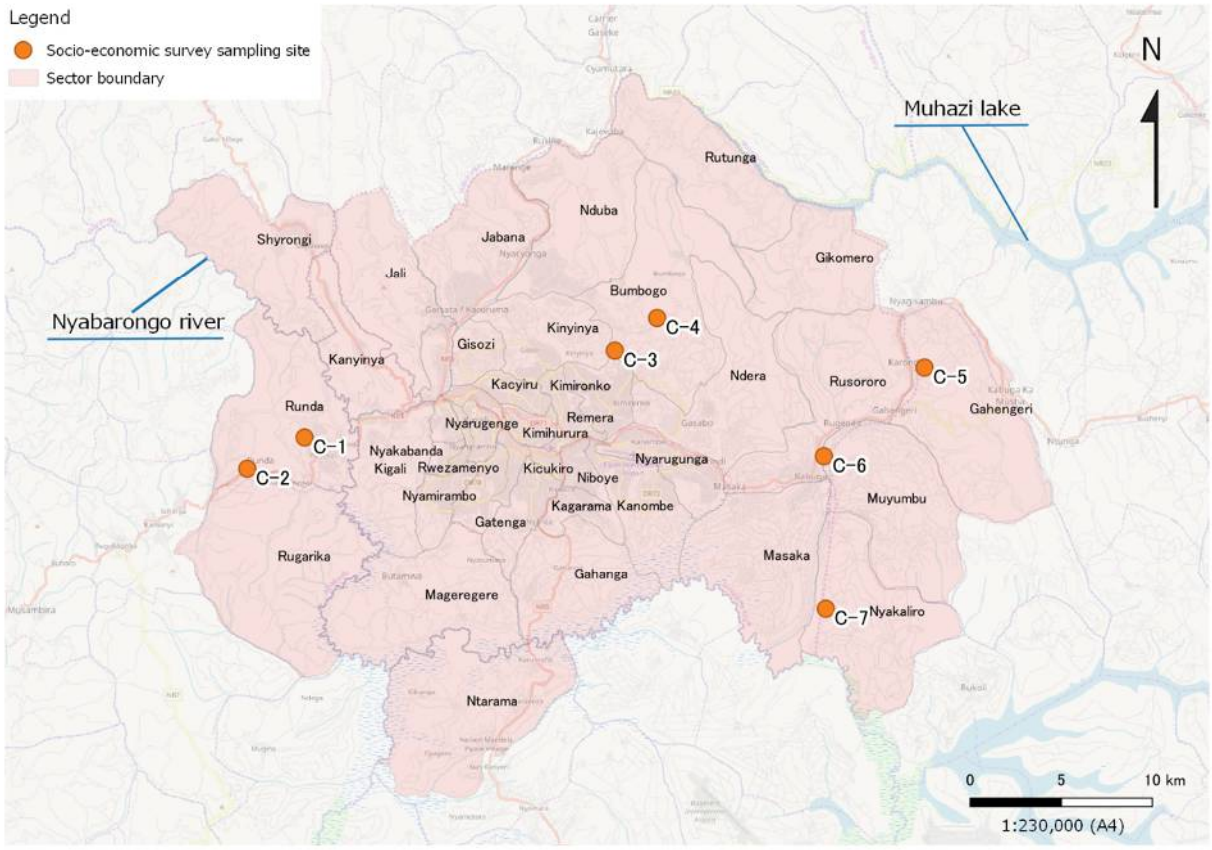
Table 11.3-1 Analysis Parameters and Analysis Methods

No.	Parameter	Analysis Method
1	Turbidity	Turbidity meter
2	Color	APHA method
3	pH	Electrochemistry method
4	Electric conductivity (EC)	Electrochemistry method
5	Total dissolved solids (TDS)	Electrochemistry method
6	Chloride (Cl^-)	Titrimetric with Silver Nitrate
7	COD_{Cr}	Digestion with Potassium Dichromate in closed reflux method
8	Nitrate nitrogen (NO_3^--N)	Cadmium reduction method
9	Nitrite nitrogen (NO_2^--N)	Diazotization method
10	Ammonia nitrogen (NH_4-N)	Nessler method
11	Sulphate (SO_4^{2-})	Turbidimetric method
12	Iron (Fe)	Phenanthroline method
13	Manganese (Mn)	PAN indicator method
14	E. coli	Spread plate method
15	Dissolved oxygen (DO)	Electrochemistry method

Source: JST

11.3.2 Sampling Site

Figure 11.3-1 shows locations of the sampling sites.



Source: JST

Figure 11.3-1 Locations of the Sampling Sites for Water Quality Survey (Socio-economic Survey)

11.3.3 Result of Water Quality Survey

Table 11.3-3 shows the results of water quality survey at sites. All samples don't meet the Rwanda Drinking Water Quality Standard. Main issues were turbidity (C-4 and C-6), pH (C2, C-3 and C-5), ammonia (C-4), iron (C-4, C-5, C-6) and manganese (C-1, C-4, C-5, C-7). Therefore, additional treatment processes (such as filtration with aeration to removal turbidity, ammonia, iron and manganese) will be necessary for these water sources. If possible, it is recommended for WASAC to provide public water service to the areas where are facing water quality problems.

Table 11.3-2 Sampling Locations of Water Quality Survey for Water Sources in the Area without Public Water Supply

No	Sector	Cell	Village	Name of Water Source	X	Y	Z	Current Status
C-1	Runda	Ruyenzi	Nyagacaca	Kadobogo	497425	4783339	1454	Damaged ground spring (it needs rehabilitation and extension)
C-2	Runda	Kabagesera	Bwirabo	Gashubi	494249	4781624	1455	Old ground spring (it needs rehabilitation and extension)
C-3	Bumbogo	Nyabikenke	Masizi	Masizi	514457	4788030	1421	Old ground spring (it needs rehabilitation and extension)
C-4	Bumbogo	Nyabikenke	Kiriza	Kiliza	516765	4789768	1508	Old ground spring (it needs rehabilitation and extension)
C-5	Gahengeri	Mutamwa	Ryasenteteri	Kamugasa	531443	4787059	1388	Ground water (hand pump)
C-6	Muyumbu	Nyarukombe	Marembo	Marembo	526005	4782240	1351	Ground water near marshland which can be obtained by forage
C-7	Nyakariro	Munini	Nyiramitemeri	Nyiramitemere	526066	4773924	1350	Ground water near marshland which can be obtained by forage

Source: JST

Table 11.3-3 Result of Water Quality Survey for Water Source in the Area without Public Water Supply

No.	Sampling No. / Sampling Date	Unit	C-1 2019/09/04	C-2 2019/09/04	C-3 2019/09/04	C-4 2019/09/05	C-5 2019/09/05	C-6 2019/09/05	C-7 2019/09/05	RDWQS [1]	WHO Guideline (2017)
1	Turbidity	NTU	3.08	2.36	0.65	11.00	1.17	6.83	2.16	5	5
2	Colour	TCU	<15	<15	<15	<15	<15	<15	<15	15	15
3	pH		6.77	6.17	6.09	6.95	5.99	7.32	6.56	6.5-8.5	-
4	Electric Conductivity (EC)	µs/cm	439	243	300	374	240	456	597	1,500	-
5	Total dissolved solids (TDS)	mg/l	205.5	116.8	144.0	163.8	117.7	229.0	267.0	700	-
6	DO	mg/l	7.11	1.52	2.74	5.60	1.48	11.29	3.56	-	-
7	Chemical Oxygen Demand (COD_{Cr})	mg/l	<2	<2	<2	<2 [3]	<2	<2	<2	-	-
8	Nitrate Nitrogen (NO_3^-,as N)	mg/l	3.50	3.50	4.50	4.40	5.20	0.40	0.30	10	11.3
9	Nitrite Nitrogen (NO_2^-, as N)	mg/l	<0.002	<0.002	<0.002	0.010	<0.002	<0.002	<0.002	0.001	0.9
10	Ammonia Nitrogen (NH_4^-,as N)	mg/l	<0.02	<0.02	<0.02	0.80 [3]	<0.02	0.37	0.25	0.5	-
11	Sulphate (SO_4^{2-})	mg/l	62	54	32	49	41	31	31	300	-
12	Iron (Fe)	mg/l	0.27	0.24	0.08	1.05 [3]	0.65	0.50	0.30	0.3	0.3
13	Manganese (Mn)	mg/l	0.257	0.084	0.002	2.100 [3]	0.187	0.002	0.253	0.1	-
14	E. Coli	cfu/100ml	Not detected	Not detected	Not detected	Not detected [3]	Not detected	Not detected	Not detected	Not be detectable	Not be detectable

1) RDWQS: Rwanda Drinking Water Quality Standard
2) 11.00 means the value exceeding Rwanda Drinking Water Quality Standard
3) Additional survey is necessary because ammonia can be an indicator of human and animal waste pollution, however, COD and E. Coli are not detected. It is also considered that iron and manganese concentrations are abnormal.

Source: JST

11.4 CONCLUSION AND RECOMMENDATION

11.4.1 Status of the Households without Access to Improved Water

Major characteristics of the households without access to improved water are considered as follows;

- Hard to find a household without access to improved water in urban areas (2.0%). Mostly such household exists in rural areas.
- Main source of income is farming activity (61.0%).
- Distribution of social-economic status such as Ubudehe categories are not different from other groups (social-economic conditions such as unemployment and ownership of house are almost the same)
- Education level is rather lower (university level, and complete secondary are less compared with urban) - around 5-10% lower
- Households' average expenditure is very low which is 20,000 Rwf per month and is almost 1/5 in urban and 2/3 in rural areas
- Majority of households have no alternative water source (72.7%)
- Family members are mobilized for fetching water, especially child and wife are the major workforces

Even though most of the payment to the distributor is within 10,000 Rwf per month or less, it is still difficult for these households to afford. Their monthly expenditure for water supply service shall occupy around half of their total expenditure. Probably due to lack of capacity to pay to distribution service or transporter, these households prefer to go fetching raw water by themselves. Due to above-mentioned reasons, at this moment, even if an initiative run by the Government provides support for these households (costs to pipe into dwelling/pipe to yard/plot or public tap), it is still very difficult for these households to pay for usage.

The households in rural areas were experiencing relatively bad health conditions due to low-quality water and were thus making more frequent medical consultations (68.8%) than households in urban areas (52.0%). In terms of infection to waterborne diseases, the % in households without access (52.0%) is three times higher than those in urban areas (16.7%).

In addition, due to poverty, consideration for gender or child labor may be neglected. For water fetching activities, family members are usually mobilized. Especially, the percentage of wives and children is higher in the case for households without access to water.

11.4.2 Willingness to Connect, and Willingness to Pay

Other than households already connected to the water supply network, most of the households basically have willingness to connect to water supply service 92.2%. However, compared to households in an urban area, households in a rural area have a very limited financial capacity for payment.

- Monthly expense of households is 1/3 (an average expenditure in an urban area was 93,000 RWF

whereas in rural was 31,000 RWF)

- The estimated amount of willingness to pay for monthly water use is 5,200 Rwf per month per household in a rural area and 10,400 RWF in an urban area (this amount is not considering respondent who didn't identify amount)
- The estimated amount of willingness to pay for connection by installment is less than 5,000 Rwf per month per household in both rural area and urban area (this amount is not considering respondent who didn't identify amount)

Paying 5,200 Rwf per month is more than 15% of the average monthly expense of rural area households and it is unlikely to turn into a realistic possibility. At the same time, in case of not enough money for paying the bill, these households prefer to fetch water from the river or lake 77.7%. It means, even if the water supply connection has provided to the households, payment for water supply service exceeds their capacity, such households will be drop out of water supply service and go to fetch free water source for getting water.

In urban areas, if above-mentioned drop out from water supply service occurs, the households may face difficulty to find a well-conditioned alternative water source, especially for those financially incapable households. In order to protect those lower-income households' wellbeing, support should be provided by the community benefitting from urbanization or government who strongly drives this urban development.

Since nearby the CoK, those rural areas will sooner or later get caught up by urbanization. The increase of environmental load (such as domestic wastewater release) will contribute to rural households' water source contamination. The absence of proper measures to prevent the barrier of water supply service usage shall threaten those households' wellbeing. Therefore, measures to accommodate rural areas and poverty groups in urban areas are very important.

In Japan (this example is specific to Tokyo since Bureau of Waterworks Tokyo Metropolitan Government runs water supply service only in Tokyo. However, similar initiatives are seen in all over Japan.), there are rules for those financially incapable households to be exempt from the minimum charge in water tariffs. In Cambodia there are Government supported schemes to support each individual connection as piped into dwelling/piped to yard/plot for water supply services. In order to establish a sustainable water supply service, such public support scheme should be developed parallel to facility development.

- In Tokyo, the total of the minimum and volumetric charge up to $10m^3$ per month are exempted or reduced for the following households;
  - Receives public assistance, such as livelihood assistance, education allowance, home allowance, medical allowance or nursing-care allowance under the Public Assistance Act
  - Receives childcare allowance, or special child-rearing allowance (persons with a child aged 18

or under in one-parent families below the income line, and parents with a child aged 20 or under with a physical or mental disability, below the income line)

- Under the Government of Cambodia, poverty reduction policy, state-owned water supply cooperation has carried out "Clean Water for Low-Income Families" since 1999.
  - Set water tariff 3 to 9 times cheaper than that of the private water providers
  - Prepare various installment payment policy and subsidy for connecting low-income households
  - The water pipe is connected indoor without additional expense and provides WHO guideline complied clean water

On the other hand, the current customer base (households in urban areas) has reported frequent water failure. As a result, these customers have to incur extra cost for fetching water (buying water from water transporter, housekeeper to fetch water, or even mobilize family member to fetch water, etc.) outside of tariff payment. It indicates the current customer base has payment capacity. But it will be exchanged for much better water supply service. In addition, in the case of money shortage, people tend to select fetching from alternative water sources by themselves instead of borrowing money or borrowing water from neighbors.

- The current customer base has to pay the extra expense for fetching water (in urban area housekeeper 33.0% and seller 15.5% are the major alternative workforce for fetching water)
- Large customer base doesn't have loyalty to water supply service (in urban area households only 10.6% stay in water supply service when in case of no money)

11.4.3 Current Water Conditions

All locations, there are 1 or more indicators that slightly exceed the Rwanda Drinking Water Quality Standard. Therefore, additional treatment processes or WASAC water supply will be necessary for these water sources.
In spite of rapid urbanization in this region, most unprotected well and unprotected spring are still providing acceptable drinking water. It is supportive situation for households without access to improved water. However, as the urbanization of the CoK exceeds, this condition may not last for long. It is better to start implementing measures for protecting such springs and wells.

11.4.4 Recommendation

Followings are recommendations

- The current customers (households in the urban area) have a potential capacity for paying the tariff. Therefore, extra revenue for WASAC can be expected by improving service level (such as 24/7 water supply)

- In urban areas, the improvement of existing water supply services may increase usage since there is a demand for water supply. It is considered a relatively easier way to increase income.
- For rural area and low-income sector, development of supporting scheme for connection and water tariff is required
- Water quality survey result shows unprotected water sources were fortunately still acceptable conditions and needs conservation effort
- The rural area has less opportunity to earn income as it requires a bigger investment and households in rural areas have less payment capacity at this moment
- The provision of water supply service at an early stage in rural areas may start with public tap and protected wells and protected spring. It may increase the redundancy of the water supply service
- It is not a good idea to remove public tap since at this moment, even in the urban areas, most of the customer has to fetch water from outside of their premise due to quite frequent water supply failure.

CHAPTER 12 STRATEGIC ENVIRONMENT ASSESSMENT (SEA)

12.1 OVERVIEW

For the Master Plan study, it is required to carry out a Strategic Environmental Assessment (SEA) in which the impacts on the environment and society are taken into account when setting priorities among the development options. Category A or B[1] projects developed within the Master Plan needs an ESC (Environmental Social Consideration) study that includes the followings;

- A comparative analysis of alternative plans and a 'without project' option,
- Assessment of possible environmental impacts, and
- Plans for mitigation measures and monitoring

These ESC studies are conducted at the Initial Environmental Examination (IEE) level, i.e., based on readily available information and simple field surveys.

12.1.1 Objective of the Study

Objective of SEA (Strategic Environmental Assessment) study is to achieve the followings:

- To identify and assess potential environmental and social impacts of the Master Scenario used for Master Plan, and priority projects in Master Plan (15 Years Investment Plan)
- To identify potential significant adverse environmental and social impacts of the development projects included in Master Plan and recommend measures for mitigation,
- To develop an alternative plan, scoping of social environmental consideration, baseline survey, and assessment of environmental impact, preparation of mitigation measures and monitoring plans for the Projects.
- Support and prepare a public consultation/meeting plans with the relevant authorities, and stakeholders regarding findings and recommendations.

12.1.2 SEA (Strategic Environmental Assessment) Guidelines

SEA (Strategic Environmental Assessment) was considering the Rwandan Guidelines and Procedures for Developing a Strategic Environment Assessment as well as JICA guidelines for Environmental and Social Considerations JICA guideline for environmental April 2010[2]. The following guidance materials have also been considered:

- UNEP (2004), EIA and SEA: Towards an Integrated Approach;
- World Bank (2011), SEA in Policy and Sector Reform: Conceptual Model and Operational Guidance

[1] Category set by JICA to evaluate impact of projects. Category A is the project which likely to have significantly adverse impact s on the environment or society. Category B is the project which may have adverse impacts on the environment or society, but these impacts are less significant than those of Category A projects.

[2] https://www.jica.go.jp/english/our_work/social_environmental/guideline/pdf/guideline100326.pdf

12.1.3 SEA Implementation Procedures

SEA study was implemented by following procedures:

1) Literature review
2) Stakeholder analysis and participation (public consultation and participation)
3) Baseline survey
4) Determining the nature and extent of impacts
5) Alternative options analysis
6) Development of mitigation measures
7) Development of monitoring plan

Result of literature review and baseline survey shall find in the following chapters;

- CHAPTER 3 General Features of the Study Area
- CHAPTER 4. Government and Related Development Plans
- CHAPTER 5. Conditions of Existing Water Supply System

Accordance with master scenario and investment plan that find in following chapters, extent of impacts, alternative option analysis, mitigation measures, and monitoring plan are formulated.

- CHAPTER 13. Master Scenario (base water supply scenario for Master Plan)
- CHAPTER 14. The 15-Year Investment Plan

12.2 IMPACT ANALYSIS AND ALTERNATIVE OPTION ANALYSIS

In general, water supply project is considered as relatively environmentally acceptable project. However, there are still possibilities of negative impact from water supply projects. Following table shows possible impacts by water supply project in the CoK and adjacent 7 sectors and considerations for such project. The next table present the summary of the environmental issues associated with the proposed facilities based on the evaluation of proposed scenario.

Table 12.2-1 Scoping Matrix for Potential Impacts of Kigali Water Supply Master Plan

SEA Issues/issue		Ground water Priority	Surface water Priority	Without Project	Remark
Socio-economic	Land availability/ land tenure	-	--	0	
	Economy	+/-	+/-	-	
	Livelihoods	+/-	+/-	-	
	Aesthetics	+/-	+/-	0	
	Health/safety	+/-	+/-	-	
	Archeological Resources	-	-	0	
	Historical/culture Resources	-	-	0	
	Crop & Livestock	-	--	0	

SEA Issues/issue		Ground water Priority	Surface water Priority	Without Project	Remark
	productivity				
	Resettlement	-	--	0	
	Infrastructures	+/-	+/-	0	
Atmosphere	Climate Change Risks	-	--	0	
	Adaptation/Mitigation to Climate Change	+/-	-	0	
	Air quality	-	--	0	
Biodiversity	Sensitive habitat	-	--	0	
	Protected areas	-	--	0	
	Fauna	-	--	0	
	Flora	-	--	0	
Water Resources	Endegered species	0	0	0	So far there is no endangered species identified.
	Water quality	-	--	0	
	Water quantity	-	-	0	
	Ground water	--	-	0	
	Flood damage mitigation	+/-	--	0	
	Climate change adaptation	+	-	0	
	Surface water	-	--	0	
Soil	Soil erosion	-	--	0	
	Soil pollution	-	--	0	
	Wetland degradation	-	--	0	
Transboundary	Water resources	-	-	0	
	Protected Ecosystem	0	0	0	No transboundary protected ecosystem to be affected
	People movement	+/-	+/-	0	
	Natural disaster	-	-	0	No transboundary natural disaster anticipated
Waste management	Solid waste	-	--	0	
	Liquid waste	-	--	0	
	Hazardous waste/Chemical waste	-	--	0	
Occupational health and Safety	Worker's health and safety	-	-	0	
	Community health and safety	-	-	-	

+	Positive environmental and Social Impacts
0	No foreseen effects (Positive or Negative)
+/-	Potential positive and Negative impacts (Mixed Effect
-	Negative impacts/effects
--	Relatively bidder negative impacts/effects

Source: BESST LTD (prepared based on RWANDA SEA guidelines), 2019

12.2.1 Assessment and Comparison of Scenarios

In SEA (Strategic Environmental Assessment), it is important to evaluate "No Project" option as an alternative option of water supply scenario. In evaluation, each water supply scenarios were evaluated

by following process.

- Evaluate "Without Project" option which is leave current situation as it is
- Compare alternative water supply scenario accordance with compliance to criteria

Under the master Plan different Master scenario are proposed. Under these master scenarios, key difference in terms of environmental and social impact is the source of water, ground water and surface water. Therefore, the SEA considered these two options plus no-option scenario to understand environmental and social impacts associated with each option.

12.2.1.1 Ground Water Prioritized Development Scenario

Summary of the ground water prioritized water source development scenario is shown in following table.

Table 12.2-2 Summary of Water Supply Scenario (1)

Water supply scenario	Ground water prioritized water source development scenario
Overview	- Water source development shall be prioritized on ground water (underflow water) that is advantageous on relatively better water quality. In the medium to long term, lake water from Mugesera Lake, or Muhazi Lake, and surface water from Nyabarongo River and Nyabugogo River shall be sequentially developed and meet future demand. - In principle, the main development sites will be the expansion / renovation of the existing water treatment plant along the Nyabarongo River. New development sites are only planned in two locations (Masaka, and Rurindo) in which the eastern and northern part of Kigali City where the future demand is expected according to Kigali City Master Plan.
Merit	- Underflow water has low turbidity compared with intake directly from Nyabarongo River (it shall reduce treatment cost and reduce environmental load). - In near future, along with population increase of Kigali City, contamination of the surface water is expected. By minimizing use of surface water (minimize use of surface water until development of sewerage system in Kigali City) it shall also minimize treatment cost. - It is also considered as effective measures for mitigating effect of climate change (preventing damage to intake facilities by flooding)
Demerit	- Utilizing ground water as water source is technically challenging. It is rather difficult works even for normal operation. - Compared with surface water, potential capacity of ground water is smaller than surface water. In addition, it is still under examination. - It is yet certain when the pollutant become eminent. It is also same for sewerage system function. - Main source is depending on Akagera River and it may say it is lack of redundancy
Short term (Priority) Project Component	- Construction of Masaka WTP and its related clear water (CW) transmission & distribution facilities - Expansion of Karenge WTP and its related transmission & distribution facilities - Expansion & renewal of Nzove 1 WTP and its related transmission and distribution facilities - Kigali City central trunk main (Nzove WTP to city west) - Strengthening the function of Nzove-Ntora Distribution System - Technical cooperation scheme under JICA assistance
Long term Project Component	- Construction of reservoir and distribution network and renewal - Expansion of Nzove water treatment plant - Development of water intake and water treatment plant development attached to Nyabarongo 2 dam construction - Yanze river dam development - Small scale water treatment plant development for spring and small stream - Development of water source and treatment plant in Kanzenze - Development of water source and treatment plant in Akanyaru River - Development of water source and construction of water treatment plant near Muhazi Lake

Source: JST, 2020

12.2.1.2 Surface Water Prioritized Development Scenario

Summary of the surface water prioritized water source development scenario is shown in following table.

Table 12.2-3: Summary of Water Supply Scenario (2)

Water Supply Scenario	Surface water prioritized water source development scenario
Overview	- Water source development shall be prioritized on surface water of Akagera River. Take advantages of available development capacity of Akagera River as much as possible. In the medium to long term, lake water from Mugesera Lake, and surface water from Akagera River shall be sequentially developed and meet future demand in eastern and northern region. - In principle, the main development sites will be the expansion / renovation of the existing water treatment plant along the Akagera River. New development sites are only planned in two locations (Masaka, and Rurindo) in which the eastern and northern part of Kigali City where the future demand is expected according to Kigali City Urban Development Master Plan.
Merit	- Maximize use of available water resource development capacity of Akagera River. - Simplify technology apply for treatment.
Demerit	- Treatment cost for turbid water may be higher than ground water (underflow water) - Due to heavy contamination of the surface water by expected urbanization of this region shall increase treatment cost - It is also required to consider effective measures for mitigating climate change (risk of suffering damage to intake facilities by flooding) - Main source is depending on Nyabarongo River and it may say it is lack of redundancy for draught
Short term (Priority) Project Component	- NRW reduction project through pressure control and pipe renewal - Construction of Masaka WTP - and Clear Water Transmission & Distribution Facilities - Rehabilitation of Karenge WTP - Expansion of Karenge WTP and Transmission & Distribution Facilities
Long term Project Component	- Construction of reservoir and distribution network and renewal - Expansion of Nzove water treatment plant - Development of water source and construction of water treatment plant in Rutonde - Development of water intake and water treatment plant development attached to Nyabarongo 2 dam construction - Yanze river dam development - Development of water source and treatment plant in Kanzenze - Development of water source and treatment plant in Akanyaru River - Development of water source and construction of water treatment plant near Muhazi Lake

Source: JST, 2020

12.2.1.3 Identification of Environmental and Social Impacts

Potential positive and negative impacts need to be identified which may fall into different categories, including:

- Direct impacts associated with alternative options within the PPP that initiate and locate specific project activities;
- Indirect impacts that are associated more with policies that may have fiscal or legislative implications;
- Cumulative impacts that involve large-scale schemes, such as infrastructure development; and
- Large-scale impacts that have regional and global effects. Impacts also may be permanent, temporary, or synergistic.

Impact assessment methods commonly applied to SEA include the following: scenario development,

risk assessment Policy impact matrix, predictive and simulation models, significance thresholds, GIS capacity/habitat analysis, cost/benefit analysis, least cost analysis, multi-criteria analysis. Each of the above methodology is used depending on available information but also the instruments that requires SEA (policy, plan or program). Based on the available information and given that the proposed Master Plan has identified specific projects; risk assessment approach is used in impacts assessment. Two Master Scenario or alternatives outlined in the MP are compared in terms of their potential environmental and Social impacts and against the business-as-usual alternative (this includes the trends identified via the baseline analysis at the scoping stage).

Table 12.2-4 Determination of Potential Environmental Impacts within Alternative Options

SEA Issues		Ground water priority	Surface water priority	Without project
Socio-economic	Loss of land or access to land	Construction of water treatment plants, water reservoir and water intake as well as water pipelines identified for the investments will result in loss of farmland, grazing land, business and structures among others by the local communities owning the land mainly during construction of WTP, Water Reservoirs, Water Intake and water pipelines	Construction of water treatment plants, water reservoir and water intake as well as water pipelines identified for the investments will result in loss of farmland, grazing land, business and structures among others by the local communities owning the land mainly during construction of WTP, Water Reservoirs, Water intake and water pipelines	No Impacts
	Livelihoods and loss of income	It is anticipated that the proposed infrastructures will affect farmland, grazing land, business and structures, which are used by communities for their livelihoods. These impacts will be permanent where water intake, WTP and reservoirs will be constructed and temporary for transmission pipelines.	It is anticipated that the proposed infrastructures will affect farmland, grazing land, business and structures, which are used by communities for their livelihoods. These impacts will be permanent where water intake, WTP and reservoirs will be constructed and temporary for transmission pipelines.	-Existing shortage of improved water shortage will increase; - People with no access to improved will continue to suffer waterborne diseases; - Country objective will not be achieved and cost of water may remain high
	Physical Resettlement	Among proposed sites none of them requires physical resettlement given that are free of human settlement.	Among proposed sites none of them requires physical resettlement given that are free of human settlement	No impacts
	Crop & Livestock productivity	The land expected to be affected include crops, trees and pastures. These assets will be affected during site clearance	The land expected to be affected include crops, trees and pastures. These assets will be affected during site clearance	No impacts
		Increased water usage for water supply may affect other users like irrigation and livestock and hence loss of income	Increased water usage for water supply may affect other users like irrigation and livestock and hence loss of income	No Impacts

12-7

SEA Issues		Ground water priority	Surface water priority	Without project
	Archaeological Resources/Cultural resources	No archaeological or cultural resources expected in the proposed sites. However, this may happen during excavation of constructions of various proposed structures	No archaeological or cultural resources expected in the proposed sites. However, this may happen during excavation of constructions of various proposed structures	No Impacts
	Employment opportunity and source of income	At this stage is not eased to estimate how many direct and indirect employment opportunity will be generated but construction works requires both skilled and unskilled people. This will generate income to workers.	At this stage is not eased to estimate how many direct and indirect employment opportunity will be generated but construction works requires both skilled and unskilled people. This will generate income to workers.	Employment opportunity will be missed
	Livelihoods, Health and safety improvement,	Provision of water to communities will improve the livelihood of population in Kigali and its surroundings and improve the health and safety conditions	Provision of water to communities will improve the livelihood of population in Kigali and its surroundings and improve the health and safety conditions	Shortage of water will remain and no improvement of existing conditions
	Labour influx and Community health and safety	Construction activities may lead to influx of workers, but the scale is likely to be low including significance. The influx of workers and followers can lead to adverse social and environmental impacts on local communities. Therefore, there is a potential risk (minimal) that the construction process for most of the investment projects could increase HIV/AIDS and other STI prevalence in the project areas especially through interactions of the locals with the labour forces. Increase in risk of sexually transmitted diseases, such as HIV/AIDS etc. due to influx of migrant workers; solid waste and effluent discharge from construction camps; risk of increase in vectors of *schistosomiasis, river blindness, Lymphatic filariasis (elephantiasis)* and malaria due to stagnant water associated with construction works/borrow pits etc.	Construction activities may lead to influx of workers, but the scale is likely to be low including significance. The influx of workers and followers can lead to adverse social and environmental impacts on local communities. Therefore, there is a potential risk (minimal) that the construction process for most of the investment projects could increase HIV/AIDS and other STI prevalence in the project areas especially through interactions of the locals with the labour forces. Increase in risk of sexually transmitted diseases, such as HIV/AIDS etc. due to influx of migrant workers; solid waste and effluent discharge from construction camps; risk of increase in vectors of *schistosomiasis, river blindness, Lymphatic filariasis (elephantiasis)* and malaria due to stagnant water associated with construction works/borrow pits etc.	Lack of water in community will remain and cause health and hygienic issues.

12-8

SEA Issues		Ground water priority	Surface water priority	Without project
	Occupation health and safety of workers	Occupation health and safety of the workers during the construction phase is likely to be a concern due to the accidents that normally occur in construction sites that could cause loss of life, limbs among others. Construction activities may also endanger the health and safety of the local community around the construction sites as a result of construction related hazards. The construction of WTP, Water Reservoirs, Water Intake and water pipelines are likely to lead to occupational safety and health impacts. Communities near generation and transmission facilities remain at risk with respect to safety	Occupation health and safety of the workers during the construction phase is likely to be a concern due to the accidents that normally occur in construction sites that could cause loss of life, limbs among others. Construction activities may also endanger the health and safety of the local community around the construction sites as a result of construction related hazards. The construction of WTP, Water Reservoirs, Water Intake and water pipelines are likely to lead to occupational safety and health impacts. Communities near generation and transmission facilities remain at risk with respect to safety	No Impacts
Atmosphere	Air pollution and air quality	Airborne dust will be caused by excavation, vehicle movement hence engine combustion and materials handling, particularly downwind from the construction sites during the construction phase of the identified investments. Uncovered stockpiles and asphalt mixing plant operations are another source of dust. Air pollution will be further caused by emissions from vehicles and construction machinery. There will be decreased air quality due to dust, suspended particles, hydrocarbon vapours, oxides of nitrogen and sulphur (NOx and SOx) and Volatile Organic Compounds (VOC) among other emissions	Airborne dust will be caused by excavation, vehicle movement hence engine combustion and materials handling, particularly downwind from the construction sites during the construction phase of the identified investments. Uncovered stockpiles and asphalt mixing plant operations are another source of dust. Air pollution will be further caused by emissions from vehicles and construction machinery. There will be decreased air quality due to dust, suspended particles, hydrocarbon vapours, oxides of nitrogen and sulphur (NOx and SOx) and Volatile Organic Compounds (VOC) among other emissions	No Impacts
Biodiversity	Sensitive habitat/protected area	None of proposed site is found in protected areas, however, water abstraction, construction of well, MMC rooms and raw water pipeline may will be done in wetlands and near rivers or lakes. This can lead to the degradation of these fragile ecosystems.	In case of surface water, only water intake and raw water pipeline are expected in wetlands near rivers and lakes and construction works may affect these ecosystem	No Impacts
	Fauna	During operational phase, over-abstraction of ground water has a negative impact on living organisms including flora and fauna. When the ground water withdrawals exceed recharge, there is a falling of water table and living organism does not have enough water.	Reptiles and birds maybe affected during site clearance and fauna living in rivers and lake may be affected with excessive water abstraction	No Impacts
	Flora	There will be vegetation loss (site specific) during the construction phase for WTP, intake, reservoirs and pipelines either to pave way for actual project construction among others. The vegetation will be cleared so that the area where the construction work is to take place is clear for the construction work to be performed.	There will be vegetation loss (site specific) during the construction phase for WTP, intake, reservoirs and pipelines either to pave way for actual project construction among others. The vegetation will be cleared so that the area where the construction work is to take place is clear for the construction work to be performed	No impacts

12-9

SEA Issues		Ground water priority	Surface water priority	Without project
Water Resources	Impacts on Water table	Ground water abstraction may have impacts in aquifer water table. Even if, proposed areas for ground water abstractions have enough quantity of ground water, water abstraction will contribute to the variation of the ground water table within the project region and downstream. Considering the available water discharge in the area, the project will have minor variation of ground water table taking into consideration the Nyabarongo river input, the abundant rainfall and other climatic patterns. It is also noted that the ground water abstraction will be limited to the fixed rate and regular monitoring is recommended.	The same as ground water, surface water abstraction may affect the amount of water available in rivers and lakes especially when is combined with seasonal or climate variation and other water use. This may have an impact on downstream users but also on the amounts of raw water expected for treatment	Pre-existing status will remain
	Climate change impacts	Apart from dust, suspended particles, hydrocarbon vapours, oxides of nitrogen and sulphur (NOx and SOx) and Volatile Organic Compounds (VOC) among other emissions, the proposed option will not much have impacts on climate and will not be affected by climatic conditions	In addition to minor emissions as it is in the first option, this option more affected by climatic conditions including reduction of amount of water but also heavy sedimentation due to floods	Pre-existing status will remain
	Sedimentation	Excavation works shall involve earth moving within the river flood plains and sections of the adjoining riverbanks and lands. This loosening of the soil and the steep slope terrain will create a situation where any heavy rains will freely wash down the silt into the downstream areas. The silt when washed down may contain high levels of organic matter and deposition of this may lead to anoxic conditions in the lower water levels with potential risks to the associated aquatic life. However, abstraction of ground water is not much affected by sedimentation and water treatment is much easier compared to surface water	Excavation works involve earth moving within the river flood plains and sections of the adjoining riverbanks and lands. This loosening of the soil and the steep slope terrain will create a situation where any heavy rains will freely wash down the silt into the downstream areas. The silt when washed down may contain high levels of organic matter and deposition of this may lead to anoxic conditions in the lower water levels with potential risks to the associated aquatic life. Surface water is much affected by sedimentation and the cost of water treatment is high. Sometimes the treatment is even impossible after heavy rains and floods	Where the project is implemented or not, sedimentation may be caused by other events such as heavy rains and soil erosion

12-10

SEA Issues		Ground water priority	Surface water priority	Without project
	Pollution of ground water	Ground water may be contaminated from hydrocarbons mainly from the contractor's machineries especially during drilling of wells	It is only expected when there is oil spillage when operating heavy equipment's/ machineries near water bodies	No impacts
	Conflicts about water usage	Inceased amount of water supply may affect other users such as agriculture and affect production and hence income	Inceased amount of water supply may affect other users such as agriculture and affect production and hence income	The current usage will remain
	Soil erosion	Soil erosion involves transport of the soil down slope by running water or, more rarely but still a significant factor, away from the site by wind. Soil compaction and disturbance, usually accompanied by vegetation and litter layer damage, are preconditions for accelerated soil erosion. Most soil damage occurs as the result of movement of machine, trucking, and to some extent through felling of trees during excavation works.	Soil erosion involves transport of the soil down slope by running water or, more rarely but still a significant factor, away from the site by wind. Soil compaction and disturbance, usually accompanied by vegetation and litter layer damage, are preconditions for accelerated soil erosion. Most soil damage occurs as the result of movement of machine, trucking, and to some extent through felling of trees during excavation works	Even without projects soil erosion will happen due to other activities such as farming
Soil	Soil pollution	The only anticipated soil pollution will be from oil spillage during construction works	The only anticipated soil pollution will be from oil spillage during construction works	No Impacts
	Wetland degradation	Ground water abstraction, installation of raw water pipe, drilling of wells will alter the features of the wetland and therefore alter their hydrology (flow and water turbidity). Temporary loss of habitat and component species within the construction corridor. Further, the construction phase will involve the use of heavy machines and vehicles and increase of circulation of people. For different purposes laydown yards will be needed, as for storage of parts and construction material, storage of pipes, parking of trucks and construction machines etc. and work camps have to be installed. You should add wells digging impacts on the wetland (immediate and in long term)…	Construction of water intake and installation of raw water pipe will alter the features of the wetland and therefore alter their hydrology. Construction phase will involve the use of heavy machines and vehicles and increase of circulation of people. For different purposes laydown yards will be needed, as for storage of parts and construction material, storage of pipes, parking of trucks and construction machines etc. and work camps have to be installed.	No impacts

12-11

SEA Issues		Ground water priority	Surface water priority	Without project
Waste management	Wastewater	Wastewater from water projects include filter backwash, reject streams from membrane filtration processes, and brine streams from ion exchange or demineralization processes. These waste streams may contain suspended solids and organics from the raw water, high levels of dissolved solids, high or low pH, heavy metals, etc.	Wastewater from water projects include filter backwash, reject streams from membrane filtration processes, and brine streams from ion exchange or demineralization processes. These waste streams may contain suspended solids and organics from the raw water, high levels of dissolved solids, high or low pH, heavy metals, etc.	No Impacts
	Solid waste	Solid waste residuals generated by water treatment include process residuals, used filtration membranes, spent media and miscellaneous wastes. Process residuals primarily consist of settled suspended solids from source water and chemicals added in the treatment process, such as lime and coagulants. Pre-sedimentation, coagulation (e.g., with aluminum hydroxide [alum] or ferric hydroxide), lime softening, iron and manganese removal, and slow sand and diatomaceous earth filtration all produce sludge. Composition of the sludge depends on the treatment process and the characteristics of the source water, and may include arsenic and other metals, radionuclides, lime, polymers and other organic compounds, microorganisms, etc.	Solid waste residuals generated by water treatment include process residuals, used filtration membranes, spent media and miscellaneous wastes. Process residuals primarily consist of settled suspended solids from source water and chemicals added in the treatment process, such as lime and coagulants. Pre-sedimentation, coagulation (e.g. with aluminum hydroxide [alum] or ferric hydroxide), lime softening, iron and manganese removal, and slow sand and diatomaceous earth filtration all produce sludge. Composition of the sludge depends on the treatment process and the characteristics of the source water, and may include arsenic and other metals, radionuclides, lime, polymers and other organic compounds, microorganisms, etc.	No impacts
	Sludge	One of the important wastes during the operational phase will be sludge from water treatment. If not well handled, this waste may contribute to water pollution and environmental degradation.	The surface water has more sludge given the high level of turbidity and sedimentation identified in various water sources especially Akagera River.	No impacts
	Hazardous chemicals	Water treatment may involve the use of chemicals for coagulation, disinfection and water conditioning. In general, potential impacts and mitigation measures associated with storage and use of hazardous chemicals are similar to those for other industrial projects	Water treatment may involve the use of chemicals for coagulation, disinfection and water conditioning. In general, potential impacts and mitigation measures associated with storage and use of hazardous chemicals are similar to those for other industrial projects	No Impacts

Source: BESST Ltd, expert's assessment, 2020

12-12

12.2.2 Evaluation and Comparison of Scenarios

Following **Table 12.2-5** summarized merit and demerit of the possible water supply scenarios.

Table 12.2-5 Comparison of Alternative Options (Water Supply Scenario)

S/N	Alternative Options			Merit	Demerit
1	Ground water prioritized water source development scenario	Water Source Development Near-by Kigali City and Adjacent 7 sectors	Utilize relatively better-quality water for water source	- Relatively lower treatment cost - Lower impact on environment - Better climate change adaptation	- Increase system complexity
2	Surface water prioritized water source development scenario		Utilize accessible water for water source	- Simplified and consolidated facility management - Quicker development - Lower social impact	- High treatment cost - More environmental impact
3	Without projects	No impact		- No adverse impact on Environment	- Socio-economically no benefit for society. It may limit development of Region; - Existing shortage of improved water shortage will increase; - People with no access to improved will continue to suffer waterborne diseases;

Source: JST, 2020

In case of without project case, there is no development of water treatment plant and distribution and transmission network development. This won't cause any environmentally adverse impact. However, it also will bring no socio-economic benefits to the community of Kigali City and adjacent 6 Sectors in the future. It may become a bottleneck for the development effort of improvement of socio-economic status of Rwandans which until now Rwanda Government has set out in target (Rwanda Vision 2020 (2012) and series of Development Plans).

In terms of ESC point of view, groundwater prioritized water source development scenario is considered as most suitable since it has a wide range of benefit. Especially it is not only complying with environmental requirements aspect (environmental and social impacts by the component projects are managed to be avoiding adverse impact) but also has advantages in adaptation to climate change and economic efficiency. Only concern is it requires capacity development of project proponent during its implementation. **Table 12.2-6** summarizes the results of comparison of scenario considered.

Table 12.2-6 Characteristics of each water source development scenario (alternative plans)

Characteristics	Ground water Prioritized	Surface Water Prioritized	Without Projects	Remark
Archive Development Goal	◎	◎	×	
Development Capacity	○	◎	-	
Construction Cost	○	◎	-	
Treatment cost	◎	○	-	
Operation Requirement	○	◎	-	
Climate Change Adaptation	○	△	-	
Environmental Impact	○	△	-	
Social impact	○	○	-	
Overall	1	2	3	

Source: JST, 2020

12.3 STRATEGIC MITIGATION MEASURES

12.3.1 Environmental and Social Strategic Options

12.3.1.1 Screening and Classification of Environment Studies Required

Both national regulations and JICA guidelines for environmental and social consideration requires screening of projects and classification in one of environmental Category. JICA guidelines classifies each project into one of four environmental categories (A, B, C, and FI) depending on the level of ESC required. Classification of the project is based on reports and documents prepared by the project proponents such as the Screening Format prepared by JICA. The project may be reclassified into a different category when there is a change in the scope or when an unanticipated impact has been identified. In Rwanda, the new environmental law classified projects into category 1 and category 2 categories mainly due to projects size. A list of typical projects classified in category 1 and two are provided as annex to the ministerial order establishing the list of projects that requires EIA.

Table 12.3-1 Classification of Environmental Category in JICA and Rwanda Guideline

Type of the Project	JICA guideline	Rwanda Guideline	Remarks
The project is likely to have significantly adverse impacts on the environment or society.	Category A	Cat 1	Require full-scale EIA
The project may have adverse impacts on the environment or society, but these impacts are less significant than those of Category A projects. These impacts are site-specific; few, if any, of them are irreversible; in most cases, they can be mitigated more readily than Category A projects.	Category B	Cat 2	Depends on scale of adverse impact full-scale EIA is not necessary
The project is likely to have minimal or no adverse impact on the environment or society.	Category C	Cat 2	Full scale EIA is not necessary
JICA provides funds to a Financial Intermediary, which in turn implements sub-projects that may have adverse impacts on the environment or society, but these impacts cannot be identified in detail prior to JICA's approval. If there is a sub-project that can be categorized as Category A, it needs to go through the same procedure as a Category A project including JICA's environmental review and information disclosure prior to its implementation.	Category FI	N/A	After categorized apply review

Source: JST

In terms of MP study, it is considered as Category B in JICA's guideline. It is almost same in Rwanda's guideline. However, Rwanda's Guideline is basically applied to each project bases, and construction of the water treatment plant and urban water supply facility are subject to EIA except rehabilitation or some other cases. Therefore, when actual EIA application, it is better to follow Guideline prepared by the Rwanda Government.

12.3.1.2 Preparation of Environmental Impacts Assessment (EIA) for Each Subprojects

This SEA contains potential mitigation measures and monitoring indicators through which the adverse impacts for specific subproject investments may be managed. However, each sub project will have to prepare an EIA/EMP. The EIA/EMP for each subproject should at a very minimum contains among others;-

- Description of the possible adverse effects that the EIA/EMP is intended to address;
- Identification of project design alternatives that would meet similar objectives, and a description of why these projects are not viable, especially if they have a lesser environmental or social impact;
- Description of planned mitigation measures, and how and when they will be implemented
- Program for monitoring the environmental and social impacts of the project, both positive and negative;
- Description of who will be responsible for implementing the EMP; and
- Cost estimate and source of funds.

12.3.1.3 Climate Change Adaptation and Mitigation Measures

Rwanda is one of the most densely populated country in Africa. In this regard, rising temperatures and variable rainfall now-days threatens the country. Especially, in the rapidly growing urban areas like the competition increases between urban water supply and agriculture water. There are increasing concerns about water shortages during longer dry spells, and the impact of flooding and landslides (increase of sediment and turbidity) on the water-intake of the water treatment plant along the Nyabarongo River.

To cope up with the climate change in this region and to ensure sustainability of the 15-Year Investment Plan, following aspects are considered to be applied.

- Reducing greenhouse gas emission
- Enhancing adaptive capacity, strengthening resilience and reducing vulnerability

Specifically, measures for reduction of greenhouse gas emission are being studied under the Masterplan and the 15-Year Investment Plan in the following manner.

- Methods of energy saving is carefully studied during preparation of water supply system, especially minimization of pumping energy in water transmission system
- Water pressure control and usage of appropriate pipe material is planned for reduction of NRW, which will contribute to reduction of water intake, purification, transmission and distribution energy,
- Usage of energy and chemicals is reduced in water treatment system using underground water

Influence of drought during dry season and flooding during rainy season on water intake facilities will increase due to climate change. Following mitigation measures are planned to reduce the risks to the water supply system.

- Intake from groundwater is planned with high priority considering reliability against drought.
- Drawdown of water table in wells is also considered when designing intake facilities.
- In order to mitigate impact of drought, numerous intake locations are planned. Three main locations are planned to be developed at upstream, middle, and downstream along the Nyabarongo/Akagera River, namely the Nzove, the Gahanga, and the Masaka, in addition to the Karenge Intake at the Mugesera Lake.
- Clear water transmission pipelines are planned to interconnect all the above water sources to mitigate impact of drought.
- Upgrading of intake facilities in the Karenge and the Nzove are planned to mitigate influence of flooding
- Preventing measures are studied against clogging of transmission pipe from the Yanze River to the Kimisagara WTP during the rainy season.

12.3.1.4 Land and Easements Acquisitions

Proposed investment under both Master Plan and 15-Years Investment Plan including construction of intake, wellfields, Water Treatment Plant and forwarding infrastructures involve land acquisition or easements. The land used is either government lands or private land. Experience and research indicate that physical and economic displacement, if unmitigated, may give rise to severe economic, social and environmental risks: production systems may be dismantled; people face impoverishment if their productive resources or other income sources are lost; people may be relocated to environments where their productive skills are less applicable and the competition for resources greater; community institutions and social networks may be weakened; kin groups may be dispersed; and cultural identity, traditional authority, and the potential for mutual help may be diminished or lost. For these reasons, involuntary resettlement should be avoided. Where involuntary resettlement is unavoidable, it will be minimized and appropriate measures to mitigate adverse impacts on displaced persons (and on host communities receiving displaced persons) will be carefully planned and implemented. It is recommended that:

- Every project undergoes screening to determine whether a resettlement plan is required and if yes, the instruments will be prepared, and compensation measures provided prior land acquisition;
- Alternative option be explored to avoid, minimize resettlement impacts;
- Where possible road reserves should be used to minimize land take on households

12.3.2 Mitigation Considerations and Options for Specific Environmental and Social Impacts

All moderate to major adverse impacts are considered for mitigation. Specific measures have been suggested in this regard where practicable. With regard to negligible and minor impacts where the

project activity is not expected to cause any significant impact in such cases, best practice measures and mitigation have also been recommended where appropriate to improve the environmental and social performance of the Project. The mitigation options considered may include project modification, provision of alternatives, project timing, pollution control, compensations and relocation assistance. In cases where the effectiveness of the mitigation is uncertain, monitoring programs are introduced.

Recommended mitigation measures for potential environmental and Social Impacts
The mitigation measures or guidelines have been designed in order to avoid, minimize and reduce negative environmental and social impacts at the project level. The mitigation measures are presented in **Table 12.3-2** in a descriptive format.

Table 12.3-2 Proposed Mitigation Measures

Impacts	Description of mitigation measures
Physical Environment	
Solid and Effluent Waste	**Solid nontoxic waste** - Adequate waste receptacles and facilities should be provided at project sites/camp sites - Training and awareness on Safe Waste Disposal in construction camps for all workers - Final disposal should be at dumpsites approved by the REMA **Waste oil /fuel** - Spent or waste oil from vehicles and equipment should be collected and temporarily stored in drums or containers at site; - Waste oil should be disposed of by oil marketing companies or agents approved or recognized and have the capacity to undertake oil disposal; - Prepare Waste Disposal Plan for every construction site; - Install waste disposal receptacles and signs in strategic places within the construction camps; - Provide training and awareness on need to avoid littering; - Ensure the construction camps have toilets and connected to the sewer system
Flood risk assessment and Management	**One of the water sources considered under Master Plan is Nyabarongo/Akagera river. The river is prone to repetitive floods (MINEMA, 2015)[3].** The flood assessment conducted at Kanzenze area found the maximum water in extreme event for both 50year and 100 years return period is about 1,5m above the ground. Thought this happens rarely, the project design should consider this level during the construction of different project component especially well fields. Potential mitigation measures may include: - For protection of wells a concrete room at reasonable height based on highest flood level - Put water treatment plants outside the swamp area and, - Design and implement water monitoring programs in areas proposed for water abstractions
Sludge management	During the operational phase two kind of waste is expected including sludge and wastewater. If not well handled, this waste may contribute to water pollution and environmental degradation. Therefore, a proper handling and disposal plan is required in order to avoid any pollution or environmental degradation. Options to be considered include: – Backwash thickeners and belt press filtrate will be recycled to the inlet of the plant and Sludge will be thickened. – **Dewatering** aims to reduce the water content further so that the solids content of the sludge is about 20 % (equivalent to 1 kg dry sludge with 4 L of water). The sludge can then be handled like a solid. Dewatering can be done mechanically using a filter press (employing pressure or vacuum), or a centrifuge. – **Sludge reuse:** the sludge can be reused for different use including in agriculture or in bricks making. The use will depend on sludge composition. The sludge may have less biological component and there may be a presence of pathogens in the sludge in high numbers which make the use in agriculture unsatisfactory. Therefore, the plausible opportunity of sludge reuse would be in bricks making. If the composition is made of biological matter, then the use of sludge for making fertilizers would be

[3] National Risk Atlas of Rwanda, Ministry of Disaster Management and Refugee Affairs,2015

Impacts	Description of mitigation measures
	considered. – **Final or ultimate disposal of sludge, which cannot be reused**, is by land filling or incineration. Since sludge for land filling usually contains heavy metals or toxic chemicals, lining of the landfill with clay or plastic liner may be required to prevent contamination of groundwater. – Sludge disposal should be done in appropriate landfill approved by District authority and in accordance with the Land Use Master Plan.
Decreased Air Quality	- Proposed investments should require that construction contractors operate only well-maintained engines, vehicles, trucks and equipment. A routine maintenance program for all equipment, vehicles, trucks and power generating engines should be in place; - The project should ensure the use of good quality fuel and lubricants only; - If dust generation at the project/construction site becomes a problem, limited wetting of sites and or unloading and reloading points should be done to reduce dust raising; - Construction traffic speed control measures should be enforced on unpaved roads (speed limits through communities should be ≤50km/hr on unpaved roads and near or at project site should be ≤30 km/hr); - Engines of vehicles/trucks and earth-moving equipment should be switched off when not in use.
Noise and vibration	- Proposed investments should require contractors to use equipment and vehicles that are in good working order, well maintained, and that have some noise suppression equipment (e.g., mufflers, noise baffles) intact and in working order. - This will be achieved by making it a component of contractual agreements with the construction contractors. - Contractors will be required to implement best driving practices when approaching and leaving the site (speed limit of ≤30 km/hr) to minimize noise generation created through activities such as unnecessary acceleration and breaking squeal. - Engines of vehicles/trucks and earth-moving equipment should be switched off when not in use.
Visual Impacts	- Landscaping of facilities after construction and restoration of disturbed areas e.g. borrow pits
Impact on traffic and public safety	- Only road worthy vehicles and trucks should be used to avoid frequent breakdowns on the roads; - Only experienced drivers should be employed; - Contractors must provide training for drivers; Establish speed limits; Enforce safe driving and take disciplinary action against repeat offenders
Water Abstraction	- Obtain water abstraction permits from the Water Resources Management Authority
Decreased Water Quality	- No garbage/refuse, oily wastes, fuels/waste oils should be discharged into drains or onto site grounds; - Fuel storage tanks/sites should be properly secured to contain any spillage; - Maintenance and cleaning of vehicles, trucks and equipment should take place offsite especially where project sites are close to water bodies; - Toilet facilities should be provided for construction workers to avoid indiscriminate defecation in nearby bush or local water bodies
Soil Erosion	- Minimize land clearing areas as much as possible to avoid unnecessary exposure of bare ground to the elements of the weather; - Re-vegetate cleared areas as early as possible using native plant species - As much as possible, avoid construction work in the rainy season
Impact on fauna and habitat	- Avoid unnecessary exposure and access to sensitive habitat areas; - For identified or suspected sensitive habitats (swamps/ wetlands), regular inspection or monitoring should be carried out in the area prior to start and during work.; - If sensitive habitats are encountered, Project activities should cease and the Project should consult wildlife agency to determine the appropriate course of action. - If the project site is discovered as a sensitive habitat area, the Project should engage the wildlife agency to develop a suitable plan. - Prohibition on hunting and consumption of bush meat by workforces - Proposed investments should require that contractors implement a hazardous materials management plan that includes specification for proper storage and handling of fuels, oil, wastes, and other potentially hazardous materials as well as a plan for containment and clean-up of accidental spills into the aquatic environment. - During pre-installation and installation of project facilities, spotting of sensitive aquatic mammals should form part of the project activities. Should these species be observed in the vicinity of the work area, the project should execute measures to avoid destruction or disturbance. - Ensure provision for water flow reserves and appropriate reservoir filling schedules - Project staff must report sightings of any injured or dead aquatic life (fishes)/ mammals immediately, regardless of whether the injury or death is caused by a Project activity. The report should include the

Impacts	Description of mitigation measures
	date and location of the animal/strike, and the species identification or a description of the animal. The report should be made to the wildlife agency in Rwanda. - The Project workforce and local communities should be educated to ensure that the importance of environmental protection and nature conservation are effectively communicated and that wider appreciation of environmental issues and construction best practice are fostered.
Downstream Impacts	- Maintain environmental flow reserves for the river, Do into retain water in reservoir during drought, ensure that water retention in dam is controlled to ensure that adequate reserve is left to flow downstream for users
Quarry Site Impacts	- Identify borrow and quarry sites away from sensitive environments and develop quarry management and rehabilitation plans
Hydrology Impacts/Changes	- Maintain environmental flow reserves for the river, Do into retain water in reservoir during drought, ensure that water retention in dam is controlled to ensure that adequate reserve is left to flow downstream for users; - Ensure water balance by monitoring and regulating water use through water abstraction permit
Social environment	
Physical displacement	- All affected persons to be given relocation assistance (cash or kind) by the Project to enable them to move their properties to new locations, i.e., in accordance with the Resettlement Action; - Resettlement Plans will be required. If a site is acquired, the State may relocate persons and their families as well as community facilities to be affected. The affected families should not be made to incur any cost during the relocation period. A resettlement plan should be prepared for this area;
Loss of employment and livelihoods	- Those whose livelihood is affected should be assisted to ensure they will not be worse off as a result of the project. This can include livelihood assistance, provision of new jobs immediately without any loss of income. The social assessments and socio-economic surveys, which will be undertaken for the preparation of individual investments/subprojects as well as the resettlement action plans, should assess these issues and provide measures in accordance with the Resettlement Action Plan. - Contractors should use local labour as much as possible and where available. As much as possible, all unskilled labour should be contracted or obtained from the local community.
Loss of land and other assets	– Due process should be followed to establish the true owner of any land, be it family or communal land. Once established, the project should acquire the site by paying appropriate compensation in accordance with the resettlement action plan.
Loss of structures/properties	– For a project site to be used, irrespective of the land ownership, appropriate compensation should be paid for any structures/ properties which are permanent structures at the site as well as investment made for any development on the land. - Depreciation should not be factored during valuation of these properties. The compensation process should satisfy the RPF developed for the project. - Appropriate compensation should be paid for any damaged or destroyed propriety that belongs to affected persons. No depreciation during valuation of these properties.
Impact on access among communities living in the project areas	- Measures will be considered in the projects' design to ensure that communities are not divided and if they are as a result of a project appropriate measures are taken to mitigate this impact.
Impacts on human health/ traffic safety and sanitation	- Trucks carrying construction materials such as sand, quarry dust, laterite etc. will have the buckets covered with tarpaulin or appropriate polythene material from or to project site - Except for areas secured by fencing, all active construction areas will be marked with high-visibility tape to reduce the risk accidents involving pedestrians and vehicles. - All open trenches and excavated areas will be backfilled as soon as possible after construction has been completed. Access to open trenches and excavated areas will be secured to prevent pedestrians or vehicles from falling in. - Adequate sanitary facilities will be available for workers and open range defecation will not be countenanced. - Construction workers will be provided with and educated to wear suitable Personal Protective Equipment (PPE) including hard hats, overalls, high-visibility vests, safety boots, earplugs, gloves etc. - Enforce use of PPEs at all times for all staff and labourers and ensure supervision of the same to minimize accidents - Construction workers should be educated to adhere to basic rules with regard to protection of public health, including most importantly hygiene and disease (HIV/AIDS) prevention.
Impacts on cultural heritage /	- The pre-construction surveys should identify cultural heritage resources and existing ecologically

Impacts	Description of mitigation measures
archaeological interest / existing ecologically sensitive areas	sensitive areas that the project should avoid and by-pass these resources. - The Project should implement a chance find procedure and reporting system to be used by contractors in the event that a cultural heritage feature or ecologically sensitive item/issue is encountered.
Impacts on human health and public safety	- The Project will require all contractors to implement an Environmental, Health and Safety (EHS) plan which will outline procedures for avoiding health and safety incidents and for emergency medical treatment. This will be achieved by making it a component of contractual agreement. - Contractors will be required to wear suitable Personal Protective Equipment (PPE) including hard hats, high-visibility vests, safety boots and gloves and life vests as appropriate in accordance with the EHS plan. - Enforce use of PPEs at all times for all staff and labourers and ensure supervision of the same to minimize accidents - All construction and other workers will be sufficiently trained in the safe methods pertaining to their area of work to avoid injuries.
Labor Influx Management	- Develop site-specific measures before the contractor starts work and update them as necessary to reflect project developments. Overall, adequate monitoring and adaptive management of the potential impacts from labour influx are key to properly addressing them and mitigating risks. Recruit as many local workers from the areas as possible. Provide training for the local communities to acquire skills needed for work opportunities if there is reasonable time especially on monitoring and maintenance. - Develop a Labour Influx Management Plan and Workers Camp Management Plan for all projects. Outline the contractor's responsibilities on influx management in contracts.
Impact on gender access to water for household use and other usage	- The project will take into consideration the different needs for water and types of access which will be affected for each of these groups and provide relevant mitigation measures which will be decided with those affected. Some mitigation measures could include water points for household use and livestock; livelihood assistance to those whose whole or partial livelihood will be affected as a result of some of the possible investments such as dams. Specific impact and relevant measures will be covered by project specific social assessment.
HIV/AIDS Spread and other related public health diseases –Water borne diseases etc.	- Design HIV/AIDS awareness, sensitization and prevention program for each project that extends to the communities as a whole; - Design programs for reducing the spread of water borne diseases like Malaria, Bilharzia etc. in collaboration with the Ministry of Health
Labour and employment related impacts	- Ensure that the local communities are given priority in relation to employment and provided with training (skilled) to provide future labour in the project e.g., operation and maintenance. Ensure that workers are provided satisfactory working conditions and work environment including pay in accordance with the laws of the country - Ensure that child labour is not tolerated in the project; - The project to prepare redundancy plans and packages to be discussed with affected workers which will include re- training and re- tooling of affected workers and aim to avoid labour strife

Source: BESST Ltd, expert's assessment, 2019

12.4 MONITORING PLAN

The goal of monitoring is to measure the success rate of the project, determine whether interventions have resulted in dealing with negative impacts, whether further interventions are needed or monitoring is to be extended in some areas. Monitoring indicators will be very much dependent on specific project contexts.

12.4.1 Overall Master Plan Level Monitoring

WASAC will be responsible for overall monitoring and reporting on compliance with the SEA. WASAC will ensure that sub projects investments are screened, their safeguard instruments prepared,

cleared and disclosed prior to sub project approval. Further, WASAC will ensure that contractors implement the specific sub project ESMP and submit reports on ESMP implementation as required. Within WASAC, monitoring and surveillance of all the sub project investments will be undertaken by the Environmental and Social Safeguards Specialist within the WASAC.

Table 12.4-1 Monitoring Indicator

Monitoring Level	Monitoring Issue	Verifiable Indicators	Responsibility
SEA level	Adequate dissemination of SEA to stakeholders Capacity building and training programs	Record of consultations and meetings; Workshop reports	WASAC Ltd
	Preparation of environmental and social impact assessment report Environmental permitting Monitoring and evaluation	- Independent consultants hired to prepare EIA and/ RAP documents - Environmental Permits for sub projects - Environmental Management Plans, - Monitoring Reports, - Annual Environmental Reports	WASAC Ltd

Source: BESST Ltd analysis, 2020

12.4.2 Subproject Level Monitoring

The second level of monitoring will be at the sub project level where the safeguard instruments for the investments will and must include a monitoring plan for which the WASAC will be responsible for ensuring that monitoring is carried out. All sub project investments will be subject to mandatory annual environmental audit /supervision to ensure that they comply with the Organic Law. Specific monitoring indicator will be included in Environmental and Social Monitoring Plan during the preparation of ESIA of subprojects. The next table presents some of the monitoring indicator based on key environmental and Social Impacts anticipated from proposed investments.

Table 12.4-2 Project monitoring indicators and responsibilities

Impact issue	Proposed action/ measures	Implementation tool/criteria	Monitoring indicators (inputs)	Monitoring indicators (outcomes)	Verification	Project stage	Responsibility
Solid waste disposal	Provide adequate waste reception facilities at construction camp sites Dispose of waste at approved waste collection sites	Waste management plan/Construction site management plan	Number of waste bins at site bins Availability of waste disposal plan Final disposal records	Percentage of workers who follow the solid waste disposal plan including use of receptacles	Weekly checks by project engineer	Construction Operation	Contactor Project engineer
Waste oil/fuel disposal	Provide drums/containers for temporary storage on site of waste oil from equipment and vehicles.	Waste management plan/Construction site management plan	Waste oil drums/containers on site Availability of waste disposal plan (waste oil)	Number of workers familiar and aware of the waste disposal plan	Monthly checks by project engineer	Construction Operation	Contactor Project engineer

Impact issue	**Proposed action/ measures**	**Implementation tool/criteria**	**Monitoring indicators (inputs)**	**Monitoring indicators (outcomes)**	**Verification**	**Project stage**	**Responsibility**
Air pollution	Purchase sound equipment/machinery for project Operate well maintained vehicles, trucks and other equipment Use good quality fuel and lubricants Suppress dust generation at project sites	Part of contract agreement Routine maintenance plan for machinery Purchase of fuel at recognized stations Schedule of works is to limit site.	Number of sound machinery and equipment purchased Availability of equipment and machinery maintenance plan Frequency of watering of surfaces to reduce dust related impacts	Percentage of workers following the good practices for equipment and machinery maintenance	Independent check by project engineers Verification of maintenance record by project engineers Self-check by contractor	Construction	Contactor / Project engineer
Noise pollution	Schedule of works is to be limited to daylight hours; Compliance with the noise emission levels/standard Provision of PPE and train workers on the use of PPEs for noise mitigation and reprimand those not complying	Part of contract agreement for the contractors	Recorded grievances Number of PPE procured for noise mitigation	Number of workers correctly and frequently using PPEs	Self-check by contractor	Construction	Contactor / Project engineer
Traffic impacts	Use only road worthy vehicles and trucks; Use experienced drivers; Contractors must provide driver training; Establish speed limits,	Purchase sound vehicles and trucks /machinery for project Driver qualification recorded Traffic Safety Plan	Traffic incidence records Grievances Recorded	Number of drivers aware and familiar with the traffic safety plan Percentage of drivers who have not committed a traffic offence for the last 6 months	Project engineers to verify	Construction	Contactor / Project engineer
Water pollution	No garbage/refuse, oily wastes, fuels/waste oils should be discharged into drains or water bodies Fuel storage tanks/sites should be properly secured Maintenance and cleaning of	Waste management plan Spill prevention and control plan Water Quality Plan to measure the quality of water including physical, chemical and biological. Implement an Integrated Pest	Visibility of oil on water bodies Procurement and installation of water monitoring and measuring gauges On site erosion observed Proposed	Increased water quality upstream and downstream shown by periodic measurements Water samples collected showing compliance to water	Daily self-checks by contractors Periodic reports on performance by contractor to project engineers Spot checks/aud	Construction Operation	Contractors /Project engineers Project engineers

Impact issue	Proposed action/ measures	Implementation tool/criteria	Monitoring indicators (inputs)	Monitoring indicators (outcomes)	Verification	Project stage	Responsibility
	vehicles, trucks and equipment should take place offsite. Provide toilet facilities for construction workers	Management Plan when using fertilizers and pesticides	actions implemented Quality of water following periodic measurements	pollution standards	its by project engineers		
Water quality	Protection of watersheds and water catchment	Watershed Management Plans	Number of watershed protected	Improved Water quality	Results of water quality sampled	Annually	Rwanda Water Body
Water balance	Monitoring water balance through water abstraction permit	Water abstraction permit, Water Resource Management Plan	Water balance in Catchment	Balanced Water level maintained	Measured water level	Annually	Rwanda Water Body
Impact on fauna and flora	Avoid unnecessary exposure or access to sensitive habitat. Avoid protected areas, critical habitats or areas with significant biodiversity (wetlands)	If a sensitive habitat is discovered in the work area or vicinity, Project activities should cease.	Wildlife incidents recorded and reported	Number or percentage of terrestrial flora and fauna unaffected by the sub projects	Regular self-checks by contractor Spot checks and audit by contractor to the client	Construction Operation Maintenance	Contractors /Project engineers/

Source: BESST Ltd analysis, 2020

Table 12.4-3 Project monitoring indicators and responsibilities-social impacts

Impact issue	Proposed action/ measures	Implementation tool/criteria	Monitoring indicators (input)	Monitoring indicators (output)	Verification	Project stage	Responsibility
Impacts on downstream water users	Maintain Environmental Flows for river basins Ensure that abstraction of water complies with the water abstraction permits	Environmental Flows Plan	Presence of an Environmental Flows Plan calculated and approved by water abstraction agency Availability of Water Abstraction Permit from Water regulation agency	Impacts on water uses and livelihoods downstream	Regular spot checks by water regulation agency Periodic checks of the flows by environmental team	Construction Operation	Contractor WASAC REMA Water regulation agency
Impacts on recreation and public areas	Place notices and warning signs at working areas	ESMP	Grievance records	Recreational Facilities and areas restored/prot	Warning signs/notices in place	Construction	Contractors/Project engineers

Impact issue	Proposed action/ measures	Implementation tool/criteria	Monitoring indicators (input)	Monitoring indicators (output)	Verification	Project stage	Responsibility
				ected			
Impacts on Human Health/ Safety and sanitation	Cover buckets of trucks carrying construction materials such as sand, quarry dust, etc. Use road worthy vehicles/trucks and experienced drivers/operators Active construction areas to be marked with high-visibility tape Provide adequate sanitary facilities Provide PPEs for construction workers. Educate construction workers on site rules/regulation and hygiene and disease (HIV/AIDS) prevention.	ESMP Vehicle maintenance programme/plan in place Construction site management plan ESMP	Health and safety incident register Grievance records	Reduced accidents and hazards in construction sites Reduced incidence of diseases spread e.g., HIV/AIDS, and other STDs Increased understanding of workers on measures to reduce STDs/HIV/AIDS etc.	Health and safety plan under implementation Daily self-checks and verification by contractor Spot checks by project engineers Periodic reports by contractor to project engineers	Construction	Contractors
Impacts on cultural heritage/ archaeological interest /existing aquatic infrastructure and services	Identify cultural heritage resources and existing ecologically sensitive areas.	Pre-construction surveys / Chance Finds procedure Plan for accidental Cultural Finds	Cultural/ archaeological resources/ existing infrastructure encounter incidence register	Number of workers familiar with the chance find procedures	Chance finds procedure under implementation Daily self-checks and verification by contractor	Preconstruction and construction and repairs/ recovery	Contractors
Impacts on Human Health and Safety	Use suitable Personal Protective Equipment (PPE). Provide Training on use of PPE	ESMP	Health and safety incident register Grievance records	Reduction in or increase in accidents due to use of or lack of use of PPEs	ESMP under implementation Spot checks and observations by project engineers	Pre-construction and construction, and repairs/ recovery	Contractors
Labor related impacts (Employment)	Ensure that the local communities are given priority in relation to employment and provided with training (skilled) to provide future labour in the project e.g., operation and maintenance	Human Resource Management Plan	Number of local residents employed in sub projects	Number of local residents employed in sub projects	Employment Records	Pre-construction and construction, and repairs/ recovery	Contractors/EA

Source: BESST Ltd analysis, 2020

12.4.3 Monitoring Roles and Responsibilities

12.4.3.1 Water and Sanitation Corporation (WASAC)

WASAC will be solely responsible for the environmental and social monitoring of the activities under Kigali Water Master Plan. WASAC will be required to prepare periodic (monthly, quarterly and

annual) monitoring reports for all sub projects subjected to further environmental analysis for submission to the JICA or other donors involved in projects under Master Plan and REMA. WASAC will be responsible for appraising and approving sub-projects, organizing the management and implementation of sub-projects, and supervising the implementation of sub-projects, including the implementation of safeguards activities.

12.4.3.2 Rwanda Environment Management Authority (REMA)

The Organic Law on environment places the responsibility of environmental protection on REMA as the coordinating agency. REMA is charged with the overall role of providing oversight in regard to monitoring for all project activities that have potential impacts on the environment in Rwanda. REMA will undertake periodic monitoring of the investment projects by making regular site inspection visits to determine compliance with the investment projects ESIAs approved and will further rely on the submitted annual audit reports submitted for each investment project annually as required by Organic Law as a way of monitoring.

12.4.3.3 Rwanda Water Board (RWB)

Rwanda Water Board is responsible for sustainable water resources management in the country and it has the responsibility to issue water abstraction permit, monitor water quality and to ensure water balance. It will also ensure distribution of water resources among water users and advise on initiative aiming at ensuring water quality.

12.4.3.4 Rwanda Development Board (RDB)

RDB will provide approvals and ESIA license to all the investments based on the ESIA reports submitted, without RDB's approval implementation of the investment project will not move forward.

12.4.3.5 WASAC -Social and environmental specialist

WASAC has a strong team of environmental and social Specialists who will provide oversight, screening of sub projects, preparation of ToRs for EIAs, facilitation, coordination, review of EIAs, monitoring and evaluation of all the sub projects.

12.5 STAKEHOLDERS MEETING AND PUBLIC CONSULTATION

Information disclosure is the key in ESC (Environmental Social Consideration). Project proponents must proactively release relevant information to the public. By sharing information with a wide range of stakeholders from the early stage, the project proponents can utilize their feedback to improve the plan/project. In addition, the project proponents can ensure that unnecessary concerns and misunderstandings among the stakeholders are ameliorated.

In this regard, the WASAC (as project proponent) held Stakeholder Meeting on July 2019 and informed in public about the overall objective of the study and implementation plan for the Project. It is following the implementation plan for public participation / consultation. Followings are outline of the

implementation plan pertaining to public participation / consultation.

- 2019 August Stakeholder Meeting
  - ✓ Announce kick-off of the study
  - ✓ Analyze stakeholders
  - ✓ Establish information flow via media
- 2020 February Stakeholder Meeting
  - ✓ General overview of Master Plan;
  - ✓ Financial & organizational issues;
  - ✓ Update of demand forecast;
  - ✓ Water resource development plan;
  - ✓ Socio economic survey & SEA;
  - ✓ Master scenario & candidate projects; and
  - ✓ Way forward .
- 2021 August Stakeholder Meeting
  - ✓ Detail of Master Plan;
  - ✓ Detail of 15 Years Investment Plan; and
  - ✓ Result of SEA and request for comment;

In this regard, discussions of Stakeholder Meeting in 2020 February were actually done in Thematic Working Group Meeting (TWG) hosted by MININFRA.

Important comments, suggestions and opinions provided through series of Stakeholder meeting are summarized as follows:

- The aim of Master plan study (WASAC/JICA M/P) is for achieving SDGs and the national target that aims at 100% access to safe water (500 m distance from sources for rural and 200 m in urban).
- Big challenges are being laid out ahead the years to come for Rwandan side including WASAC and MININFRA to approach the SDGs targets as well as future demand according to the Study.
- Interim result of the Study implies that the huge investment is inevitable to cover future water demand and in this context, he added that today's meeting to share the Study progress among the concerned development partners would help Rwandan side including WASAC and MININFRA to seek future financial sources.
- The Master Plan is being prepared as a sort of "technical cooperation program" under which the Rwandan side including C/P are actively involved in the process of planning with the JST.

12.6 CONCLUSION AND RECOMMENDATION

12.6.1 Conclusion

This study includes findings regarding baseline of affected area to the application of Master Scenario for water supply in the CoK and adjacent 7 Sectors. It is meant to collect for ESC (Environmental Social Consideration) study to carry out scoping of the water supply scenario derived from selection of optimal water source development scenario. Followings are major findings of this study.

- By developing groundwater as a main source of water treatment plant, there shall be positive and negative environmental impact in each site. However, in each candidate site, it will not cause serious impact on surrounding environment and community.
- Compared with surface water from the Nyabarongo River, utilization of groundwater has advantage on water quality and climate change adaptation measure.
- Even this scenario expecting surface water development in later stage, it is expected to be less impact on environment
- Regulations for EIA in Rwanda have not much difference with the JICA's guideline 2010 and the World Bank Safeguard Policy. Difference only lies in procedure regarding information disclosure and public consultation etc. There are several minor differences between them. But they are basically consistent with the JICA's guideline
- This water supply scenario is following Vision 2020, NST1 and series of plans and policies set out by the Rwanda Government. The development following this scenario shall comply to plans and policies of Rwanda's development.

12.6.2 Recommendation

Basically, construction of water treatment plant and urban water supply system is requiring full-scale EIA by the REMA's Guideline for Environmental Impact Assessment for Water Resources Management in Rwanda 2009 March. Actual implementation of projects listed in the Master Plan following Master Scenario may be subject of application of EIA. Application consists of followings;

- Submission of Project Brief
- Screening
- Submission/Approval of TOR
- EIA Study
- Public Hearing
- Decision making by Tech Committee

Project proponent should start application of EIA for prioritized projects. Following are points to consider.

- EIA shall be implemented based on procedures stipulated in Rwanda's Environmental Law

- EIA should be carried out by project proponent at candidate sites following International Guidelines and/or Rwanda's Guideline such as "Guideline for Environmental Impact Assessment for Water Resources Management in Rwanda 2009 March"
- In case it requires to evaluate potential evaluation survey, EIA should be carried out at candidate site before the survey and even after the survey.
- In accordance with the result of the survey, EIA should be revised (require additional study)
- It is required to earn approval for EIA before the application of operation license
- Resettlement implication will be assessed during EIA preparation and a decision should be made whether a RAP is required or not.

Other permits required prior to the construction and operation of proposed infrastructure includes water abstraction permit and construction permit. Application of these permits shall be made upon the availability required documents such as hydrological study, final designs and EIA studies.

CHAPTER 13 MASTER SCENARIO

The "Master Scenario" gives an overall scenario for water supply in the Study Area up to 2050, considering the water resources development plan, and appropriate WTP, transmission and distribution of water system to meet the future water demand. The Master Scenario is the basis of the 15-Year Investment Plan.

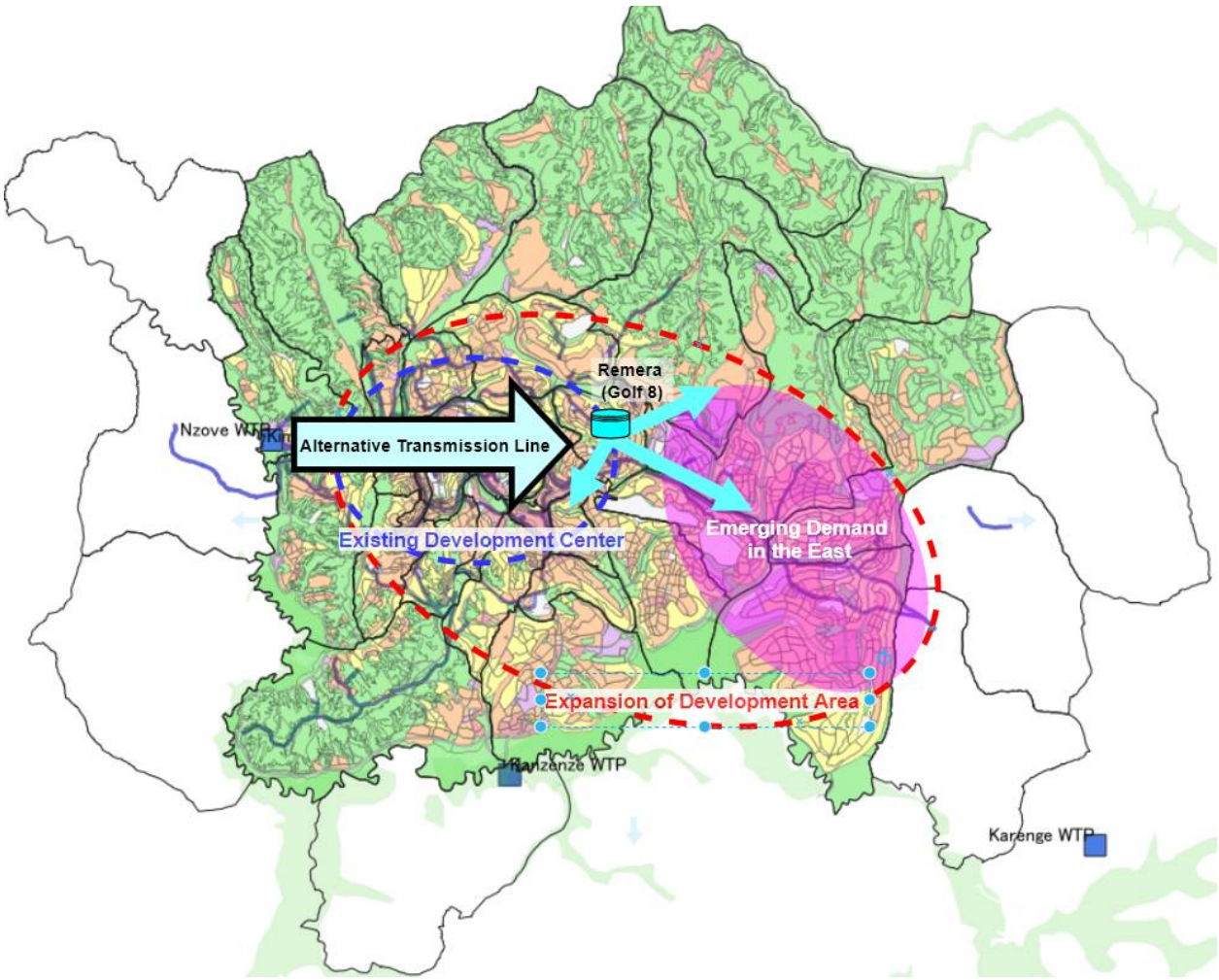
13.1 OBJECTIVES

The objective of this chapter is to determine the Master Scenario for water supply up to 2050 from the multiple options considering a broad perspective. For this purpose, JST compared the various water supply scenarios using the water supply balance model to illustrate the blueprint. Then, the water supply scenarios are evaluated qualitatively, clarifying the risks and costs for each case of water supply expansion. The Master Scenario will be the basis of the 15 years investment plan and feasibility studies.

13.2 PRINCIPLES

Available water sources to meet the large demand are restricted to the Nyabarongo River basin and Mugesera/Sake Lake and other upcountry water sources, as it was shown in **Section 10**. Therefore, the future water supply scenario should be illustrated what the best mixture of those water sources (**Section 13.3 and 13.4**). The technical aspects to be considered for the best mixtures in water transmission (**Section 13.5**), treatment processes (**Section 13.6**), and distribution (**Section 13.7**) in order that the scenarios can be evaluated from water *stability*, *flexibility*, *resiliency,* and the *life-cycle cost* (See the evaluation criteria in **Section 13.9**).

In particular, the key issues on the water supply are improving the *efficiency* and the *flexibility* of the water supply **Figure 13.2-1**. The efficiency problem is attributed mainly to the energy cost issue which is currently over 50% of the production cost in the study area. The bottleneck to improve the transmission energy efficiency is the route from Nzove WTP to Remera Reservoir as the existing transmission route is limited to go through the hilltop of Ntora and Mont-Kigali. Under this background, as a presumption of the master scenario, the Central Transmission Main which goes through the central area of the study area is proposed for future expansion. The design and technical study were described in detail in **Section 13.5.2**. In addition, the water supply should be *flexible* to the actual city's development and the demand growth. To make the water supply system flexible, a new route to meet the emerging demand through Remera (Golf 8) reservoir was proposed in **Section 13.5.3.** Considering that the demands are concentrated on the eastern area (e.g., Ndera, Rusororo and Masaka), Remera Golf 8 is located in a strategically good place both in terms of its height and distance from the demands.



Source: JST

Figure 13.2-1 Strategy to Improve Flexibility and Efficiency as Presumption of Master Scenario

13.3 WATER SUPPLY SCENARIOS

13.3.1 Methodology

13.3.1.1 Models for Water Supply Balance

To describe the extensive City-wide water balance and long perspective up to 2050, we established a comprehensive and simple model to describe the water balance of each region. The detail of the model is explained later in the "Water Supply Area (WSA)" The water balance is expressed as the flow and exchange of the water from each existing/planned WTP and among the forecasted demands in the Water Supply Area. Water demand is allocated to each area based on the Water Demand Projection previously described in **Chapter 9.**

13.3.1.2 Hydraulic Model

A hydraulic model study was used to examine the reachability of water, diameters of pipes, and corresponding energy consumption. The basic parameters used for the calculations are shown in **Table 13.3-1** .

All calculations were done by spreadsheets or EPAnet2.0.

Table 13.3-1 Basic Parameters of Calculations

Hydraulic Calculation	
Formula	Hazen-Williams
Coefficients	C=130 (for Transmission Mains)
	C=110 (for Distribution Pipes)
Pump efficiency (η_p)	0.8
Motor efficiency (η_m)	0.9
Cost Calculation	
Unit electricity tariff	148.68 RWF/kW
Benchmark Year of Cost	2019
Evaluation Period for the lifetime cost	20 years
Social Discount Rate (SDR)	6%
Others	
Elevations	From WASAC GIS point data or estimated from Google Earth.

Source: JST

13.3.2 Future Water Supply Area

The summary of the water supply regions set out in this study is shown in **Table 13.3-2** and **Figure 13.3-1**. Water supply areas are divided into 12 areas each as a sum of responsible sector. The minimum unit demand was defined as a sector. It is reasonable to plan the areas by sector administrative boundary because most of the boundaries are valley line or spine of each hill. Some sectors which can be supplied from multiple sources are expressed as the balance (inflow/outflow) of each supply area.

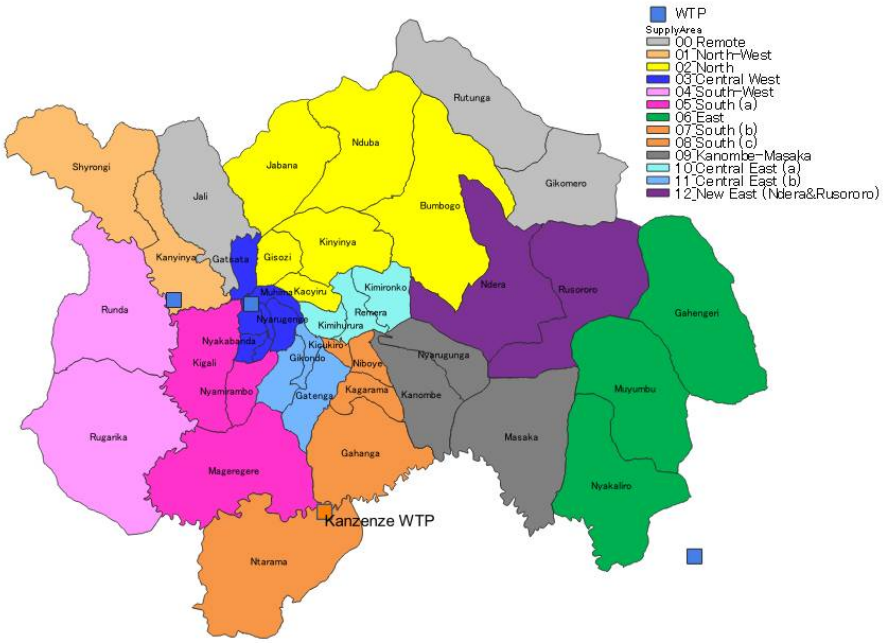
The principles for setting the water supply regions are as follows;

a) Maximize utilization of existing facilities
b) Consider topography
c) Flexibility: Setting “Mixed Area” from multiple water sources

Table 13.3-2 Summary of Future Supply Area

ID	Supply Area	Sectors	Main Supply Strategy	Legend
0	Remote Area	Rutunga, Gikomero	Independent Water Supply	
1	North-West	Kanyinya, Shyolongi	Nzove-Kanyinya route	
2	North	Bumbogo, Gisozi, Jabana, Kacyiru, Kinyinya, Nduba, Jali, Jabana	Nzove-Ntora	
3	Central West	Gitega, Kimisagara, Muhima, Nyakabanda, Nyarugenge, Gatsata	Kimisagara (or Nzove)	
4	South-West	Runda, Rugarika	Nzove-Karama	
5	South (a)	Kigali, Nyamirambo, Mageregere	Nzove-Mont-Kigali	
6	East	Muyumbu, Gahengeri, Nyakaliro	Karenge	
7	South (b)	Gahanga, Kagarama, Kanombe, Niboye, Kicukiro	Kanzenze-Gahanga	
8	South (c)	Ntarama	Kanzenze-Bidudu	
9	Kanombe-Masaka	Kanombe, Masaka, Nyarugunga	Masaka	
10	Central East (1)	Kimihurura, Kimironko, Remera	Remera (Nzove/Karenge/Kanzenze)	
11	Central East (2)	Gatenga, Gikondo, Kigarama		
12	New East	Ndera, Rusororo	Mixed (Remera, Karenge)	

Source: JST



Source: JST

Figure 13.3-1 Schematic of Supply Area

Table 13.3-3 represents the breakdown of the water demand at the proposed/future WSA. For the year 2019 to 2050, the daily average water demand was adopted as the basis of the master scenario to make a realistic and feasible plan and to achieve the demand progressively. For the year 2050, the daily maximum was adopted to fully satisfying the water demands (See detail in **Chapter 9**).

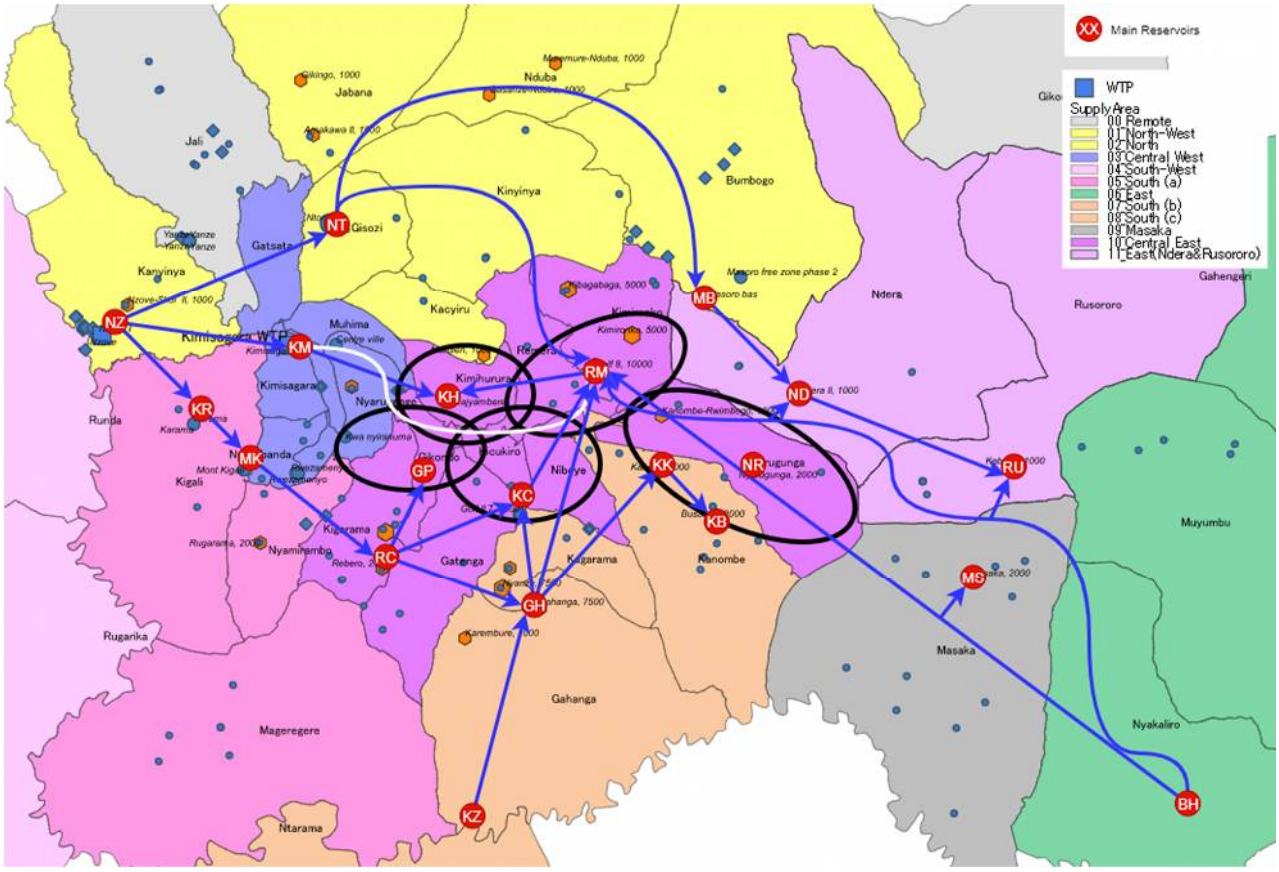
Table 13.3-3 Breakdown of Water demand at Water Supply Area by Sectors

WSA	Sector	Day Average Water Demand (m3/day)				Day-max
		2019	2025	2035	2050	2050
0	Gikomero	689	909	1,561	2,888	3,754
	Jali	1,042	1,447	2,702	5,640	7,332
	Rutunga	1,061	1,558	3,130	7,082	9,206
1	Kanyinya	1,448	2,049	3,919	8,391	10,909
	Shyorongi	1,285	1,716	3,145	6,724	8,741
2	Bumbogo	2,941	5,200	12,672	33,842	43,995
	Gisozi	2,610	3,387	6,056	12,585	16,360
	Jabana	1,704	2,488	4,960	11,116	14,451
	Kacyiru	2,948	3,794	6,435	11,669	15,169
	Kinyinya	5,065	7,949	17,328	38,518	50,074
	Nduba	1,174	1,812	3,871	9,315	12,110
3	Gitega	1,572	1,716	2,145	2,318	3,014
	Kimisagara	2,820	2,978	3,442	2,897	3,766
	Muhima	3,330	4,139	6,489	10,677	13,880
	Nyakabanda	1,325	1,531	2,155	3,040	3,952
	Nyarugenge	2,677	3,596	6,048	10,430	13,558
	Rwezamenyo	1,074	1,357	2,161	3,595	4,673
	Gatsata	1,994	2,173	2,709	2,905	3,777
4	Runda	2,261	3,207	6,687	15,182	19,737
	Rugalika	1,867	2,757	5,826	13,681	17,785
5	Kigali	1,764	2,810	6,193	15,269	19,850
	Mageregere	1,633	2,821	7,752	25,055	32,571
	Nyamirambo	3,080	4,310	7,493	13,186	17,142
6	Muyumbu	1,141	2,200	5,782	16,371	21,282
	Gahengeri	1,262	2,433	6,395	18,106	23,538
	Nyakariro	1,092	2,138	5,688	16,229	21,098
7	Gahanga	3,681	6,704	19,916	65,835	85,586
	Kagarama	2,815	4,769	9,419	17,758	23,086
	Kanombe	5,006	8,156	18,383	41,458	53,896
8	Ntarama	881	1,363	4,271	13,836	17,986
9	Masaka	3,697	6,210	18,714	89,050	115,765
10	Kimihurura	2,170	2,819	4,606	7,797	10,135
	Kimironko	5,602	8,227	14,828	26,645	34,639
	Remera	4,170	5,877	10,273	18,137	23,578
	Gatenga	3,164	4,096	7,279	15,007	19,510
	Gikondo	1,806	2,483	4,257	7,427	9,655
	Kicukiro	2,432	3,262	5,478	9,436	12,267
	Kigarama	2,607	3,327	5,348	8,954	11,640
	Niboye	2,249	3,196	6,221	12,710	16,524
	Nyarugunga	3,891	5,736	11,661	24,596	31,975
11	Ndera	5,404	9,207	25,188	77,062	100,181
	Rusororo	5,771	10,600	26,978	67,335	87,536
Total		106,208	158,507	335,564	819,756	1,065,682

Note: WSA; Water Supply Area

Source: JST

The “Mixed Area” idea is illustrated in **Figure 13.3-2**. Considering the existing and possible transmission lines among the major reservoirs, water can be flexibly transmitted from any sources around the CoK to the Central-east area (shown in dark purple). The detail idea of the Mixed supply area is described under (11) in this section.



Source: JST

Note: NZ ; Nzove, NT; Ntora, KM; Kimisagara, KR; Karama, MK; Mont-Kigali, GL; Gikondo-Low (Proposed), GP; Gikondo Premiere, RC; Rebero Carrier, KC; Kicukiro (Golf 7), RM; Remera (Golf 8), GH; Gahanga, KZ; Kanzenze. BH; Bihembe (from Karenge), MB; Masoro-bas, ND; Ndera, RU; Rusororo, MS; Masaka, NR; Nyarugunga, KK; Kanombe Rwimbogo KB; Kanombe Busanza

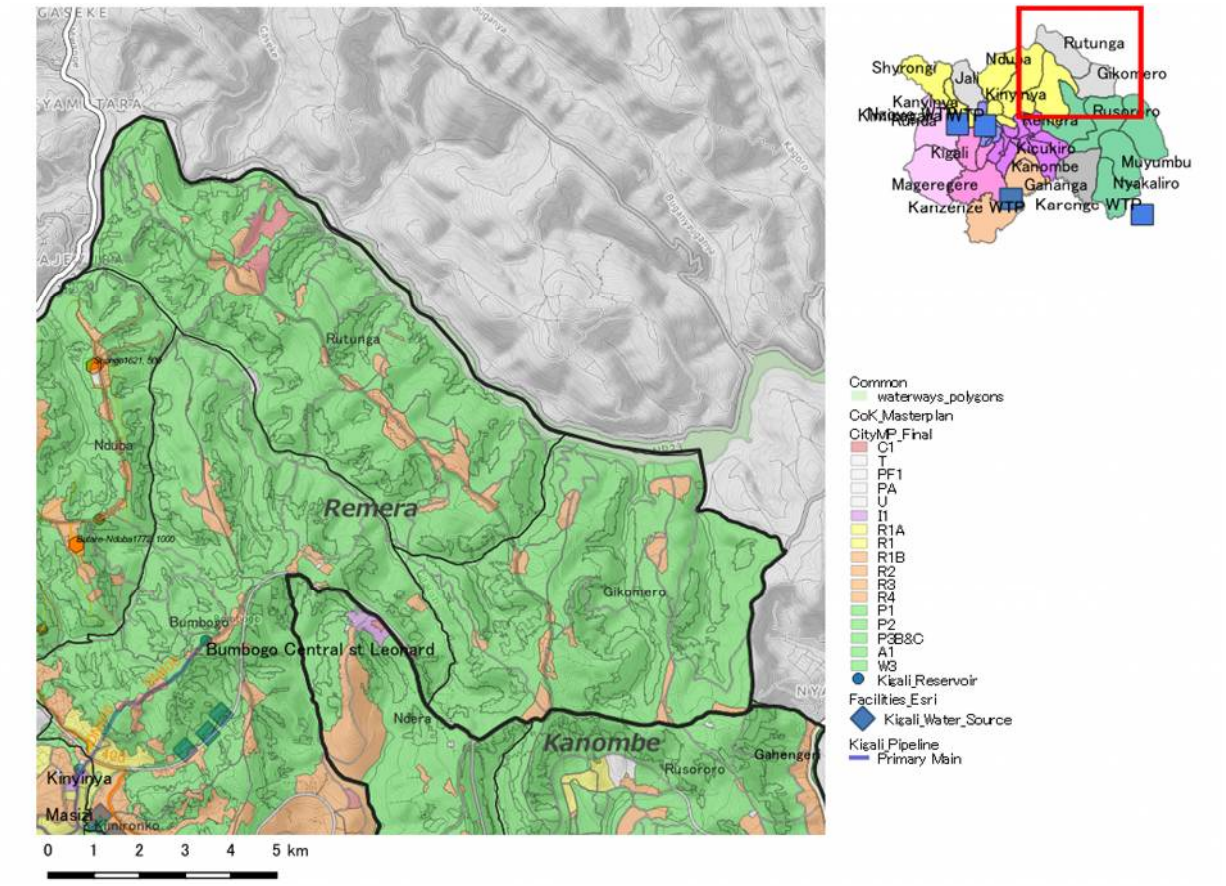
Figure 13.3-2 Schematic for Transmission Route for Mixed Area

13.3.2.1 Remote Area

There are three sectors that are difficult and not efficient to connect with the centralized water supply systems because they are located in remote areas: Rutunga, Gikomero, and Jali. These sectors are efficient to supply from independent water supply systems considering their future development and water sources nearby.

Rutunga and Gikomero are located in the northern part of the CoK adjacent to the Lake Muhazi and Nyabugogo River (**Figure 13.3-3**). The access road to these sectors is from the lake or from the Bumbogo Sector. The development areas in this region are limited to the Muhazi lakeside and the ridgeline of the mountain.

These areas are remoted from the city; the major development area in the north-west part of the sector is approx. 23 km away from the Bumbogo sector office, and even the nearest development area at Gikomero (on top of the mountain, EL+1,880m) is 11km away. Therefore, it is efficient to supply water from the Muhazi Lake as it is obviously not efficient to supply water from the city side.



Source: JST

Figure 13.3-3 Development Plan in CoK MP: Rutunga and Gikomero Sector

13.3.2.2 North-West (Kanyinya-Shyolongi)

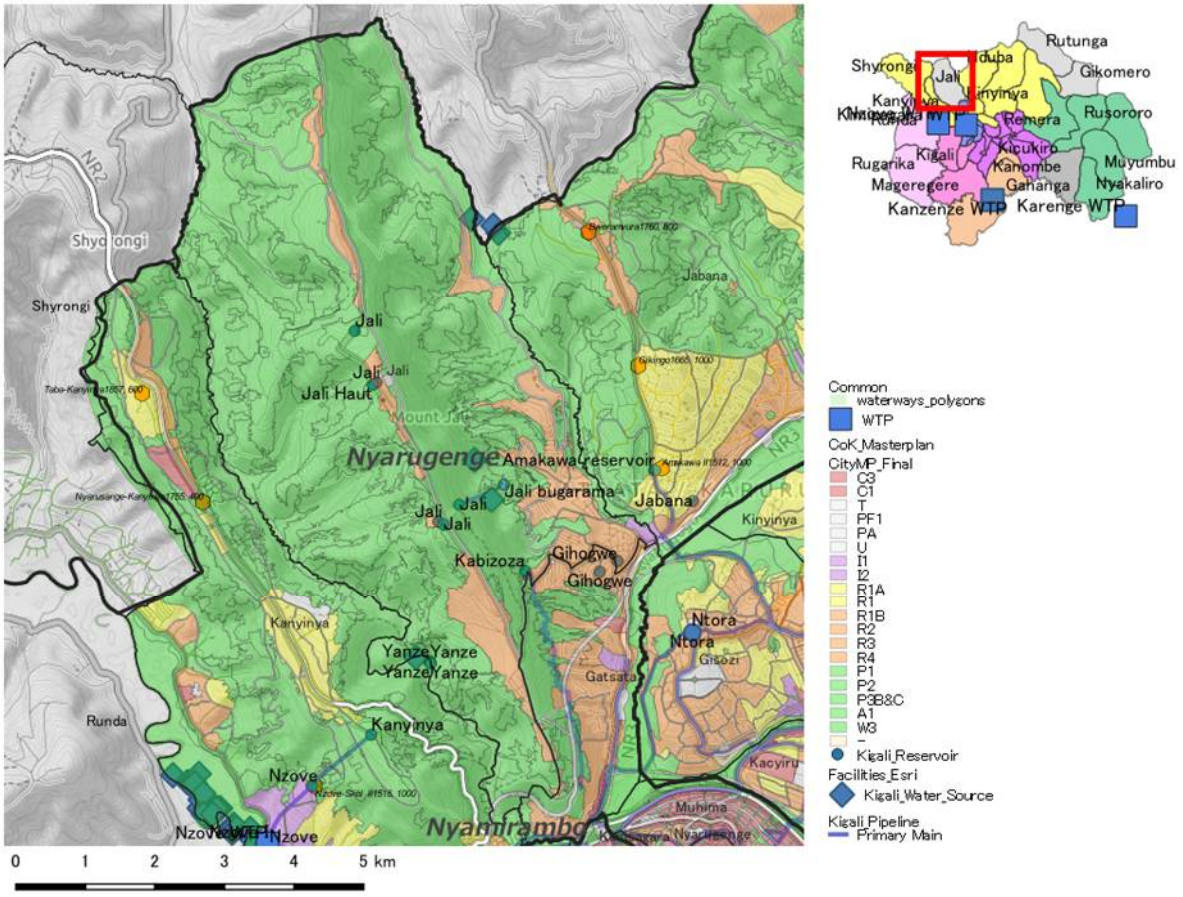
This area is located in the northern part of the supply area of the existing Nzove WTP. The water demand is growing especially for the areas along RN4 road which are located in the western part of the Kanyinya hill. There are existing and on-going water supply development from Nzove WTP along the Nyabarongo River and RN4.

13.3.2.3 North (Expanded Ntora Area)

The area is the current and on-going water supply area by the Ntora reservoir. Gisozi, Kacyiru, and Kinyinya sectors are near the Ntora reservoir and destined to be supplied from Ntora. Jabana, Nduba, Bumbogo sectors are not fully covered by the Ntora at the present but will be covered by the North-ring water transmission mains which are to be constructed as part of the on-going Project.

Jali is included in this North area. The sector is located on the north-eastern part of the CoK (**Figure 13.3-4**). Most of its land is in the Mount-Jali whose height is 1,500 to 2,000m. The future development is centered in the eastern area, which is the part of Gihogwe area development in Gatsata sector. Another part of the development is along the mountain ridge of Mount-Jali from 1600 to 1900 m elevation. For

both areas, the type of development is categorized as Rural Residential Zone (R1B). Major water supply station for this area is the Ntora Reservoir. Because of supply area is located at the high elevation, booster pumping stations are necessary to supply water coming down from the Ntora reservoir.



Source: JST

Figure 13.3-4 Development Plan in CoK MP: Jali Sector

13.3.2.4 Central-West (CBD and surrounding areas)

This area includes CBD, south up to Rwezamenyo, and the north at Gatsata sector. The strategic center of this area is the Kimisagara WTP at EL +1,529 m. The capacity of the Kimisagara WTP is only 22,000 m^3/day and will not be able to cover all the demand in this area. So, the part of water should be transmitted from other WTP.

The Central-West area is planned as exclusively covered by the Kimisagara in the proposed supply area. On the contrary, the on-going project (Section 3 and 4, funded by AfDB) will construct the pipeline from Mont-Kigali through Rwezamenyo to the Centre Ville Sonarowa. This line aims at meeting the current demand growth at the CBD and surrounding area. However, the unit energy consumption through the Mont-Kigali is excessively high at 2.00 kWh (Transmission only). Therefore, the water supply from the Mont-Kigali line is not considered in the future plan, and the line is only considered as a backup water

supply in case of an emergency. This will be further discussed in detail in **Section 13.10.2** .

13.3.2.5 South-West (Runda and Rugarika)

The areas are located to the west and outside the CoK (adjacent sectors). The areas are isolated from the CoK by the Nyabarongo River. At present, water is transmitted from the branch of transmission pipes from Nzove to Ntora (DIP ND600) which may be obsolete after the operation of the new Nzove-Ntora transmission pipeline (ND900) under Japan's Grant Aid. The area is expressed as the transmission from Nzove via the new Karama reservoir since a pipe route from the Karama reservoir is planned under the on-going AfDB project.

13.3.2.6 South (a) (Kigali, Mageregere, Nyamirambo)

These are mostly the highland area which should be covered by the Mont-Kigali (Haut) reservoirs. Water supply to the Mageregere sector is expressed as the supply via Kimisange Golf 5 station from this Mont-Kigali line. Note that some parts of the area should be covered by the other water supply scheme considering the elevation of the water supply scheme.

13.3.2.7 East (Gahengeri, Muyumbu, Nyakaliro)

These are the upcountry sectors located to the west of the CoK (Adjacent sectors), currently and will be exclusively supplied from the Karenge WTP.

13.3.2.8 South (b) (Gahanga, Kagarama, Kanombe)

The area is located in the south part of the CoK. The development in this area is proceeding rapidly as a gate city of the new airport. This area will be exclusively supplied from the Kanzenze WTP through Gahanga new reservoir constructed by the on-going project.

13.3.2.9 South (c) (Ntarama)

Ntarama sector is located to the south and outside of the CoK isolated by the Nyabarongo River from the City. The area is planned to be covered by the Kanzenze WTP via the Bidudu reservoir under the on-going project.

Note that the demand in the airport area (10,000 m^3/day, as a planned amount under the Kigali Bulk Water Supply Project) is not included in this area. The demand growth in the airport is a provisional condition which is not covered by this study.

13.3.2.10 Masaka

This area is set as an independent area from other sectors. The sector is currently only partly supplied water from the Karenge WTP. Water supply deficiency is severe in this region because the demand is urgently growing while supplied water is low due to a deficiency of water supply capacity and leakages due to aged facilities. The area is identified considering the possibility to construct the WTP in this sector sourcing water from Nyabarongo wetland or the Akagera River.

13.3.2.11 Central East (Mixed supply area)

The area includes the Central east part of the city, mainly along the main roads and in-between CBD and the existing Kigali Airport. Most of the regions in this area are accessible from following key reservoirs (gravity or pump); Remera, Kicukiro, Kimihurura, Gikondo Premier, Nyarugunga and Rebero Carrier. Here, some part of the southern Gatenga (Rebero area) and Kigarama (western part of Nyanza) are actually be covered by other minor reservoirs in the Mont-Kigali line but is expressed as the Rebero Carrier for ease.

As this area can be supplied from the Nzove-Ntora line, the Nzove-Mont Kigali line, the Kanzenze-Gahanga line and the Karenge line, the water balance in this area is expressed as the mixture of the input from the lines. Note that the water transmission from the Nzove to Remera is a bottleneck to supply these areas, as well as to supply further eastern parts of the city from the Remera reservoir. This will be further discussed in **Section 13.10.2 .**

13.3.2.12 New East (Ndera, Rusororo)

These are emerging industrial and residential areas located towards the north of the existing airport, and the development areas are extending further to the north. These areas are currently supplied from the Karenge northern pipeline (ND300). There is another route to access this area from the west at the Masoro bas reservoir, which is expected to be connected from the northern line from the Nzove-Ntora and from/to the Remera new reservoir. This area is set as a mixed supply area in 2035 and 2050 seeing the possibility of following two supply routes.

(1) Masoro-bas route

The water from the Nzove-Ntora can be transmitted to the Masoro-bas after the north-ring line is constructed. The water at the Masoro-bas (EL+1,524) or the Masoro-Haut (EL+1,570) can be transmitted to the east by the new road proposed to be constructed in this area, which is described in the land-use plan in the CoK M/P. In this route, the water is transmitted from the Nzove-Ntora or the Remera.

(2) Karenge route

The Karenge route is the same route with the current pipeline from the Karenge WTP. The water can be transmitted from the Remera to the east by this route if the new pipelines are to be constructed.

The routes are illustrated in **Figure 13.10-6** and discussed on their ability to transmit water by gravity (See **Section 13.10.3**)

13.3.3 Benchmark Years

Water supply scenarios were planned by setting three benchmark years including the target year of 2050 (**Table 13.3-4**). The year 2025 and 2035 are set to illustrate the demand and supply strategy in the

intermediate years toward 2050 in order that we plan a gradual (phased) investment plan.

Table 13.3-4 Benchmark Years for Master Scenario

Benchmark year	Remarks
2025	Benchmark for emerging priority projects.
2035	An intermediate year between 2025 to 2050.Benchmark as the basis of the 15 years investment plan.
2050	Target year of the Masterplan.

Source: JST

13.3.4 Estimation of Quantities and Costs

Cost estimates are conducted based on the water supply scenarios. The cost estimates are the comparison purpose only; it is necessary to study further to estimate the total amount of the investment.
The basic assumption on the cost estimates are as follows;

[Capital Investment Cost]

- Current price in 2019, Price escalation is NOT considered
- Fixed Exchange rate (3 months average from Sep to Nov 2019, 911 RWF/USD)
- Tax, administration cost for projects by WASAC, and financial cost were not included
- The estimation of the unit price is according to **Appendix-20 and 21**.
- **Water Sources and Water Treatment Plant**: Based on the cost function in the Appendix.
- **Transmission Mains, Sub-mains and Distribution Mains**: Estimated the route and diameter from the water demand allocation in the master scenario. The costs for 3 scenarios for each the benchmark year 2035 and 2050 were individually calculated. The cost for 2050 was described as the expansion cost from the baseline case (2035 Case 1). Quantities for transmission sub-mains (the pipes from key reservoirs to the smaller reservoirs responsible for each distribution zone) are estimated based on the ratio of the ND90-160 pipes to the total of the length of existing/on-going pipelines.

  Cost increase by difficult construction (e.g., river crossing and poor subsoil conditions) was not specifically considered in the cost but assumed to be covered by the contingencies (10%).
- **Distribution sub-mains and meters:** Per-capita length by diameter was estimated from the existing/on-going project's pipelines.
- **Reservoirs:** Assumed to place one small reservoir per distribution zone. The capacity per the small reservoir is fixed at 500 m3. The required capacity is assumed to be 8 hours of Daily average demand in 2035 and 12 hours of Daily maximum demand in 2050. By this assumption, following facility investment were assumed as a common condition for three scenarios both in 2035 and 2050;

➢ **2019-2035:** Construct 14.3 reservoirs per year
➢ **2036-2060**: Construct 14.3 reservoirs per year plus large reservoirs at any locations (in total 150,000 m3).

Land acquisition cost was included in the cost, assuming 20% of the construction cost for the small

reservoir and 6% for the large reservoir.

- **Customer connections and meters**; excluded from the estimation as they are borne by the customer.

[Operational Cost]

- Current price in 2019, Price escalation is NOT considered
- Chemical cost, salaries and maintenance costs are based on the yearly averaged cost of each WTP administrative area (Nzove, Kimisagara and Karenge) of WASAC (WASAC Annual Report 2018/2019).
- Electricity costs are calculated assuming the pump head which was calculated based on the pipeline routes and elevation differences. The topography was based on the WASAC's GIS data or Google Earth.
- Electricity tariff was fixed at the current average tariff paid by WASAC: **148.68 RWF/kW**

13.3.5 Overall Scenarios

The overall scenarios for water supply expansion are as shown in **Table 13.3-5** . For 2035 and 2050 each, three scenarios were examined to illustrate the situation in which the JST used the water resources from different locations. Allocated water demands for each supply area are shown in **Table 13.3-6** .

Table 13.3-5 Simulation Cases for Master Scenario

Year	Simulated Scenario(s)			Demand	Note
2035	Case 1	Case 2	Case 3		Models to compare the possible future scenario of water transmission.
	Baseline (Near demand principle)	Nzove Oriented	Kanzenze Oriented		
2050	Case 1	Case 2	Case 3	Day Max	
	Nyabarongo/Upcountry water source-oriented	Akagera River upstream oriented	Mugesera Lake oriented		

Source: JST

Table 13.3-6 Summary of Water Demand at each Supply Area

ID	Supply Area	Main Supply Scheme	Day Average Water Demand (m^3/day)				Day Max
			2019	2025	2035	2050	2050
0	Remote	Independent Water Supply	3,000	4,000	7,000	16,000	21,000
1	North-West	Nzove-Kanyinya	3,000	4,000	7,000	15,000	20,000
2	North	Nzove-Ntora	16,000	25,000	51,000	117,000	152,000
3	Central West	Kimisagara	15,000	17,000	25,000	36,000	47,000
4	South-West	Nzove-Karama	4,000	6,000	13,000	29,000	38,000
5	South (a)	Mont-Kigali	6,000	10,000	21,000	54,000	70,000
6	East	Karenge	3,000	7,000	18,000	51,000	66,000
7	South (b)	Kanzenze-Gahanga	12,000	20,000	48,000	125,000	163,000
8	South (c)	Kanzenze-Bidudu	1,000	1,000	4,000	14,000	18,000
9	Masaka	Masaka	4,000	6,000	19,000	89,000	116,000
10	Central East	Mixed	28,000	39,000	70,000	131,000	170,000
11	New East	Mixed (Remera-Karenge)	11,000	20,000	52,000	144,000	187,000
Total			106,000	159,000	335,000	821,000	1,067,000

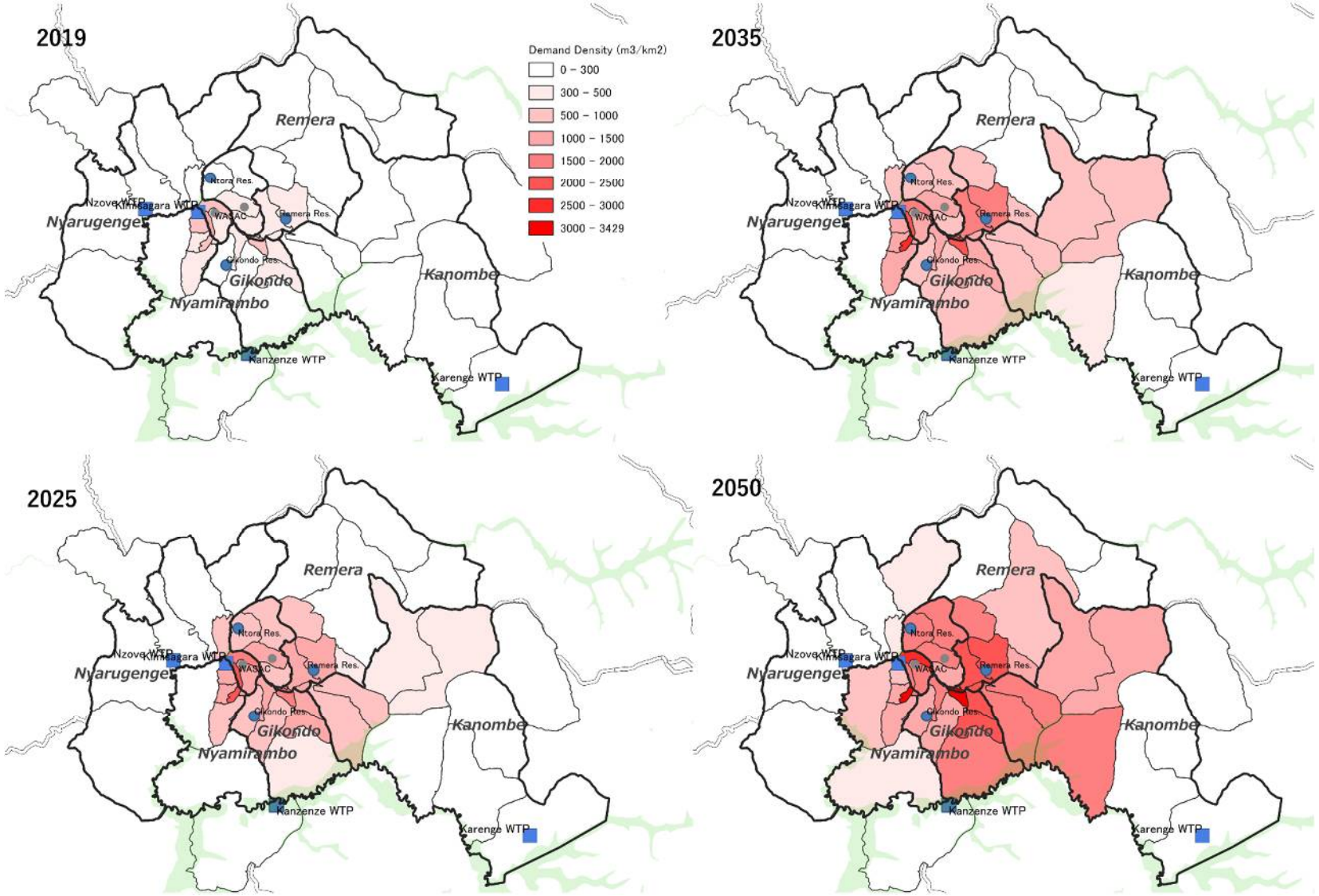
Source: JST

13.4 COMPARISONS OF SCENARIOS

13.4.1 Overall Water Demand Growth and Distribution

Overall demand distribution up to 2050 is as shown in **Figure 13.4-1**. The demand is shown as the density (Day Max Demand m^3/km^2) in order to comprehend the actual needs as the city water supply. The figure implies;

- There is the emerging demand growth in the east (Masaka, Ndera Rusororo). The means to transmit the water to those areas are currently limited to the line from the Karenge and its amount is predominantly insufficient. Meanwhile, the full-scale demand growth will only be materialized after 2035 toward 2050 considering the city's development shown in the CoK M/P.
- The demand in the city center to the central east is relatively high in 2019 to 2035. Particularly, the demand for Remera-Kimironko is growing rapidly. So, the water transmission to that central-east area is urgent.



Source: JST

Figure 13.4-1 Schematic of the Regional Growth Tendency of Water Demand

13.4.2 Scenarios in 2025

The Master Scenario in the year 2025 is determined as shown in **Figure 13.4-2**. The estimated demand-supply balance implies that new water sources are emergently necessary as the water shortages are severe in the Kanombe and the Gikondo branch areas. The fact conforms to the current situation that there is a strict "water rationing (only 3-4 days of intermittent water supply)" in this eastern area, as well as the water demand projection, which shows that the demand is growing urgently. The master scenario simulation (**Figure 13.4-2**) is planned based on the Contingency Scenario with the NRW 38.8% as well as the projected water demand under NRW 25%. The results found that water demand can be fully met with the additional production capacity.

The policy for the investment toward the year 2025 is as follows;

a. Accelerate NRW reduction measures to achieve WASAC's target (25%) progressively
b. Meeting the demand in the east: To construct a new WTP near the high demand area (the Sectors of Masaka, and Karenge) or transmit water from the Remera to the east

The specific projects to be implemented according to the policy are as follows;

Extensive Rehabilitation of Distribution Pipes and Block Zonings: Replacement of Customer Pipes and Meters

The NRW target of "25% in 2025" is a tough target to achieve under normal business operations. It is necessary to conduct extensive rehabilitation of supply pipes and distribution networks, apart from the on-going project.

Construction of the Masaka WTP (Phase 1: 20,000 m^3/day)

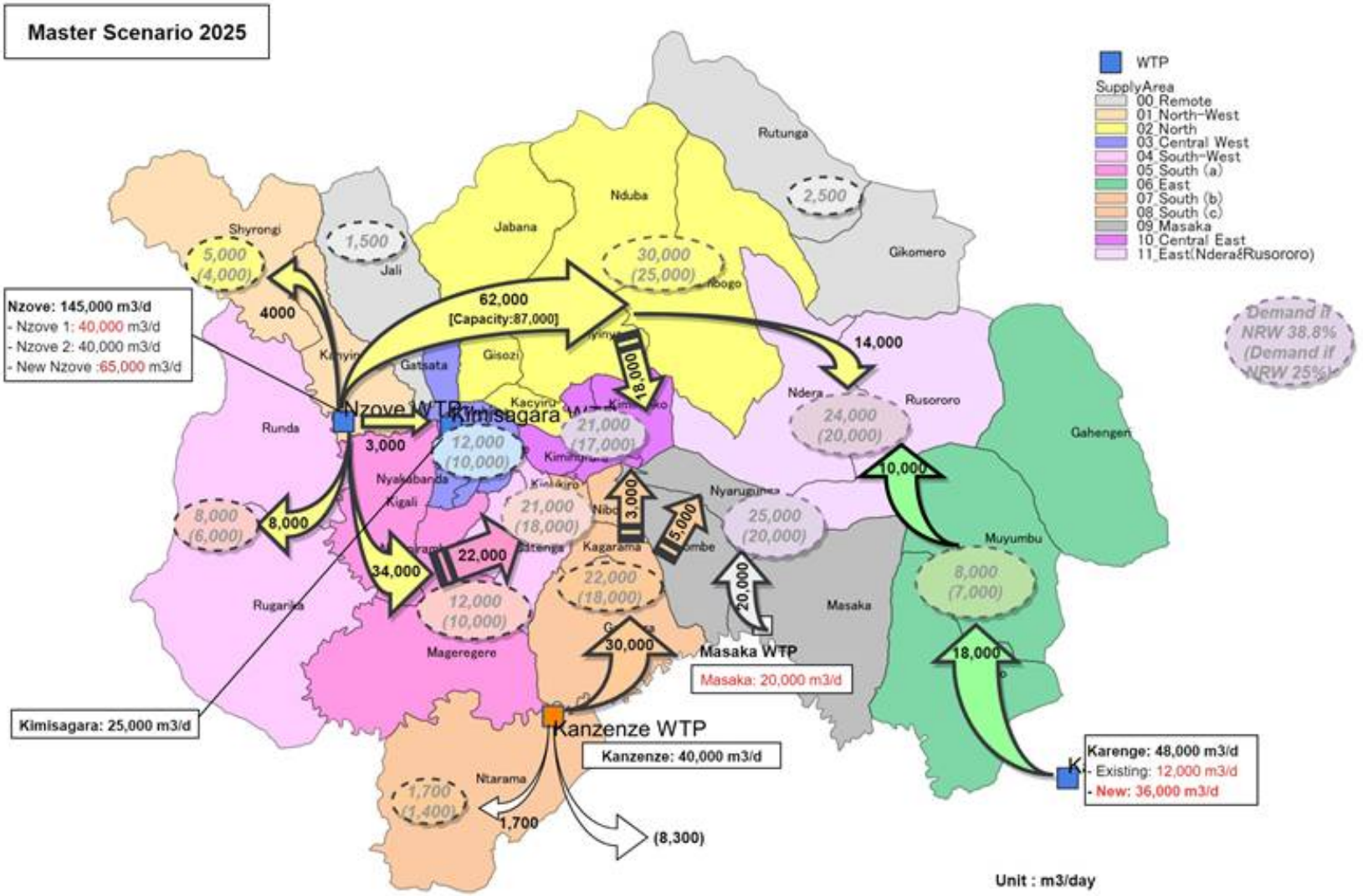
It is necessary to construct the WTP near the demand. The capacity for the WTP is temporary set at 20,000 m^3/day to be consistent with the future water demand in 2035. Its capacity shall be re-examined during the detailed feasibility study considering 1) actual and on-going development plan in and around the Masaka area, 2) transmission routes to deliver water to surrounding sectors (the Sectors of Ndera, Rusororo and Nyarugunga).

Table 13.4-1 shows on-going projects and additional facilities for 2025.

Table 13.4-1 On-going Project and Additional Facilities for 2025

On-going Projects	
Rehabilitation of Nzove 1	+23,000 m^3/day (from 17,000 to 40,000 m^3/day)
Expansion of New Nzove:	+25,000 m^3/day (from 40,000 to 65,000 m^3/day)
Rehabilitation of Karenge WTP	+3,000 m^3/day (from 15,000 to 18,000 m^3/day)
Additional Facilities for 2025: +20,000 m^3/day (Total: 247,000 m^3/day)	
Masaka WTP and forwarding infrastructures	+20,000 m^3/day
NRW Reduction Measures	Phase 1 to 2

Source: JST



Source: JST

Figure 13.4-2 Master Scenario in 2025

13.4.3 Scenarios in 2035

13.4.3.1 Common Components

Fixed scenarios are as follows;

- New water sources are limited to the Nyabarongo River and Mugesera Lake. Therefore. the wiggle rooms for the scenario selection are between 1) Nzove, 2) Kanzenze and 3) Mugesera.
- The existing small water sources scattered in the CoK (e.g., Mburabuturo, Rwampara etc.) were neglected under this scenario because they are small (in total 5,000 m^3/day) located in the downhill at the city where the sustainability and future availability is questionable in terms of quantity and the quality
- Water transmission capacity from the Nzove to the Northern area is fixed at 86,000 m^3/day which is the approximate capacity (87,000 m^3/day) after the on-going expansion. The supply amount to the North-West (Kanyinya) and the South-West (Runda and Rugarika) are set at the demand.
- The amount in the Karama-Mont-Kigali line is set at 40,000 m^3/day, the existing transmission capacity. This is because this line is not energy efficient. The line can be utilized as the back-up line in case of the major accidents in other lines.
- The Masaka sector is borne by the new Masaka WTP because it is more efficient than any other supply method from the Karenge or the Nzove.
- The demand growth in the South area is so large that the supply capacity on-going bulk water supply project at the Kanzenze will be in short. To meet that demand, a minimum of 40,000 m^3/day expansion is considered.
- Rehabilitation of the Karenge is considered in all the scenarios. This is because the Karenge WTP is currently over the supply capacity and may be defective and interrupted without any rehabilitation. Increasing +3,000 m^3/day capacity is the minimum additional to the rehabilitation.
- Remote sectors (Jali, Rutunga and Gikomero) need independent Water Supply Schemes (WSS) by this target year. Each capacity is total of the sector estimated from the CoK M/P and needs to be examined according to the actual development in those sectors. The existing supply capacities in those sectors are neglected in this statement because they are rather small compared to the demands.

Expansion of New Nzove:	+25,000 m^3/day (from 40,000 to 65,000 m^3/day)
Kanzenze 2 WTP and forwarding infrastructures:	+22,000 m^3/day
Masaka WTP and forwarding infrastructures:	+20,000 m^3/day
Rehabilitation of Karenge WTP:	+3,000 m^3/day (from 15,000 to 18,000 m^3/day)
Small Scale WSS for Rutunga and Gikomero:	+3,000 m^3/day (Jali) +5,000 m^3/day (Rutunga, Gikomero)

The critical area for further comparison study in 2035 is the Ndera-Rusororo area where the demand growth is considered to be significant while there are no existing pipelines to supply the large amount (52,000 m^3/day only for the two sectors).

13.4.3.2 Case 1: Water Supply Expansion Near the Demands (Baseline Case)

Case 1 is the baseline case that the major water supply expansion will be conducted near the water demand (**Figure 13.4-3**). Apart from the common components, the facilities to be constructed are as follows;

The Karenge 2 WTP and forwarding infrastructures: **+36,000** m^3/day

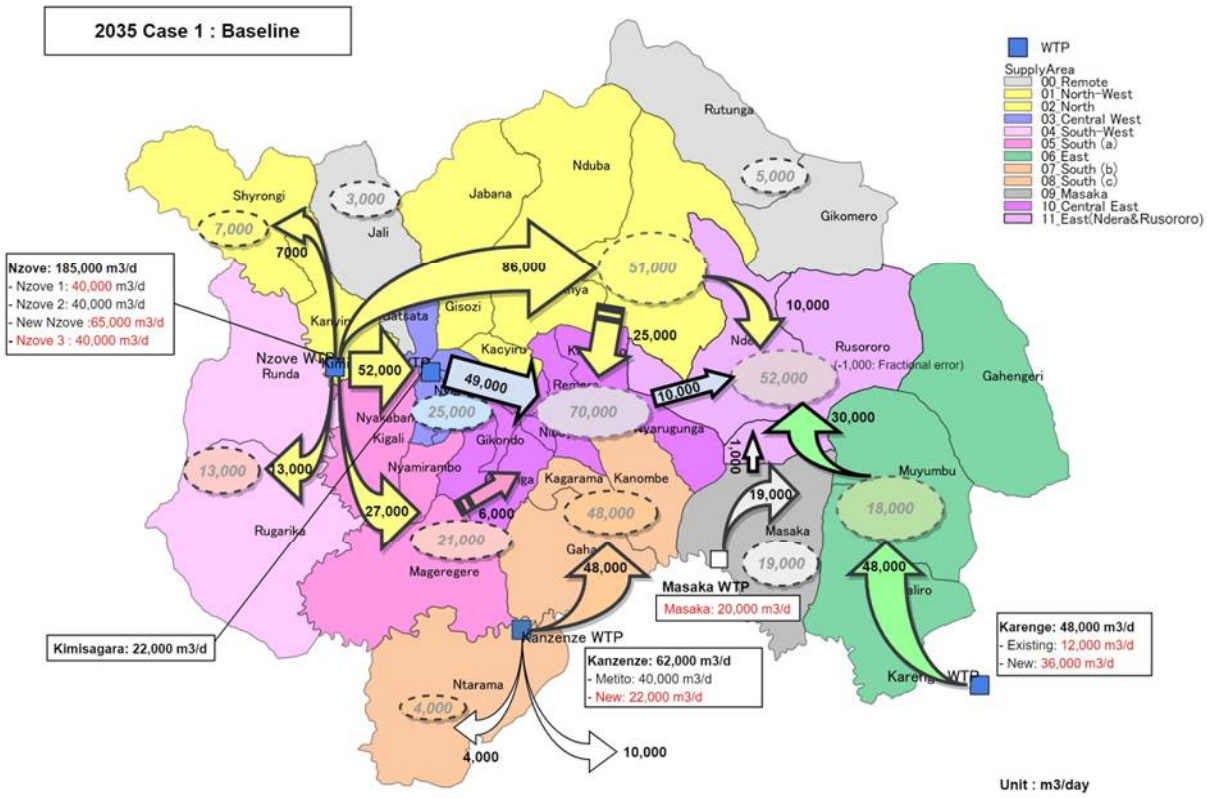
As the Ndera-Rusororo area is covered by the Karenge WTP currently, the simplest way is to supply water from the Karenge WTP. To supply the 36,000 m^3/day amount to the Rusororo and the Ndera, the pipeline should be replaced for at least ND800 for an approx. 20km. The existing pipeline can be utilized as the distribution pipes connected to the new mains.

The Nzove 3 WTP (Groundwater): **+40,000** m^3/day

The Nzove 3 refers to the proposed WTP near the existing Nzove, possibly the opposite shore of the Nzove WTP. 40,000 m^3/day is the amount to meet the remaining demand from other WTP.

The Central Main

At the same time with the Nzove 3 expansion, it is necessary to expand water transmission capacity accordingly. The diameter for the Central Main was examined in **Section 13.10.2** . Only in this baseline case, existing ND600 DIP from the Nzove to the Ntora can be utilized for the Nzove-Kimisagara transmission, alternatively to the ND800 Central Main.



Source: JST

Figure 13.4-3 Year 2035 Case 1: Water Supply Expansion near the Demands

13.4.3.3 Case 2: Nzove Expansion Oriented Water Supply

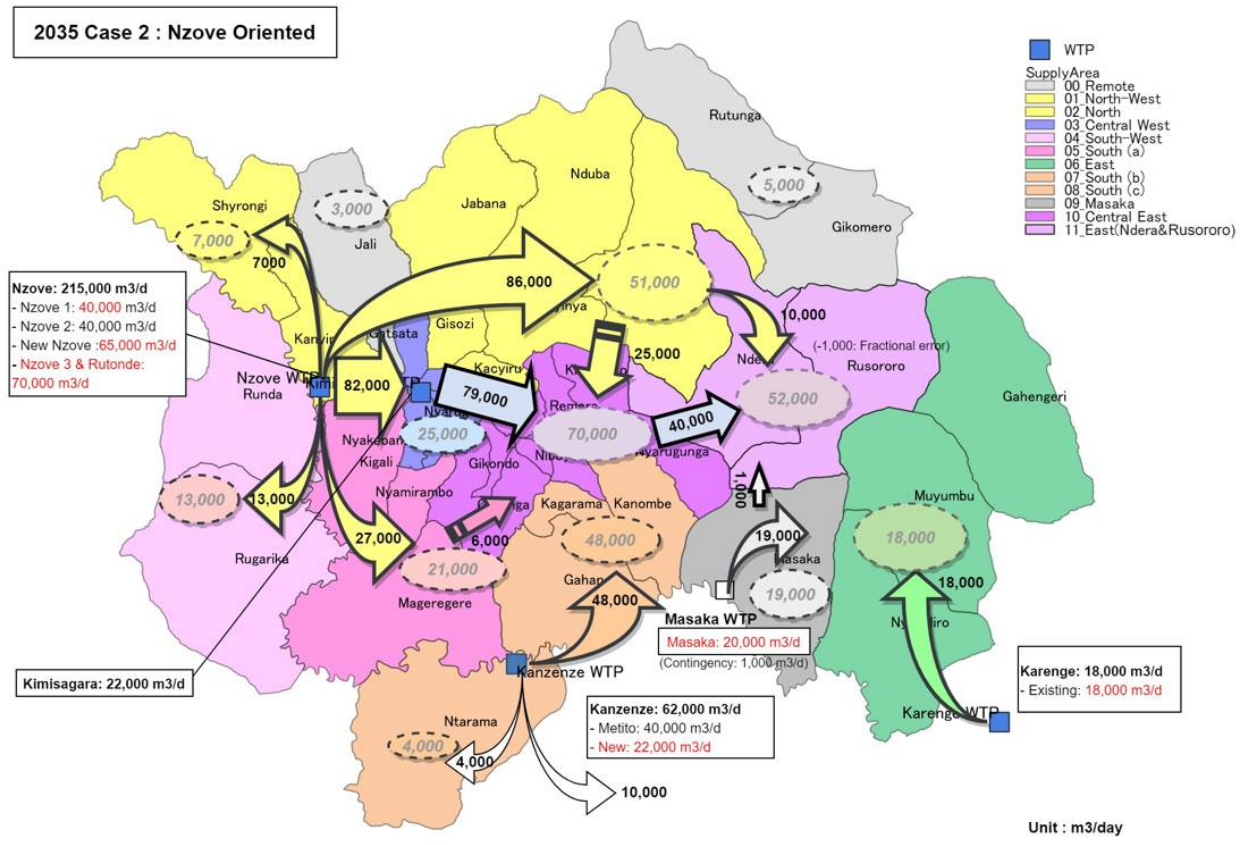
Case 2 assumes water supply expansion at the Nzove WTP instead of the Karenge WTP and transmission of water from west to east (**Figure 13.4-4**). In this case the Central Mains are more important and should have a capacity of 66,000 m^3/day (ND800). Facilities to be constructed are as follows;

The Nzove 3 WTP (Groundwater and Surface water): **+70,000** m^3/day

As the current groundwater source capacity in the Nzove is only 25,000 m^3/day and planned to be expanded to 40,000 m^3/day, the maximum groundwater source capacity of the new Nzove 3 WTP on the opposite shore are assumed to be 40,000 m^3/day. Remaining 30,000 m^3/day is assumed to be surface water sources directly from the Nyabarongo River.

The Central Main

See **Section 13.10.2** .



Source: JST

Figure 13.4-4 Year 2035 Case 2: Nzove Expansion Oriented Water Supply

13.4.3.4 Case 3: Kanzenze Expansion Oriented Water Supply

Case 3 assumes additional water supply expansion at the new Kanzenze WTP instead of Karenge or the Nzove (**Figure 13.4-5**).

The Kanzenze 2 WTP and forwarding infrastructures: **+66,000** m^3/day

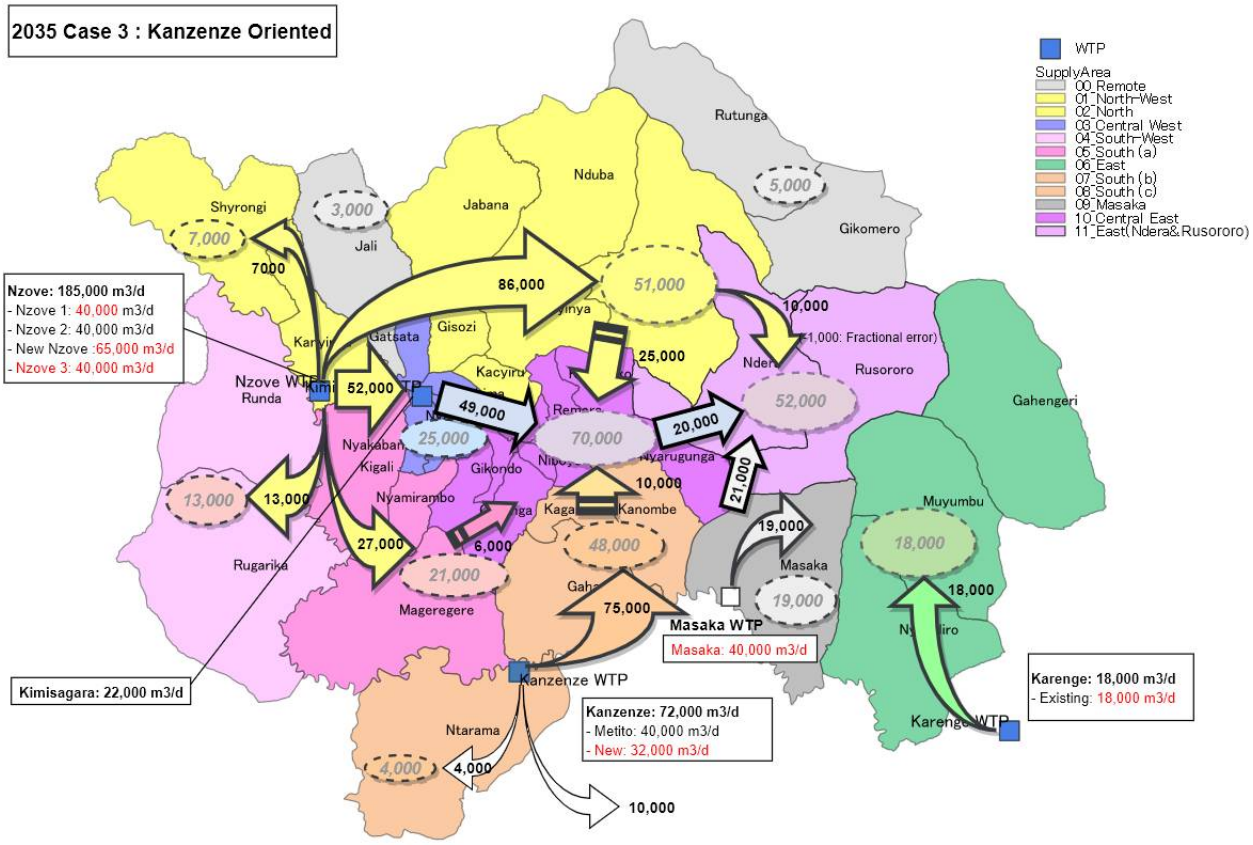
An additional 26,000 m^3/day capacity shall be prepared for the Kanzenze 2, sourcing the raw water from the Nyabarongo River. The case 1 and 2 assume 40,000m^3/day development at the Kanzenze 2 and the groundwater sources as same as the on-going bulk water supply project.

The Nzove 3 WTP (Groundwater): **+40,000** m^3/day

See Case 1.

The Central Main

See **Section 13.10.2** .



Source: JST

Figure 13.4-5 Year 2035 Case 3: Kanzenze Expansion Oriented Water Supply

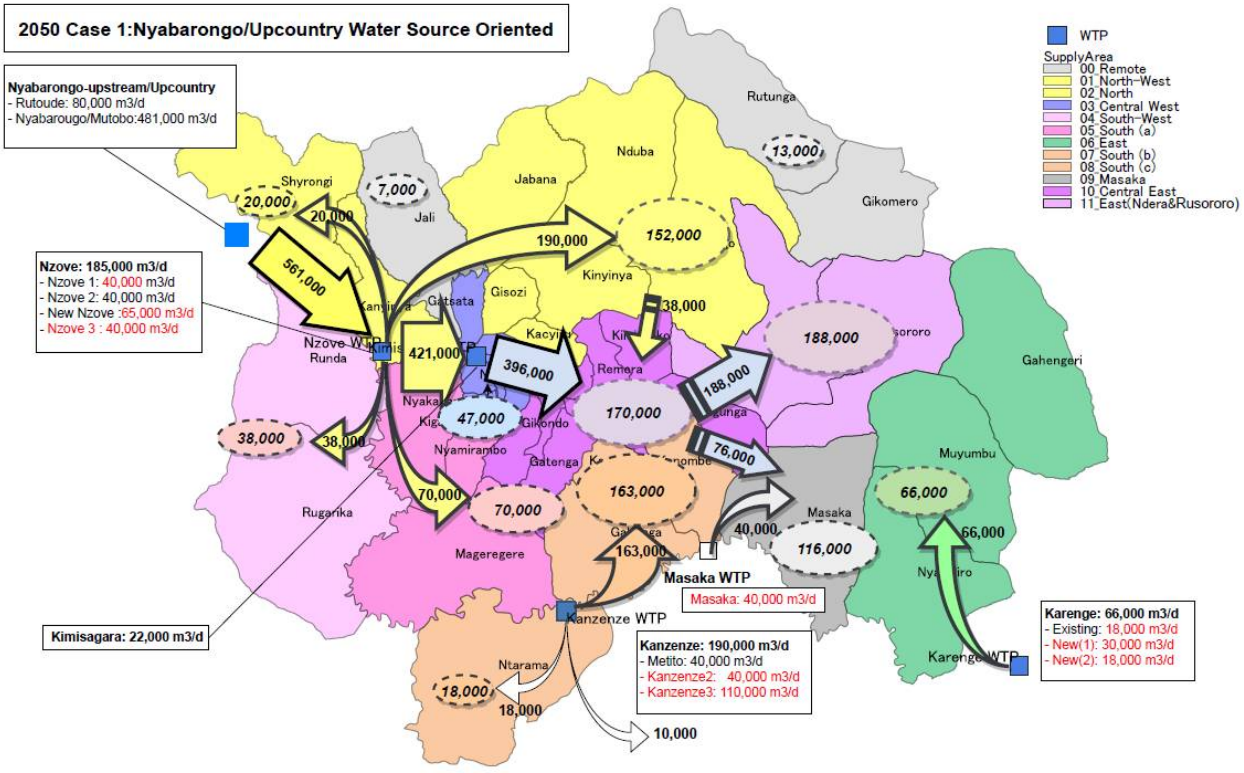
13.4.4 Scenarios in 2050

The scenario in 2050 is principally water-source-oriented. To meet the huge demand of 1,067,000 m^3/day (Daily Maximum, Total in the CoK and adjacent 7 sectors), water supply capacity has to be sourced from the Nyabarongo River or upcountry water sources as the Mutobo (Case1), the Nyabarongo-Akagera River particularly in the middle at the CoK (Case 2), or the Mugesera Lake (Case 3).

13.4.4.1 Case 1: Nyabarongo/Upcountry Water Source Oriented Water Supply

The main water sources are assumed to be the Nyabarongo River (surface water) or the Mutobo. The water transmission inside the study area is the same as the Nzove because the transmission route from the Mutobo should be once connected to the Nzove before supplying for the central to the eastern area of the CoK (**Figure 13.4-6**).

In this scenario, most of the demand in the Central-east area, the Ndera-Rusororo area and a part of the demand in the Masaka sector are borne by the Nyabarongo-Mutobo water source through the Nzove and the Central Mains. The amount necessary for the Nyabarongo-Mutobo is estimated to be 481,000 m^3/day. Most of its amount (421,000 m^3/day) should be transmitted through the Central Main to the Remera and the eastern area.



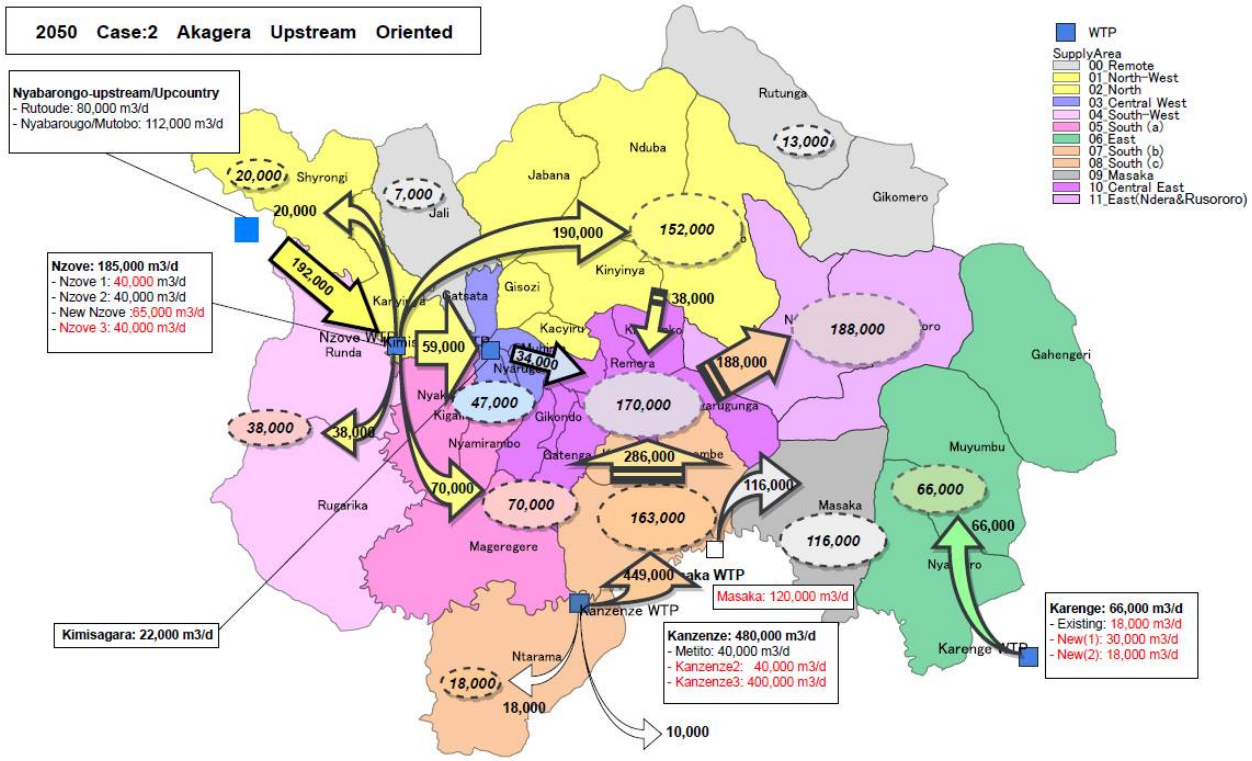
Source: JST

Figure 13.4-6 Year 2050 Case 1: Nyabarongo/Upcountry Water Source Oriented Water Supply

13.4.4.2 Case 2: Akagera River Upstream Source Oriented Water Supply

The main water source is assumed to be the Nyabarongo-Akagera River, which is after the confluence of the Akanyaru River from the south (**Figure 13.4-7**). The water intake is set near the Kanzenze, as the Kanzenze 3 WTP. The Masaka is considered as an independent sector and will be supplied from the Masaka WTP (120,000 m^3/day).

The amount necessary for the Kanzenze 3 is estimated to be 400,000 m^3/day. A large part of the water is consumed in the South area (163,000 m^3/day) while the remaining large part will be transmitted to the Ndera-Rusororo via Remera.

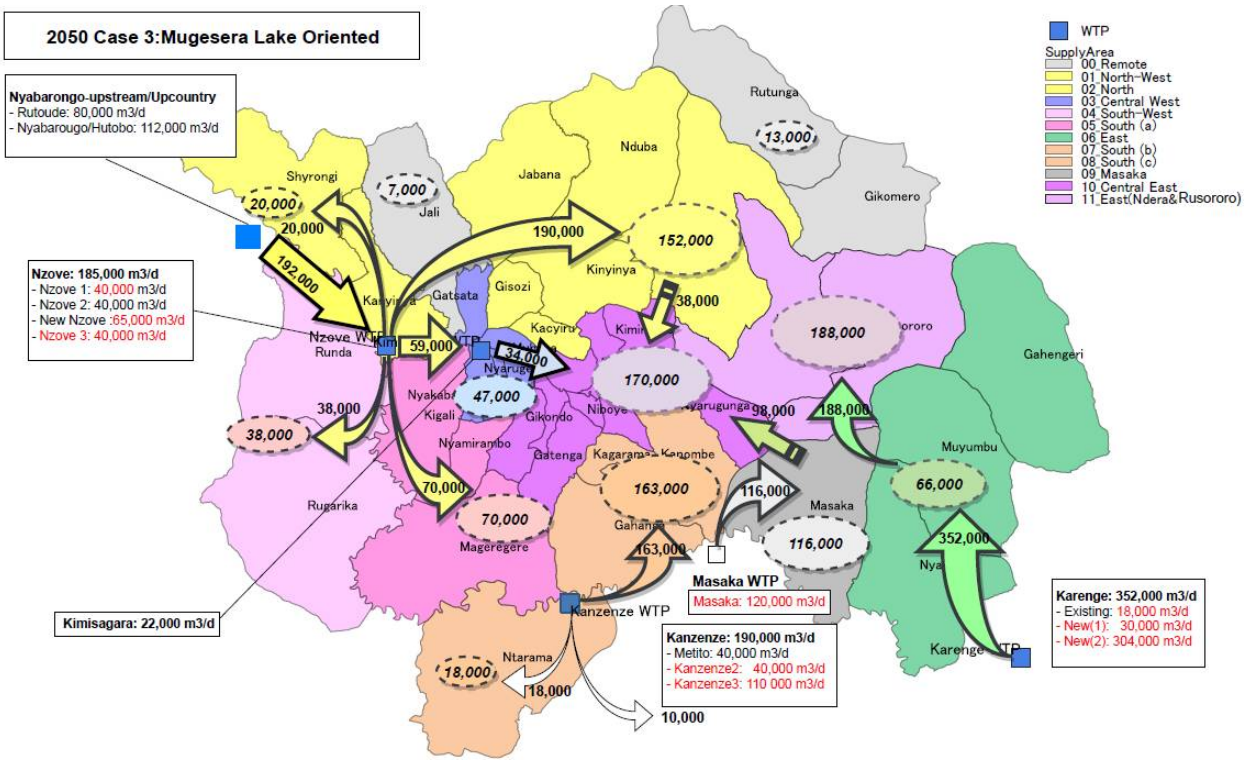


Source: JST

Figure 13.4-7 Year 2050 Case 2: Akagera River Upstream Source Oriented Water Supply

13.4.4.3 Case 3: Mugesera Lake Source Oriented Water Supply

The main water source for case 3 is Mugesera Lake. Water intake and the water treatment plant will be at the Karenge near the existing Karenge WTP. The amount necessary for the Karenge WTP (Kanzenze) will be 304,000 m^3/day, apart from the first stage expansion of 30,000 m^3/day. In this scenario the amount of the main water source is smaller than other cases because some of the western and southern demands are far from the Karenge, and thus it will be efficient to supply near the sources (**Figure 13.4-8**).



Source: JST

Figure 13.4-8 Year 2050 Case 3: Mugesera Lake Source Oriented Water Supply

13.5 EVALUATION AND DETERMINATION OF MASTER SCENARIO

13.5.1 Evaluation Criteria

The Master Scenario was selected in the JCC in July 2020. Various options were considered before the selection of the master scenario with clear evaluation criteria, namely *stability*, *flexibility*, *resiliency,* and *efficiency: life cycle cost,* which includes the capital and O&M costs (**Table 13.5-1**). The evaluation criteria were prepared to clarify the ideas and presumptions for selecting the Master Scenario.

Table 13.5-1 Evaluation Criteria for the Master Scenario

Evaluation Criteria	Explanation
Stability; of water sources in terms of quality and quantity	This criterion is to clarify the risks of the variations of the water quantity and quality for the major water source under each scenario and to examine whether the water supply will be stable.
Flexibility; to the Change of Demand and Development	Water demand is based on the water demand projection based on the city's development plan (the CoK M/P in 2019 and the physical plans obtained from sector/district offices). However, the actual city's development may change from time to time; the water demand is sensitive to the change of development location and timing. This criterion intends to clarify the ability to respond to the change in the water demand; e.g. water supply can be used in the other regions.
Resiliency; for the preparedness to disasters and Climate Change	The major direct risks on the Climate Change is the change of rainfall pattern, temperature rising, change of migration pattern. As a result, the water quality and availability affected by urbanization may also affect the water quality of the sources and may accelerate the drawdown of the sources. The risks and possible mitigation measures will be clarified in the statement under this criterion.
Cost	Capital and O&M costs for water supply expansions according to the cases. Total costs are presented in the yearly averaged costs.
Recommendation	Recommendation based on the criteria.

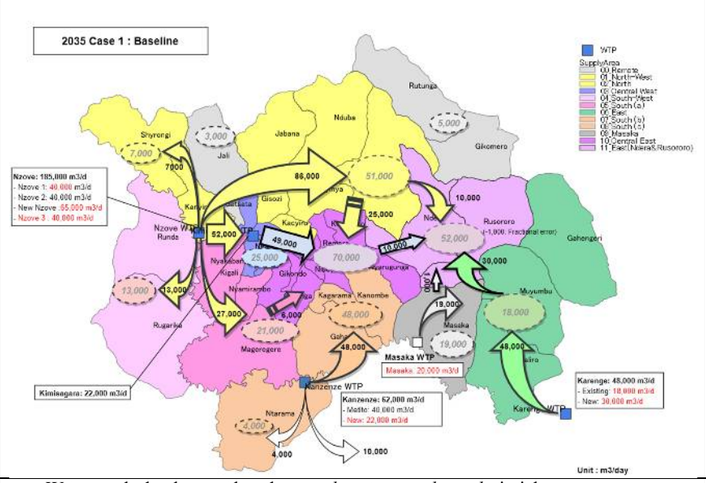
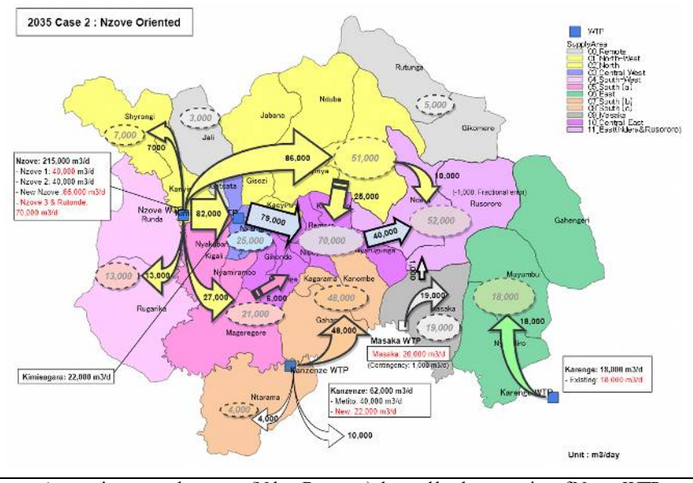
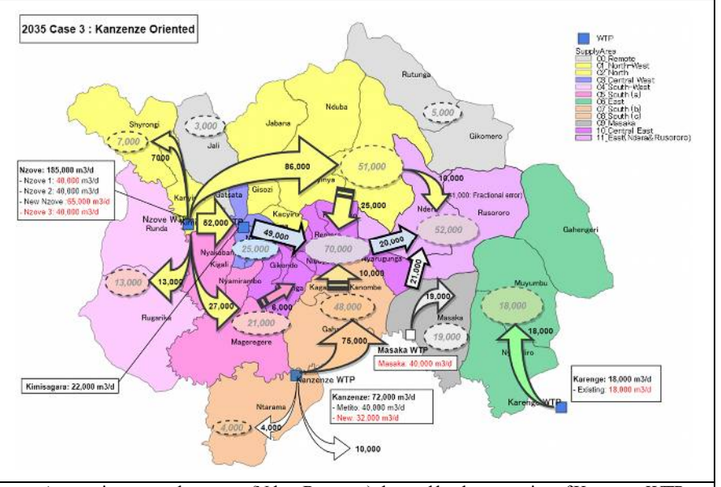
Source: JST

13.5.2 Evaluation and Analysis

13.5.2.1 Year 2035

The comparison and evaluation in the year 2035 are shown in **Table 13.5-2** . The flexibility to the change of development area and its demand is the highest under the Case 2035-1. The cost is the lowest under Case 2.

Table 13.5-2 Evaluation of Scenarios in Year 2035

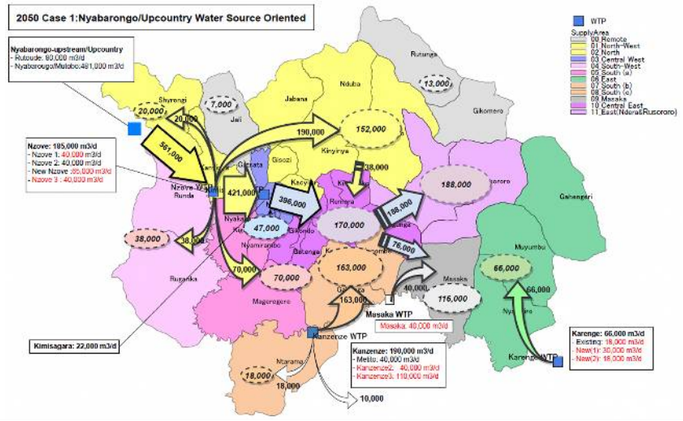
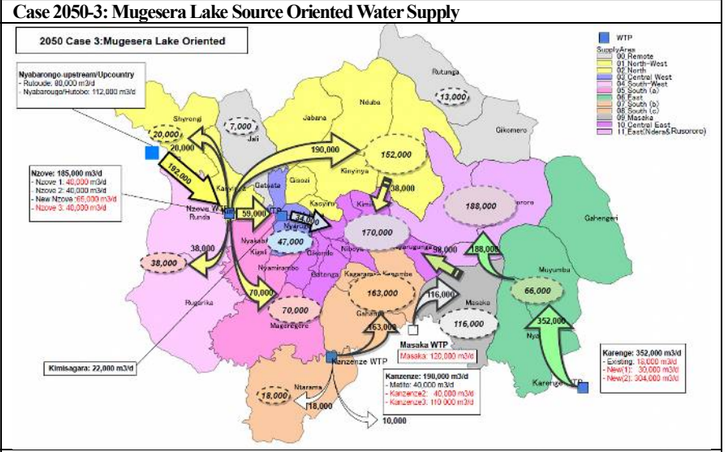
Scenario	Case 2035-1: Baseline	Case 2035-2: Nzove Oriented	Case 2035-3: Gahanga Oriented
Schematic			
Overview of the Case	- Water supply development based on *supply water near demand* principles. - Expand the capacity of Karenge WTP by 30,000 m³/day, and construct a new WTP in Masaka for 20,000 m³/day responding to the water demand increase. - Construct water transmission systems to the Central-eastern area (52,000 m³/day), mainly for the Central-East area (Gikondo, Kicukiro and partly to Remera). - Upgrade the pipelines to supply 10,000 m³/day from Remera to meet the demands in Ndera-Rusororo through Masoro-Bas (for limited areas such as FTZs).	- A scenario to meet the eastern (Ndera-Rusororo) demand by the expansion of Nzove WTP. - Construct a new WTP in Masaka for 20,000 m³/day responding to the water demand increase. - Construct water transmission systems to the Central-eastern area (82,000 m³/day), mainly for the Central-East area and eastern area (Ndera, Rusororo). - Upgrade the pipelines to supply 40,000 m³/day from Remera to meet the demands in Ndera-Rusororo through the existing Karenge line or through Masoro-Bas.	- A scenario to meet the eastern (Ndera-Rusororo) demand by the expansion of Kanzenze WTP. - WTP expansion at Kanzenze (New WTP) for 32,000 m³/day apart from the one by Kigali Bulk Water Supply Project. The transmission line is necessary from Remera to the eastern Ndera-Rusororo. - Construct a new WTP in Masaka for 20,000 m³/day responding to the water demand increase. - Construct water transmission systems to the Central-eastern area (52,000 m³/day), mainly for the Central-East area (Gikondo, Kicukiro and partly to Remera). - Upgrade the pipelines to supply 10,000 m³/day from Remera to meet the demands in Ndera-Rusororo through the existing Kanrege line or through Masoro-Bas (for limited areas such as FTZs up to Ndera).
Necessary Construction Projects	- Rehabilitation of Nzove 1: +15,000 m³/day (from 25,000 to 40,000 m³/day) - Expansion of New Nzove: +25,000 m³/day (from 40,000 to 65,000 m³/day) - Nzove 3 WTP (Groundwater): +40,000 m³/day - Kanzenze 2 WTP and forwarding infrastructures: +22,000 m³/day - Masaka WTP and forwarding infrastructures: +20,000 m³/day - Rehabilitation of Karenge WTP: +3,000 m³/day (from 15,000 to 18,000 m³/day) - Karenge 2 WTP and forwarding infrastructures: +30,000 m³/day - Central Transmission Main (ND 800)	- Rehabilitation of Nzove 1: +15,000 m³/day (from 25,000 to 40,000 m³/day) - Expansion of New Nzove: +25,000 m³/day (from 40,000 to 65,000 m³/day) - Nzove 3 & Rutonde WTP (Groundwater): +70,000 m³/day - Kanzenze 2 WTP and forwarding infrastructures: +22,000 m³/day - Masaka WTP and forwarding infrastructures: +20,000 m³/day - Rehabilitation of Karenge WTP: +3,000 m³/day (from 15,000 to 18,000 m³/day) - Central Transmission Main (ND 800)	- Rehabilitation of Nzove 1: +15,000 m³/day (from 25,000 to 40,000 m³/day) - Expansion of New Nzove: +25,000 m³/day (from 40,000 to 65,000 m³/day) - Nzove 3 WTP (Groundwater): +40,000 m³/day - Kanzenze 2 WTP and forwarding infrastructures: +32,000 m³/day - Masaka WTP and forwarding infrastructures: +40,000 m³/day - Rehabilitation of Karenge WTP: +3,000 m³/day (from 15,000 to 18,000 m³/day) - Karenge 2 WTP: +30,000 m³/day - Central Transmission Main (ND 800)
Stability; of water sources in terms of quality and quantities	**Low/Intermediate:** [Pros]Two major sources; Nyabarongo/Karenge. [Cons] Transmission from the west to east is difficult because of the difference of elevation (Need an additional investment to transmit water to Remera and further to the west). ➔ *Merit to have two major sources in this stage is limited because the amount from Karenge is not enough to cover the entire region and it is difficult to transmit water from the east to the west.*	**Intermediate:** [Pros] Water supply can be easily switched using the Remera reservoir as the key station. [Cons] Relies highly on the Nyabarongo river basin. ➔ *Water source development until 2035 is mainly by groundwater (subsoil water of Nyabarongo river). Therefore, the risks of water quality and quantity are mitigated.*	**Intermediate:** [Pros] Water supply can be easily switch using the Remera reservoir as the key station. [Cons] Relies highly on the Nyabarongo river basin. ➔ *Water source development until 2035 is mainly by groundwater (subsoil water of Nyabarongo river). Therefore, the risks of water quality and quantity are mitigated.*
Flexibility; to the Change of Demand and Development	**Intermediate:** The water supply from Karenge can be alternatively transmitted to Remera.	**High:** The expansion at Nzove can be transmitted to the widest area in CoK utilizing exiting forwarding infrastructures. Having three main routes to Remera (by constructing a larger "Central Main") gives a system more flexible and reliable.	**Low to intermediate**: Water expansion at Kanzenze can be only transmitted to the Southern area, Kanombe, Nyarugunga if there is no expansion of forwarding infrastructures. Having a large amount of water supply in the Masaka area may limit the water flexibility; the water from Masaka can be only utilized Masaka, Kanombe, Ndera and Rusororo regions.
Resiliency; for the preparedness to disasters and Climate Change	**Intermediate risks on qualities but can be mitigated:** [Risks] (Mugesera lake source) - Water quality deterioration of the Karenge Lake (eutrophication). [Mitigation Measures] (Karenge WTP) - Introduce treatment systems including dissolved air floatation, biological processes or powder activated carbons.	**Intermediate risks on qualities but can be mitigated:** [Risks] (Nzove) - Water quality deterioration of the surface water at Nzove by the Dam operation. [Mitigation Measures] - Utilizing well intake (sub-soil water)	**Intermediate risks on qualities but can be mitigated:** [Risks] (Kanzenze) - Water quality deterioration of the surface water at Kanzenze. [Mitigation Measures] - Point source management (Regulation on industrial wastewater). - Active stakeholder involvement by water safety plan.
Cost	**Yearly Averaged Cost** / **2035 Case 1** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 38.9 Reccurent Expenditure (O&M for T&D) MUSD/year 30.8 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **69.7** Cost per m3 (Opex) USD/m3 0.262	**Yearly Averaged Cost** / **2035 Case 2** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 39.9 Reccurent Expenditure (O&M for T&D) MUSD/year 29.3 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **69.2** Cost per m3 (Opex) USD/m3 0.248	**Yearly Averaged Cost** / **2035 Case 3** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 42.5 Reccurent Expenditure (O&M for T&D) MUSD/year 29.3 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **71.8** Cost per m3 (Opex) USD/m3 0.248
Recommendation		○ High flexibility of water supply and the Lowest cost	

Source: JST

13.5.2.2 Year 2050

The comparison and evaluation in the year 2050 are shown in **Table 13.5-3** . The flexibility to the change of development area and its demand is the highest under the Case 2050-1. The cost is the lowest for the Case 2050-2.

Table 13.5-3 Evaluation of Scenarios in Year 2050

Scenario	Case 2050-1: Nyabarongo/Upcountry Water Source Oriented Water Supply	Case 2050-2: Akagera River Upstream Source Oriented Water Supply	Case 2050-3: Mugesera Lake Source Oriented Water Supply
Schematic			
Overview of the Case	- A scenario to prioritize the Nyabarongo river upstream development, upstream dam sources. - Need transmission pipeline for 421,000 m3/day via the Central Main. Eastern (Ndera, Rusororo, Masaka) demand is born by Nzove via Remera. - Nzove-Ntora line needs 190,000 m3/day transmission capacity. - Karenge needs to have 66,000 m3/day capacity to meet only adjacent 3 sector's demand. - Kanzenze needs to have 190,000 m3/day capacity only for the South area.	- A scenario to prioritize the Kanzenze and Masaka surface water sources (Akagera River). - Kanzenze needs to have 480,000 m3/day capacity to meet Southern, Central and eastern demand in CoK. - Masaka needs 120,000 m3/day capacity only to meet the demand in the Masaka sector. - Minimized Nzove and upstream development. Still, need transmission pipeline for 192,000 m3/day via the Central Main. Nzove-Ntora line needs 190,000 m3/day transmission capacity. - Karenge needs to have 66,000 m3/day capacity to meet only adjacent 3 sector's demand.	- A scenario to prioritize the Mugesera Lake (Karenge) surface water sources. - Karenge needs to have 480,000 m3/day capacity to meet eastern demands and cover major part of the demands in the Central Area. - Masaka needs 120,000 m3/day capacity only to meet the demand in the Masaka sector. - Nzove and upstream development was minimized. Still, need transmission pipeline for 192,000 m3/day via the Central Main. Nzove-Ntora line needs 190,000 m3/day transmission capacity.
Necessary Construction Projects	- Rehabilitation of Nzove 1: +15,000 m3/day (from 25,000 to 40,000 m3/day) - Expansion of New Nzove: +25,000 m3/day (from 40,000 to 65,000 m3/day) - Nzove 3 WTP (Groundwater): +40,000 m3/day - Rutonde WTP (Nyabarongo upstream from Nzove): +80,000 m3/day - Nyabarongo River/Dam : 481,000 m3/day - Central Transmission Main (421,000 m3/day, ND2000) - Kanzenze 2 WTP and forwarding infrastructures: +40,000 m3/day - Kanzenze 3 WTP and forwarding infrastructures: +110,000 m3/day - Masaka WTP and forwarding infrastructures: +40,000 m3/day - Rehabilitation of Karenge WTP: +3,000 m3/day (from 15,000 to 18,000 m3/day) - Karenge 2 WTP and forwarding infrastructures: +30,000 m3/day - Karenge 3 WTP: +18,000 m3/day	- Rehabilitation of Nzove 1: +15,000 m3/day (from 25,000 to 40,000 m3/day) - Expansion of New Nzove: +25,000 m3/day (from 40,000 to 65,000 m3/day) - Nzove 3 WTP (Groundwater): +40,000 m3/day - Rutonde WTP (Nyabarongo upstream from Nzove): +80,000 m3/day - Nyabarongo upstream: 112,000 m3/day - Central Transmission Main (59,000 m3/day) - Kanzenze 2 WTP and forwarding infrastructures: +40,000 m3/day - Kanzenze 3 WTP and forwarding infrastructures: +400,000 m3/day - Masaka WTP and forwarding infrastructures: +40,000 m3/day - Rehabilitation of Karenge WTP: +3,000 m3/day (from 15,000 to 18,000 m3/day) - Karenge 2 WTP and forwarding infrastructures: +30,000 m3/day - Karenge 3 WTP: +18,000 m3/day	- Rehabilitation of Nzove 1: +15,000 m3/day (from 25,000 to 40,000 m3/day) - Expansion of New Nzove: +25,000 m3/day (from 40,000 to 65,000 m3/day) - Nzove 3 WTP (Groundwater): +40,000 m3/day - Rutonde WTP (Nyabarongo upstream from Nzove): +80,000 m3/day - Nyabarongo upstream: 112,000 m3/day - Central Transmission Main (59,000 m3/day) - Kanzenze 2 WTP and forwarding infrastructures: +40,000 m3/day - Kanzenze 3 WTP and forwarding infrastructures: +110,000 m3/day - Masaka WTP and forwarding infrastructures: +40,000 m3/day - Rehabilitation of Karenge WTP: +3,000 m3/day (from 15,000 to 18,000 m3/day) - Karenge 2 WTP and forwarding infrastructures: +30,000 m3/day - Karenge 3 WTP and forwarding infrastructures: +304,000 m3/day
Stability; of water sources in terms of quality and quantities	**Intermediate/High:** [Pros] Water supply can be easily switched using the Remera reservoir as the key station. [Cons] Relies highly on the Nyabarongo river basin.	**Low/Intermediate:** [Pros] Water supply can be easily switched using the Remera reservoir as the key station. [Cons] Relies highly on the Nyabarongo river basin. Risks on water supply interruption by water quality accidents (e.g. wastewater/oil spill from industrial factories) will be higher than the upper stream intake.	**Intermediate:** [Pros] Having two major water sources. Nyabarongo and Mugesera will make the water supply stable. Water supply can be easily switched using the Remera reservoir as the key station. [Cons] High energy consuming system may be a risk of electricity
Flexibility; to the Change of Demand and Development	**High:** Water from Nzove can be easily transmitted to CoK via Remera, Nzove or Mont-Kigali.	**High:** Kanzenze is also near to the central and eastern areas, so the water supply management can be flexible according to the change of development. The water can also be utilized outside Kigali, particularly for the New Bugesera airport area.	**Low to intermediate**: Water transmission from Remera to Central and northern area is necessary if the development area shifted to the west. Difficult to adopt the possible demand surge in Bugesera and Kamonyi district.
Resiliency; for the preparedness to disasters and Climate Change	**Intermediate risks but can be mitigated:** (Nzove) - Water quality deterioration of the surface water at Nzove by the Dam operation. - The dropdown of water level at dry season [Mitigation Measures] - Advanced Treatment Systems, - Raw water ponds/reservoirs.	**Intermediate risks but can be mitigated:** [Risks] (Kanzenze) - Water quality deterioration of the surface water at Kanzenze. - The dropdown of water level at dry season [Mitigation Measures] - Point source management (Regulation on industrial wastewater). - Active stakeholder involvement by water safety plan.	**Intermediate risks but can be mitigated:** [Risks] (Mugesera lake source) - Water quality deterioration of the Karenge Lake (eutrophication). - Water level change by underground tunnel construction [Mitigation Measures] (Karenge WTP) - Introduce treatment systems including dissolved air floatation, biological processes or powder activated carbons.
Cost	**Yearly Averaged Cost** / **2050 Case 1** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 99.0 Reccurent Expenditure (O&M for T&D) MUSD/year 70.7 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **169.7** Cost per m3 (Opex) USD/m3 0.243	**Yearly Averaged Cost** / **2050 Case 2** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 91.9 Reccurent Expenditure (O&M for T&D) MUSD/year 74.1 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **166.0** Cost per m3 (Opex) USD/m3 0.255	**Yearly Averaged Cost** / **2050 Case 3** / **MUSD/year** Capital Expenditure (Yearly averaged cost) MUSD/year 97.9 Reccurent Expenditure (O&M for T&D) MUSD/year 82.5 **Estimated Total Expenditure/year (Capex+Opex)** MUSD/year **180.4** Cost per m3 (Opex) USD/m3 0.284
Recommendation	○ High Stability and Flexibility of Water Supply, Cost is the same level as Case 2 (102%)	○ High Flexibility. Slightly Lower Cost than Case 1	

Source: JST

13.5.3 Determination of the Master Scenario

The Master Scenario was determined based on the result of discussion in the JCC held on 13th February 2020. The adopted cases for the year 2035 and 2050 are shown in **Table 13.5-4** .

For the year 2035, an alternative case prioritizing the development of Masaka WTP and Karenge WTP. was selected. The alternative case is based on the combination of Case 2035-1 with some adjustment of the capacity of Nzove and Kanzenze. For the year 2050, the combined idea of Case 2050-1 and 2050-2 was proposed in order to balance the water supply from Nzove/upcountry source and Akagera river.

The components of the facilities to be constructed are presented in **Table 13.9-1**. The roadmap for water supply expansion, according to the final Master Scenario.

Table 13.5-4 Adopted Cases for the Master Scenario

Year	Adopted Cases
Year 2035	**Combination of Case 2035-1 and 2: Karenge and Masaka Prioritized** (with some modifications of common components)
Year 2050	**Combination of Case 2050-1: Nyabarongo/Upcountry and Case 2050-2: Akagera River Upstream**

Source:JST

13.6 MASTER SCENARIO: THE YEAR 2025

The policy for the investment toward the year 2025 is as follows;

a. Accelerate NRW reduction measures to achieve WASAC's target (25%) progressively
b. Meeting the demand in the east: To construct a new WTP near the high demand area (the Sectors of Masaka, and Karenge) or transmit water from the Remera to the east

The specific projects to be implemented according to the policy are as follows;

Extensive Rehabilitation of Distribution Pipes and Block Zonings: Replacement of Customer Pipes and Meters

The NRW target of "25% in 2025" is a tough target to achieve under normal business operations. It is necessary to conduct extensive rehabilitation of supply pipes and distribution networks, apart from the on-going project.

Construction of the Masaka WTP (Phase 1: 20,000 m^3/day)

It is necessary to construct the WTP near the demand. The capacity for the WTP is temporary set at 20,000 m^3/day to be consistent with the future water demand in 2035. Its capacity shall be re-examined during the detailed feasibility study considering 1) actual and on-going development plan in and around the Masaka area, 2) transmission routes to deliver water to surrounding sectors (the Sectors of Ndera, Rusororo and Nyarugunga).

Table 13.6-1 On-going Project and Additional Facilities for 2025

On-going Projects	
Rehabilitation of Nzove 1	+23,000 m^3/day (from 17,000 to 40,000 m^3/day)
Expansion of New Nzove:	+25,000 m^3/day (from 40,000 to 65,000 m^3/day)
Rehabilitation of Karenge WTP	+3,000 m^3/day (from 15,000 to 18,000 m^3/day)
Additional Facilities for 2025: +20,000 m^3/day (Total: 247,000 m^3/day)	
Masaka WTP and forwarding infrastructures	+20,000 m^3/day
NRW Reduction Measures	Phase 1 to 2

Source: JST

13.7 MASTER SCENARIO: THE YEAR 2035

The Master Scenario in the year 2035 is determined as shown in **Figure 13.7-1**.

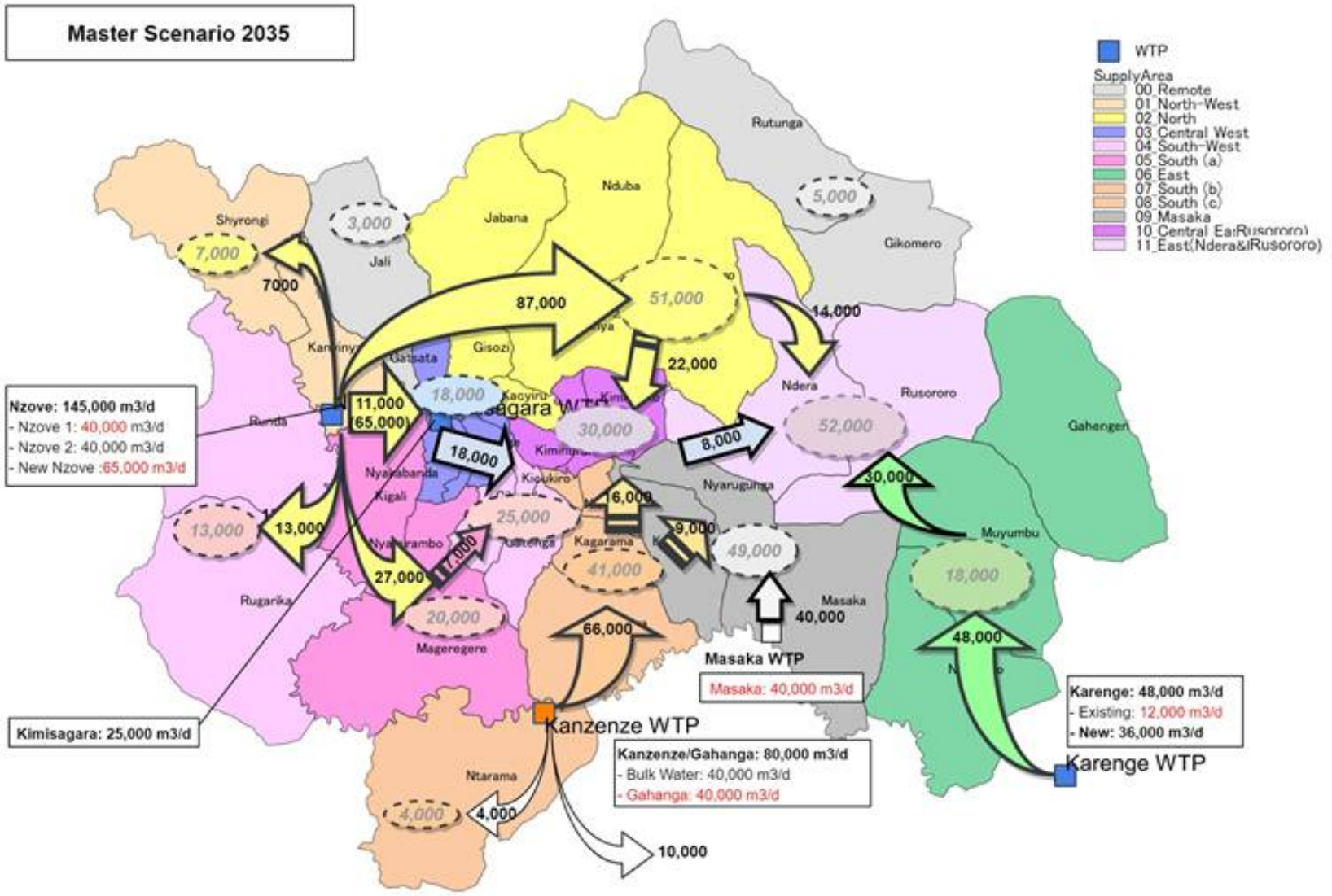
- The Nzove-Ntora capacity is regarded as 105,000 m^3/day considering the transmission capacity of the pipelines (ND900).
- The amount in the Karama-Mont-Kigali line will not be expanded and kept 40,000 m^3/day as the existing transmission capacity. This is because this line is not energy efficient. The line can be utilized as the back-up line in case of the major accidents in other lines.
- The Masaka sector is borne by the new Masaka WTP because it is more efficient than any other supply methods from the Karenge or the Nzove.
- The demand growth in the South area is so large that the supply capacity from the on-going bulk water supply project at the Kanzenze will be in short. A minimum of 40,000 m^3/day expansion is considered.
- Karenge needs to be rehabilitated first, then expanded to the capacity of the maximum amount of water permission.
- Remote sectors (the Sectors of Rutunga and Gikomero) need independent Water Supply Schemes (WSS) by this target year. Each capacity is total of the sector estimated from the CoK M/P and needs to be examined according to the actual development in those sectors. The existing supply capacities in those sectors are neglected in this statement because they are rather small when compared to the demands.

The critical area for further comparison study in 2035 is the Ndera-Rusororo area, where the demand growth is considered to be significant while there are no existing pipelines to supply the large amount (52,000 m^3/day only for the two sectors).

Table 13.7-1 Additional Facilities for 2035

Additional Facilities for 2035: +98,000 m^3/day	
Gahanga WTP	+40,000 m^3/day (New)
Masaka WTP	+20,000 m^3/day (Total: 40,000 m^3/day)
Karenge WTP	+336,000 m^3/day (Expansion plus Rehabilitation)
Small Scale WSS	+5,000 m^3/day (For remote areas: Rutunga, Gikomero)
Transmission and Distribution Pipelines for the abovementioned facilities: NRW Project: Phase 3 to 5	

Source: JST



Source: JST

Figure 13.7-1 Master Scenario in 2035

13.8 MASTER SCENARIO: THE YEAR 2050

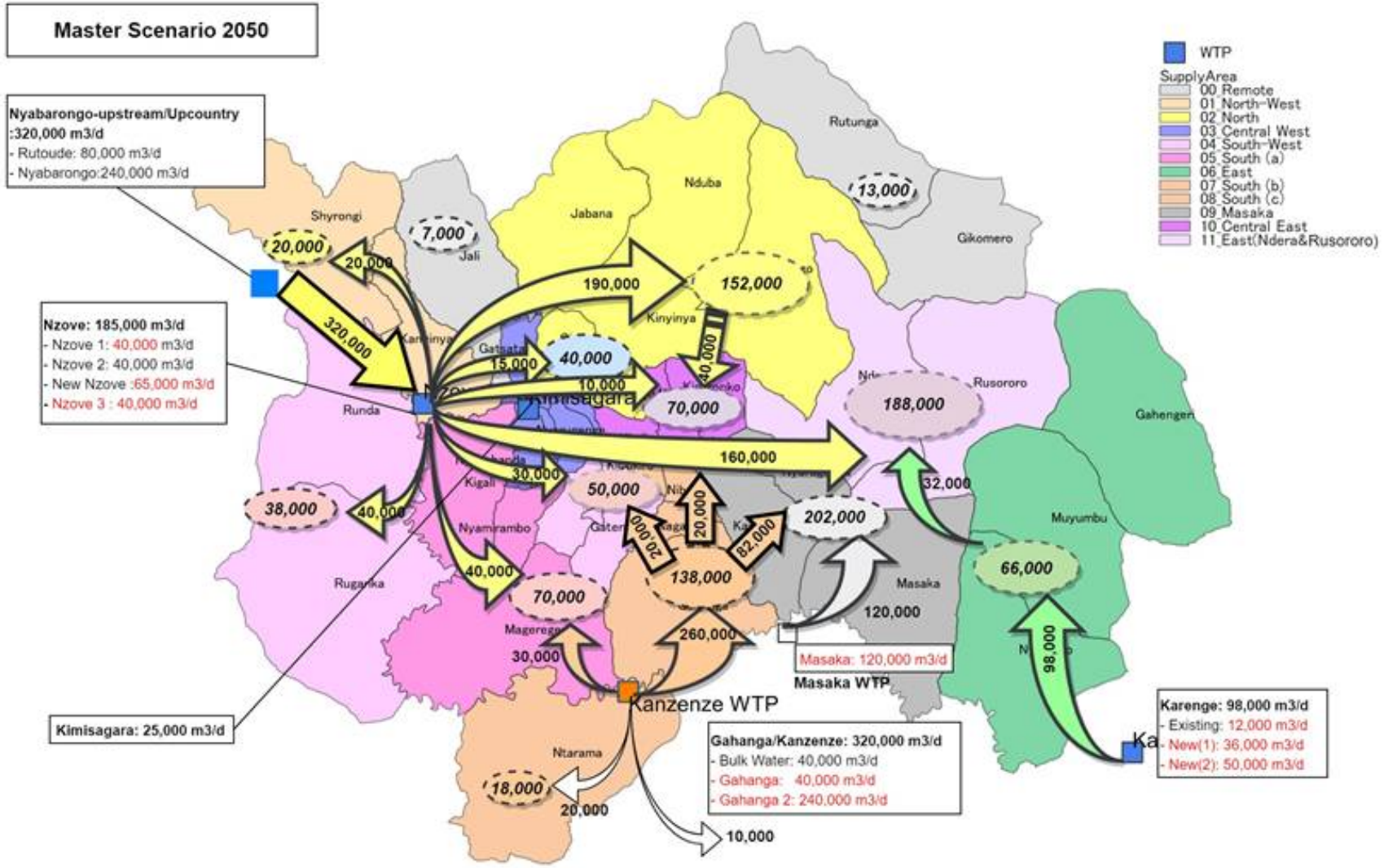
The Master Scenario planning in 2050 is aimed at the determination of the mix of the water source by the given conditions as specified in the CoK M/P (**Figure 13.8-1**). To meet the huge demand of 1,067,000 m^3/day (Daily Maximum, Total in the Study Area), new water sources have to be developed from the Nyabarongo River or upcountry water sources of the Nyabarongo-Akagera River and the Mugesera Lake. The Master Scenario excluded the water use from the Mutobo water source in Musanze District since there are requirements for further study at the national level, basin-based integrated water resource management framework and communications among various stakeholders. Yet, the Nyabarongo and the Mutobo sources are compatible in terms of clear water transmission inside the study area.

Under this scenario, most of the demand in the Central-east area, the Ndera-Rusororo area and a part of the water demand in the Masaka sector are borne by the Nyabarongo water source through the Nzove and the Central Mains. The amount necessary for the Nyabarongo is estimated to be 481,000 m^3/day. Majority of this amount (421,000 m^3/day) should be transmitted through the Central Main to the Remera and the eastern area. Additional facilities for the long term are shown in **Table 13.8-1** .

Table 13.8-1 Additional Facilities for the Long Term (2050)

Additional Facilities for Long Term (2050) +754,000 m^3/day	
Nzove 3	+40,000 m^3/day (New)
Rutonde	+80,000 m^3/day (New)
Nyabarongo	+240,000 m^3/day (New)
Gahanga2	+240,000 m^3/day (New)
Masaka2	+80,000 m^3/day
Karenge	+50,000 m^3/day
Small Scale WSS	+10,000 m^3/day (For remote areas)
Transmission and Distribution Pipelines for the abovementioned facilities.	

Source: JST



Source: JST

Figure 13.8-1 Master Scenario in 2050

13.9 IMPLEMENTATION OF THE MASTER SCENARIO

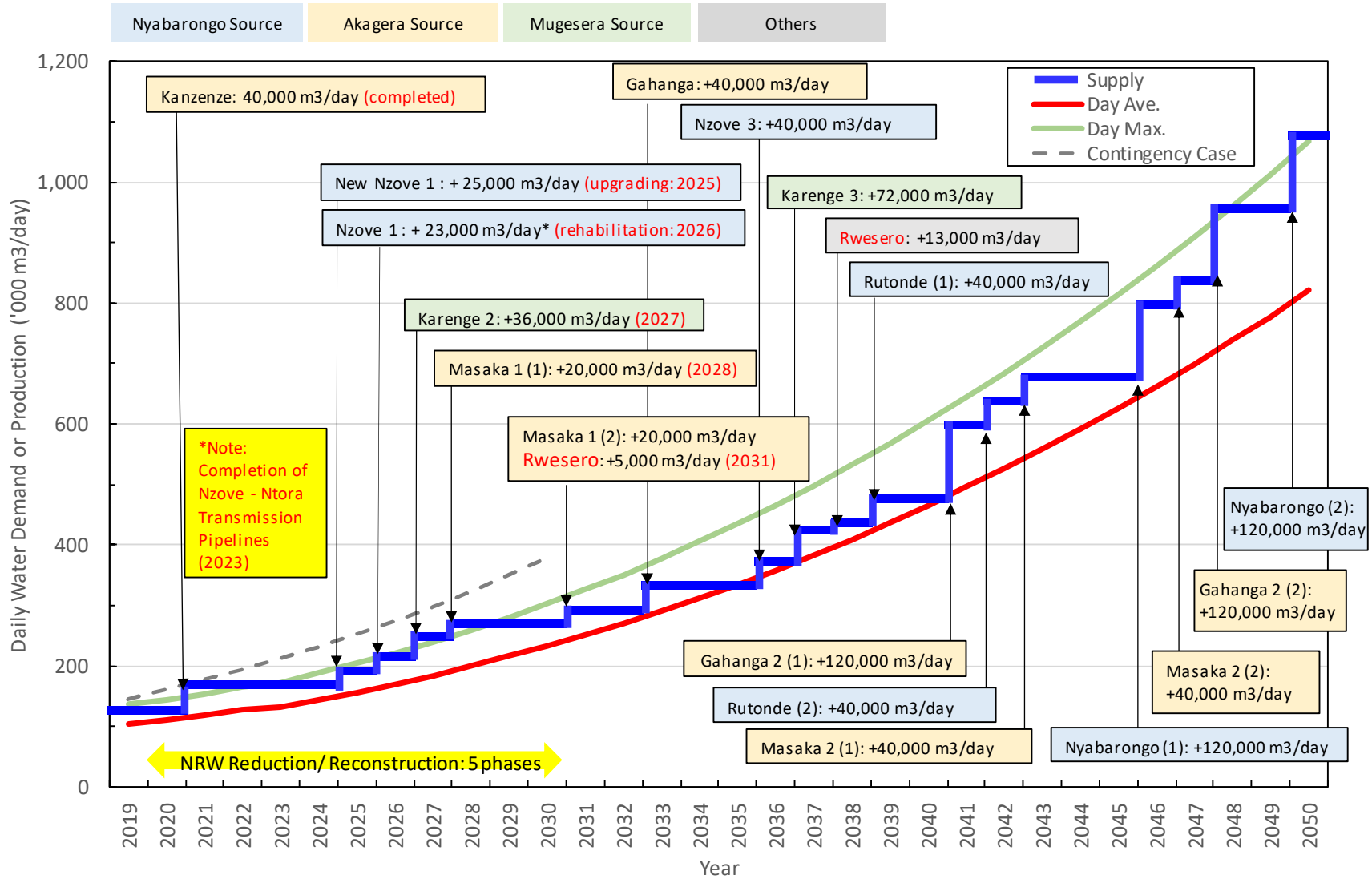
For road-mapping, the implementation, supply-demand strategy, construction of transmission pipelines, and reconstruction of distribution systems for NRW reduction are elaborated here.

13.9.1 Supply-Demand Strategy

- Meeting the Emerging Demand in the East: The CoK M/P (2019) showed that there is the emerging demand growth in the east (the Sectors of Remera, Masaka, Ndera, and Rusororo). The water production from the Karenge WTP and the Kanzenze WTP (the Kigali Bulk Water Supply) is insufficient to meet the demand. It is necessary to construct the water transmission lines from west to east in the long run; however, it is essential to build the water production facility in those areas to meet the demand instantly.

- Progressive Achievement of NRW Reduction: WASAC set an NRW Target of 25% by 2023, while it is 38.8% in 2020 as the status-quo. Despite the success of WASAC NRW reduction team in the pilot area, it is difficult to commit an NRW target without the extensive reconstruction of distribution systems. The reconstruction takes a long time; this M/P set the target year for full achievement in 2030. Compromising the NRW target means the necessity of additional water production to meet the water demand since the demand in this study is the production basis. The M/P targets water production until the year 2025, according to the "Contingency Scenario," as shown in **Figure 13.9-1**. The contingency scenario represents the water demand if the NRW ratio remains 39% until the year 2030.

- Decentralization of Production: Three primary water sources (the Nyabarongo River, the Akagera River, Mugesera Lake) are developed considering their balances. This measure is to keep the flexibility to the actual city's development and to avoid the risk of large-scale water suspension due to overconcentration. The Masterplan found out that it is not realistic to construct the single giant source to cover all the demand in the Study Area, while it is practical to use the local water sources from far and wide regions around the study area. Under this approach, it can also shift the order of water source development considering the risk of the change of water quantity due to Climate Change and the raw water quality deterioration by urbanization.



Source: JST

Figure 13.9-1 Supply-Demand Balance for the Roadmap for the Master Scenario

Table 13.9-1 List and Schedules of Water Supply Expansion for the Roadmap for the Master Scenario

Location	WTP	2019 (Existing)		2021	2025/	2027/	2030/	2035	2040	2045	2050	Total	Areawise	Remarks
		Capacity	Actual	(Ongoing)	2026	2028	2031					Capacity	Capacity	
Nzove	Nzove 1	25,000	17,000	17,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	185,000	505,000	Rehabilitation of Nzove 1
	Nzove 2	40,000	41,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000	40,000			
	New Nzove 1	40,000		40,000	65,000	65,000	65,000	65,000	65,000	65,000	65,000			New Nzove Expansion (25,000 m3/day)
	Nzove 3								40,000	40,000	40,000			Opposite shore of existing Nzove.
Nyabarongo-upstream/ Upcountry	Rutonde								40,000	40,000	80,000	80,000		New locations upstream from the Nzove.
	Nyabarongo								120,000	120,000	240,000	240,000		Nyabarongo 2 dam and/or upcountry sources.
Kimisagara	Kimisagara	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	22,000	
Gahanga/ Kanzenze	Kanzenze			40,000	40,000	40,000	40,000	40,000	40,000	40,000	22,000	302,000	302,000	
	Gahanga							40,000	40,000	40,000	40,000			Opposite shore of existing Kanzenze
	Gahanga 2									120,000	240,000			New WTP in Gahanga (surface water)
Masaka	Masaka 1					20,000	40,000	40,000	40,000	40,000	40,000	120,000	120,000	New WTP (Groundwater)
	Masaka 2									40,000	80,000			New WTP (Surface water)
Karenge	Karenge	12,000	15,000	15,000	15,000	12,000	12,000	12,000	12,000	12,000	12,000	120,000	120,000	Existing
	Karenge 2					36,000	36,000	36,000	36,000	36,000	36,000			Expansion (Phase 1)
	Karenge 3										72,000			Expansion (Phase 2)
Others	Independent	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	7,000	7,000	7,000	Existing
	Rwesero						5,000	5,000	5,000	5,000	13,000	13,000	13,000	For Rutunga/Gikomero
Total Capacity		144,000	100,000	179,000	227,000	280,000	305,000	345,000	545,000	705,000	1,089,000	1,089,000	1,089,000	
Demand outside Study Area				10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	Kanzenze (Airport Area)
ter Supply Amount in Study A		144,000	100,000	169,000	217,000	270,000	295,000	335,000	535,000	695,000	1,079,000	1,079,000	1,079,000	

* Red fonts: Highlight for the New Location / the Year of Expansion and Construction

* Value shown in m3/day as production capacity of treated water (up to 10% surpluss is necessary for water intake)

13.9.2 Water Production Facilities

The facilities to be constructed towards 2050 are listed in **Table 13.9-2** as per the production facility basis.

Table 13.9-2 Facilities to be constructed towards 2050

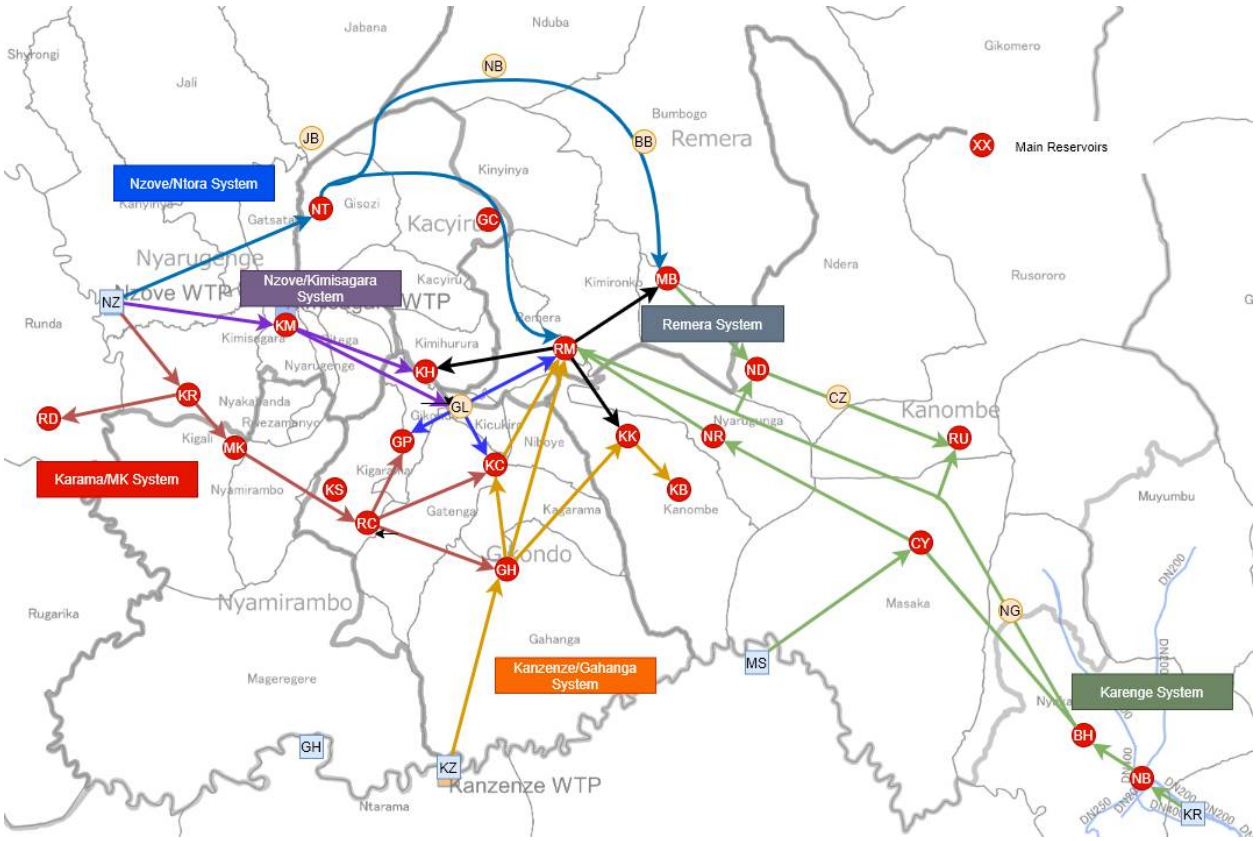
Name of Facilities	Descriptions
Existing Facilities: 162,000 m^3/day[*1]	
On-going Facilities: +65,000 m^3/day (Total: 227,000 m^3/day) [*2]	
Additional Facilities for 2025: +20,000 m^3/day (Total: 247,000 m^3/day) [*3]	
Additional Facilities for 2035: +98,000 m^3/day [*4]	
Gahanga WTP	+40,000 m^3/day (New)
Masaka WTP	+20,000 m^3/day (Total: 40,000 m^3/day)
Karenge WTP	+36,000 m^3/day (Expansion plus Rehabilitation)
Small Scale WSS	+5,000 m^3/day (For remote areas: Rutunga, Gikomero)
Transmission and Distribution Pipelines for the abovementioned facilities	
Additional Facilities for Long Term (2050) +754,000 m^3/day	
Nzove 3	+40,000 m^3/day (New)
Rutonde	+80,000 m^3/day (New)
Nyabarongo	+240,000 m^3/day (New)
Gahanga2	+240,000 m^3/day (New)
Masaka2	+80,000 m^3/day
Karenge	+50,000 m^3/day
Small Scale WSS	+10,000 m^3/day (For remote areas)
Transmission and Distribution Pipelines for the abovementioned facilities	

[*1]: Nzove 120,000 m^3/day, including the rehabilitation, Kimisagara 22,000 m^3/day, Karenge 15,000 m^3/day, and Small-Scale Water Sources 5,000 m^3/day.
[*2]: Kanzenze (Kigali Bulk Water Supply) 40,000 m^3/day, including the demand for Bugesera Airport (10,000m^3/day), which is out of the study area and New Nzove 1 expansion of 25,000 m^3/day.
[*3]: Masaka WTP 20,000 m^3/day

Source: JST

13.9.3 Transmission Pipelines: Grand Design

The transmission pipelines to deliver the clear water from the WTP to the Key Reservoirs are shown in **Figure 13.9-2**. There are six (6) major clear water transmission systems considering the long-term planning perspective, namely the Nzove/Ntora, the Karama/MK (Mont-Kigali), the Nzove/Kimisagara, the Kanzenze/Gahanga, the Karenge/Masaka and the Remera. All these investments are included in the WTP expansion or the NRW reduction projects, as shown in **Table 13.9-3** .



Note: Nzove, NT; Ntora, KM; Kimisagara, KR; Karama, MK; Mont-Kigali, GL; Gikondo-Low (Proposed), GP; Gikondo Premiere, RC; Rebero Carrier, KC; Kicukiro (Golf 7), RM; Remera (Golf 8), GH; Gahanga, KZ; Kanzenze. BH; Bihembe (from Karenge), MB; Masoro-bas, ND; Ndera, RU; Rusororo, MS; Masaka, NR; Nyarugunga, KK; Kanombe Rwimbogo KB; Kanombe Busanza

Source: JST

Figure 13.9-2 Masterplan for Clear Water Transmission Systems (Ultimate Figure of 2050)

Table 13.9-3 Transmission Routes and Construction Framework

Transmission Scheme	Descriptions	Construction Framework
The Nzove/Ntora	The Nzove WTP (Source: the Nyabarongo) is a single water source. All treated water is transferred to the Ntora Reservoir except the minor transmission to the Mount-Jali, the Kanyinya and the Shyolongi. The line covers the northern area of the entire Kacyiru branch, the Nyarutarama, Remera, and a part of the Kimironko. The branch of the line covers the future north-ring line to the Nduba and the Bumbogo.	On-going Expansion: The North-ring (On-going) and the Ntora-reconstruction (Priority project) Future Expansion: After 2040 along with the Nyabarongo WTP (240,000 m^3/day two phases)

Transmission Scheme	Descriptions	Construction Framework
Karama/MK	The Nzove WTP is a single water source. The water is pumped up to the Mont Kigali (MK) reservoir through the Karama Pumping Station. The major portion of water goes to the Kimisange, the Nyanza, and reaches the Kicukiro. This is a back-up line to supply water to the Rwezamenyo and the CBD, while it is not the mainline due to its low energy efficiency. A part of water goes from the Karama to the Runda and the Rugarika areas and will be the major transmission line after the on-going pipeline expansion.	On-going Expansion: The Karama to the Runda-Rugarika (On-going) Future Expansion: After 2040 along with the Nyabarongo WTP
Nzove/Kimisagara	The primary water source is the Kimisagara WTP (Source: the Yanze) and minor source from the Nzove as on 2020. The major source will be switched to the Nzove after the alternative transmission line (Central Mains) is constructed.	Future Expansion: Towards 2036 for the Nzove 3 and the Rutonde as "the Central Main."
Kanzenze/Gahanga	The new transmission pipelines are constructed from the Kanzenze WTP (Bulk water supply) to the Kicukiro, the Remera, the Kanombe-Kabeza, and the Busanza. The systems will be expanded to the southern part of the lower Gahanga in order to meet the new demand for the gateway city to the new airport.	On-going Expansion: Along the completion of the Kanzenze WTP. Future Expansion: By 2032 along with the Gahanga WTP, After 2040 under the Gahanga 2 and 3 (240,000 m^3/day 2 phases)
Karenge/Masaka	The Old Karenge I and II systems from the Karenge WTP (Source: the Mugesera Lake) to the Remera need expansion and rehabilitation. The northern line (the Karenge II) should be reconstructed with the expansion of the Karenege WTP to supply water to the Upcountry areas (the Nyakaliro, the Muyumbu, and the Gahengeri) and the Rusororo, the Ndera to the Remera. The southern line (the Karenge I) will be reconstructed for and along with the new Masaka Water Sources to feed water to the Masaka, the Nyarugunga, a part of the Rusororo.	Future Expansion: By 202,5the Karenge II along with the Karenge 2 WTP Expansion and by 2036 the Karenge I for the Karenge 3 WTP Expansion.
Remera	The system needs to allocate water from the Remera reservoir to the key reservoirs, namely; the Kicukiro, the Kimihurura, the Kimironko, the Masoro-bas, and the eastern area (the Ndera).	Future Expansion: By 2025 along with the NRW reduction (the Kacyiru/South and the Kicukiro)

Source: JST

13.9.4 Phasing of Rehabilitation for NRW Reduction

The reconstruction of distribution systems is phased in 8 target areas, as shown in **Table 13.9-4** . Setting up of the target areas facilitates the implementation to comprehend the system; each target area contains 100 to 200 km of the existing pipeline. The phasing plan is indicated in **Figure 13.9-3**

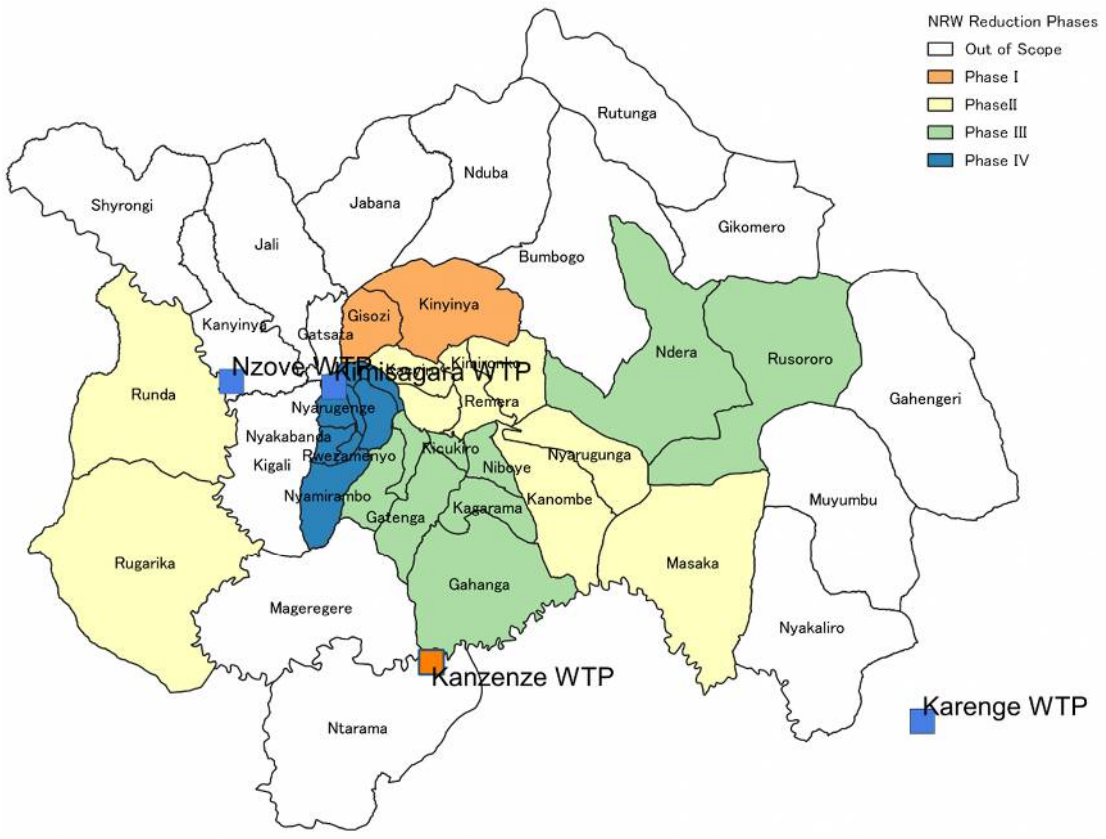
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Table 13.9-4 Target and Phasing of NRW Reduction

Target Areas	Reconstruction framework	Priority/Phase
Nyarugenge/CBD	The CBD and adjacent areas include the Nyarugenge, the Muhima, and the Gitega sectors, where the pipes are aged and tangled. Extensive replacement of water supply pipes (e.g., Galvanized pipes and fittings) along with the PVC distribution mains and distribution sub-mains with small diameters. The Kimisagara: Small reservoirs and pressure control through the block system are necessary to be constructed.	Phase IV
Nyamirambo	The area includes the Kimisagara-Rwezamenyo-Nyakabanda to the Mount-Kigali, where pipes are not capable and possibly suffering from high NRW ratio. This should also include the reconstruction of existing small-scale water sources (the Mburabuturo).	Phase IV

Target Areas	Reconstruction framework	Priority/Phase
Kacyiru/North	The area includes the Gisozi, Kinyinya, and a part of the Remera (the Nyarutarama), which is the supply area of the Ntora-Remera transmission pipeline. The topography is relatively simple, and the system is not very old. The areas can be portrayed as a model for good practices on pressure control and can be disseminated to the other areas.	Phase I
Kacyiru/South	The area includes the Kacyiru, the Remera, the Kimironko and the Kimihurura. An old and complicated system where the pipelines from the Ntora, the Remera, the Kimihurura, Kicukiro are tangled. The system's reconstruction should focus on hydraulic separation and NRW reduction rather than the new reservoir construction.	Phase II
Ndera Rusororo	Mainly focus on the reconstruction of the FTZ and the FTZII supplying system and strategic construction of main distribution systems through a new road from the Masoro to the Kabuga.	Phase III
Gikondo (Kicukiro and lower)	The area includes the distribution systems from the Kicukiro reservoir and the Nyanza reservoir. Hydraulic separation considering the elevation, is the key consideration.	Phase III
Runda Rugarika	The area includes existing and newly developing areas in the Runda and the Rugarika sectors. Setting small reservoirs, reconstruction of incapably small diameters and replacement of the supply pipes along with their expansion are the key considerations for the system.	Phase II
Kanombe/Masaka	Reconstruction of the Masaka existing systems through the Karenge 1 system. Major system construction should be done in the Masaka WTP F/S in order that the system design is along with the Masaka New Water Source.	Phase II

Source: JST



Source: JST

Figure 13.9-3 Schematic of the Phasing of NRW Reduction Project

13.10 TECHNICAL CONSIDERATION: WATER TRANSMISSION AND DISTRIBUTION

For planning the master scenarios, some technical bottlenecks needed detail analyses before illustrating the overall scenario for water supply. First, the JST proposed the design principles which were applied for making the master scenario and should be applied for the design of the future facilities to establish quality facilities and sustainable water services. This will lead to the design standards, which will be proposed in the Master Plan.

13.10.1 Principles

The principles proposed for the design of the facilities are as follows;

a. Pipe Route: Pipe route shall be selected considering maintenance, initial cost and running cost. Pipe shall be installed basically along the road, but open space or slope may be used when it is acceptable. (Accessibility shall be considered.)
b. Transmission main (connecting main reservoirs): Alternative pipe route for emergency cases shall be considered to transmit water to main reservoirs during accidents.
c. Transmission sub-main pipes: Alternative pipe route from main reservoirs shall be considered when power is suspended for a long time
d. Pumps and motors:
   - Suitable pump systems (according to required Q and H) shall be selected for each transmission system. Numeral pump systems are required at Kimisagara WTP.
   - Equipment shall be selected considering efficiency and stability (life span)
e. Protection from Water hammer:
   - Air vessels (or fly-wheel): Suitable methods and size shall be selected based on surge analysis results.
   - Careful operation of valves (slow valve close/open) shall be trained with guideline
f. Pipe diameter:
   - When water is pumped up, economical diameter considering initial cost and operation cost shall be studied
   - When water is transmitted by gravity, the flow rate shall be between 3 m/s and 0.3 m/s.
g. Pipe material: Suitable pipe material and pipe class shall be selected considering quality, reliability, water pressure and cost.
h. River crossing: Methods of river crossing shall be decided to suit site conditions such as soil condition, water pressure, pipe diameter, and flood water level.
i. Pipe protection: Suitable method shall be selected for road crossing and countermeasures for thrust force.
j. Pipe installation on a steep slope: Several aspects shall be considered such as protection of surface and drain of groundwater.
k. Pipe apparatus, such as air valves, drainage, and valves: shall be installed at the required location. (Example; Valves shall be installed at least every 2 km.)

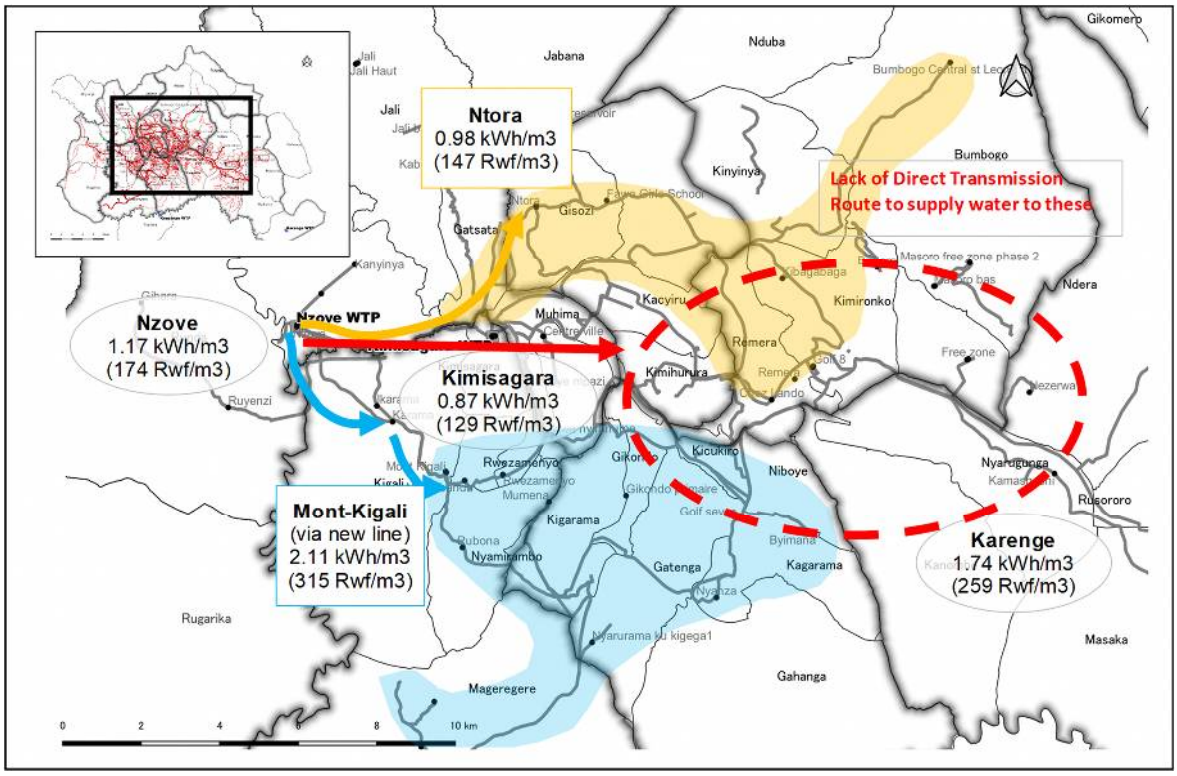
13.10.2 Efficient Water Transmission from the West to the East: The Central Main

As was discussed in the scenarios for 2035 **(Section 13.4.3**), it is necessary to transmit the water from the Nzove to meet the demand in the Central-east area and the Eastern area (Ndera and Rusororo). The recently expanded Nzove–Karama2–Mont-Kigali route consumes more than twice unit power in comparison with the Nzove–Ntora distribution. Meanwhile, this Nzove–Karama2–Mont-Kigali route largely contributes to meet the emerging water demand at the Nyakabanda, the Nyanza, the Rwandatel, and the Kicukiro. However, this could be avoided if the water is planned to be supplied from other routes such as through the Kimisagara or the lower locations (Central transmission Main). It should be noted that the Mont-Kigali reservoirs are located at +1,792 m and the highest elevation of the Kimisagara route is around +1,500 m while demands along the route are mostly located at an elevation between 1,400 m to 1,500 m. The cost impact of energy savings by changing water transmission route will be large and future water management must be optimized from the view of energy efficiency in the long run.

13.10.2.1 General Description

The Central Main refers to the transmission line from the Nzove to the Central and the Eastern area of the CoK in order to reduce the electricity consumption by the transmission. The existing transmission route through the Nzove and the Mont-Kigali to the Remera is inefficient. This is because they are transmitted from the high elevation mountain as well as the route is diverted from the city center and thus is a long way to the eastern area (**Figure 13.10-1**).

The strategic center to supply the water to the emerging demand is the Remera reservoir. The Remera reservoir is also a development center as well as the location near the eastern Kimironko, Ndera, Rusororo, and Kanombe. The route presumes it is the minimal length, so it is through Kimisagara WTP straight on the way from the Nzove to the Remera. The route from the Nzove to the Kimisagara is determined by the topography, to the existing Nzove-Ntora route up to the Nyabugogo bus station right in front of the Kimisagara WTP.



Source: JST

Figure 13.10-1 Schematic of the Central Main

13.10.2.2 Route selection of the Central Main

Figure 13.10-2 represents the possible route from the Kimisagara to the Remera. There are two routes from the Kimisagara to the junction near the University of Rwanda (1A and 1B), and three routes from there to the junction near the Shez-Lando hotel on the way to the Remera reservoir (2A, 2B and 2C). The longitudinal profile of each route is shown in **Figure 13.10-3.**

The characteristics of all the routes are explained in **Table 13.10-1** .

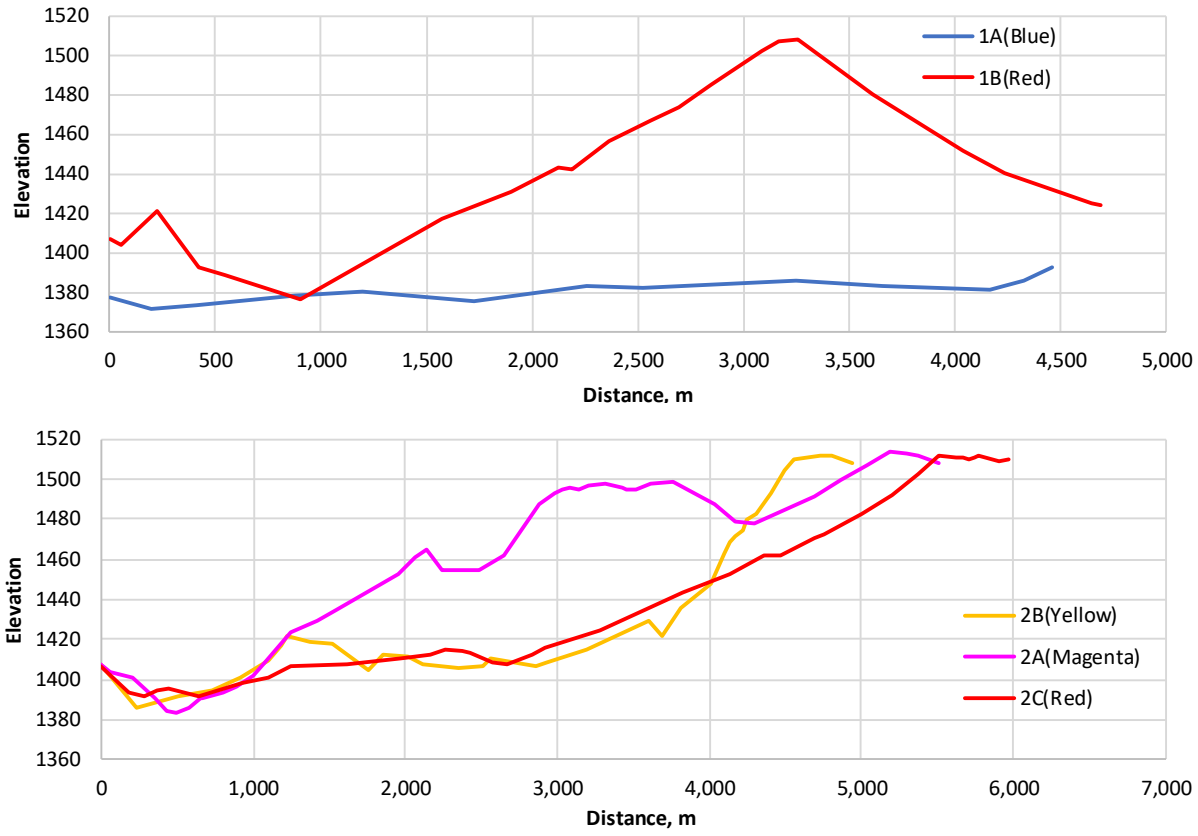
- Construction is difficult along 1B which goes through the highly developed CBD. 1A follows the low elevation route which the length is not much different with 1A.
- 2B is the shortest among the three routes. Most of the routes are low elevation and in less developed areas.

Therefore, route 1B and 2B are selected for further study. The different route lengths and selection of the optimal route is presented under **Table 13.10-2** .



Source: JST

Figure 13.10-2 Schematic of Comparison of the routes from Kimisagara to Remera



Source: JST

Figure 13.10-3 Comparisons of Critical Route from Kimisagara to Remera

Table 13.10-1 Identification and Characteristics of the Routes

Route	Length, m	Highest Elevation, m	Remarks
0. Kimisagara-BS	905	1420.7	
1A. BS-KN7-RwandaU	**4,826**	**1407.9**	**Low elevation and not highly developed area.**
1B. BS-CBD-RwandaU	4,927	1507.9	High elevation and Construction not easy.
2A. RwandaU-KimihururaTop-ShezLando	5,502	1513.3	Highly developed area.
2B. RwandaU-Kimihurura South-ShezLando	**4,937**	**1511.6**	**Low elevation and not highly developed**
2C. RwandaU-Kicukiro-ShezLando	5,965	1511.4	Need a longer length.
3. ShezLando-Remera	1,717	1526.7	

Source: JST

Table 13.10-2 Route Length and Selection

Route	Length	Remarks
0-1A-2A-3	12,630	
0-1A-2B-3	**12,035**	**Adopted**
0-1A-2C-3	13,412	
0-1B-2B-3	12,487	
0-1B-2C-3	13,514	

Source: JST

13.10.2.3 Detailed Transmission Method

According to the elevation of the selected route (0-1A-2B), it is possible to transmit water by gravity flow from the Kimisagara WTP to the intermediate location. The entire route of 1A is low elevation below 1,400. **Figure 13.10-4** shows the comparison of the hydraulic profile of water transmission directly from the Nzove to the Remera (Case A, shown in red) and that through the Kimisagara WTP and a new reservoir (named "Gikondo-Low" reservoir) and pumping station at the low elevation place on the way to the Remera reservoir (Case B, blue). The figure presumes demand allocation, the optimal diameter of pipes considering the initial and energy cost, and the hydraulic gradient as a result. The detail calculation is shown in **Appendix-22**.

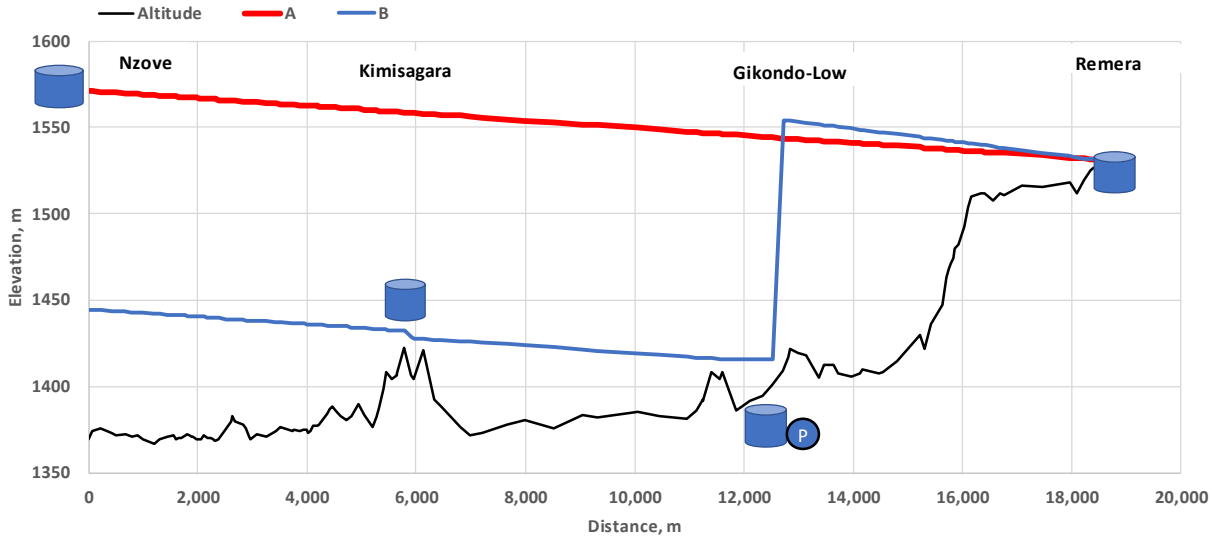
Case A needs high-pressure pumps at 200 m and needs to keep the pressure in more than 150 m for approx. 12 km. This requires expensive high-grade pipes (DIP, PN25), careful thrust anchoring measures, and puts the pipes at risk of high leakages and hazardous bursts. Case B requires more facility and maintenance at an additional pumping station while the high-pressure part will be only limited to approx. 3 km.

The allocated demand for each reservoir and electricity required for transmission and distribution is shown in **Table 13.10-3** . The estimated electricity consumption is lower in Case B because some parts of the demands can be consumed on the way from the Kimisagara to the Remera.

The overall cost comparison between Case A and Case B is as shown in **Table 13.10-4** . The initial cost for Case B is lower than Case A. The cost by using high-grade pipes under Case A is more expensive

than the additional pumping station cost under Case B. O&M cost for Case B is also lower than that of Case A, though the maintenance cost for additional pumping station is needed for Case B.

From the results, it is recommended to select the Case B, with an additional relay reservoir in the middle of the route to transmit the water from the Nzove to the Remera.



Source: JST

Figure 13.10-4 Hydraulic Profile from the selected route (Nzove-Kimisagara-Remera)

Comparison between Direct transmission from the Nzove (Case A) and relay at the intermediate location (Case B)

Table 13.10-3 Demand Allocation and Energy Cost to Distribute Water from the Reservoirs

Reservoirs	Allocated Water Demand			Unit Energy		Yearly Cost in 2035		Yearly Cost in 2050		Comparison
	2035 Day Average	2050 Day Average	2050 Day Max	Case A, kWh/m3	Case B, kWh/m3	Case A, MUSD	Case B, MUSD	Case A, MUSD	Case B MUSD	Case B/A
Remera (RM)	33,200	60,000	78,000	0.77	0.91	1.52	1.81	2.75	3.26	84%
Rebero Carrier (RC)	6,900	6,900	9,000	2.00	2.00	0.83	0.83	0.83	0.83	100%
Gikondo Premier (GP)	6,100	11,200	14,600	0.77	2.00	0.28	0.73	0.51	1.35	38%
Gikondo Low (GL) *Proposed	3,900	7,500	9,800	0.29	0.91	0.07	0.21	0.13	0.41	32%
Kicukiro Golf 7 (KC)	11,700	22,100	28,700	0.70	0.92	0.49	0.65	0.93	1.22	76%
Gahanga (GH)	8,200	17,200	22,400	0.92	0.92	0.45	0.45	0.95	0.95	100%
total	70,000	124,900	162,500	-	-	3.6	4.7	6.1	8.0	78%

Source: JST

Table 13.10-4 Cost Comparison between the Transmission Method Case A and B

Case A		**MUSD**
Plant	Transmission Pump (M&E)	1.30
	Transmission Pump Station (Civil)	0.96
	Distribution Reservoir at Nzove	3.33
Pipe	Transmission Pipe (Nzove-Remera)	31.4
	Transmission Pipe (Brnch-GikondoPremier)	2.7
	Transmission Pipe (Branch--GikondoPremier)	3.3
Total		**42.99**

Care B		**MUSD**
Plant	Transmission Pump at Nzove(M&E)	0.91
	Transmission Pump Station at Nzove (Civil)	0.96
	Distribution Reservoir at Kimisagara	1.66
	Transmission Pump at Gikondo-Low(M&E)	1.28
	Transmission Pump Station at Gikondo-Low (Civil)	0.81
Pipe	Transmission Pipe (Nzove-Kimisagara)	9.89
	Transmission Pipe (Kimisagara-Gikondo-Low)	11.8
	Transmission Pipe (Gikondo-Low-Remera)	8.2
	Transmission Pipe (Gikondo-Low-GikondoPremier)	2.7
	Transmission Pipe (Gikondo-Low-GikondoPremier)	3.3
Total		**41.53**

Lifecycle Cost

Condition

Evaluation Period 20 years

Social Discount Rate 6%

Calculation

	Initial Cos	O&M Cos	Lifecycle Cost
A	42.99	2.98	508.6
B	41.53	2.83	491.4

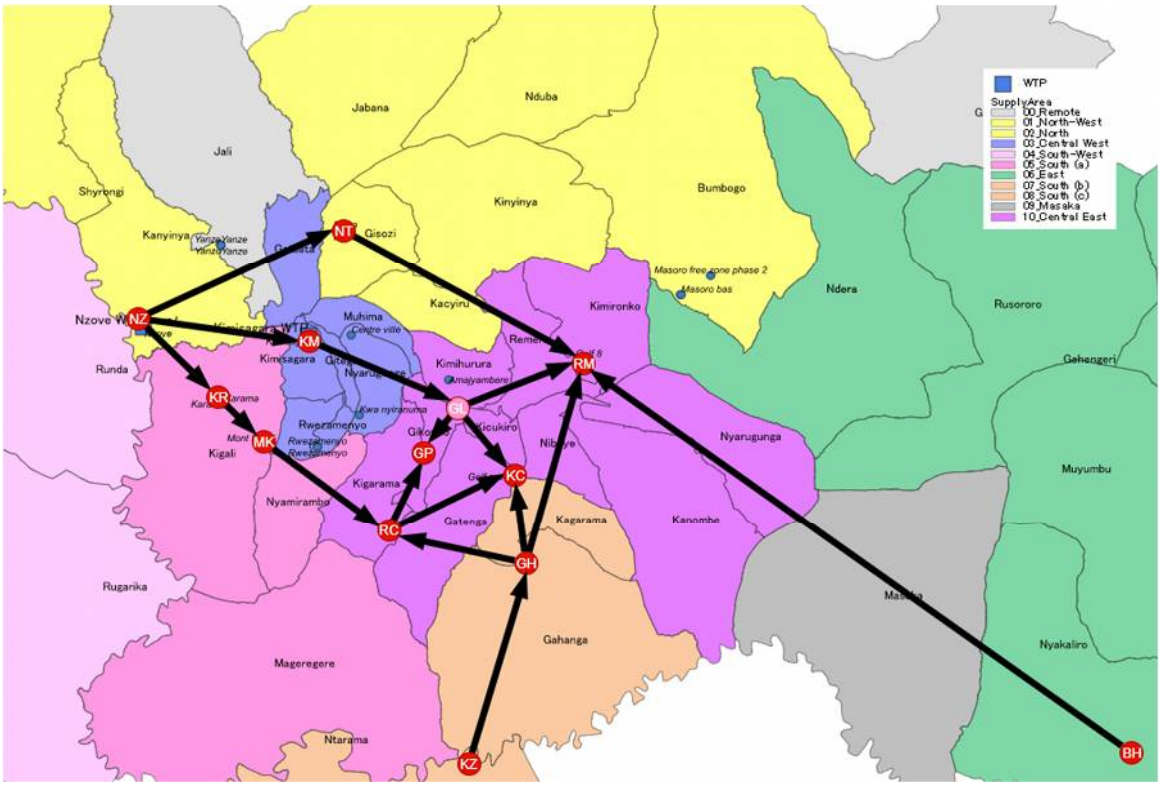
Source: JST

13.10.2.4 Reaffirmation of the O&M cost by existing and proposed transmission method

Figure 13.10-5 shows the overall water transmission model to the Remera including existing and proposed routes. The legends and its elevations of the reservoirs are separately shown in **Table 13.10-5** . In the calculation of electricity cost, the JST assumed the same hydraulic gradient among the routes. O&M costs by water treatment are calculated based on the WASAC annual report of 2018/2019 (See **Appendix-22** in detail).

The results of the calculation are shown in **Table 13.10-6** . The Central Main gives the lowest electricity consumption for water supply from the Nzove to the Remera. The unit electricity consumption is 0.77 kWh/m^3 in the estimate; approximately 84% of the Nzove-Ntora(-Remera) line, 83% of the Kanzenze-Remera line, 55% of the Karenge-Remera line, and 38% of the Mont-Kigali (up to Kicukiro Golf 7) line. Also, remarkably, the electricity to the Kicukiro Golf 7, the Gikondo Premier and the Lower Gikondo sectors will be lowered significantly by the line. The electricity consumption is particularly low, less than one third (0.29 to 0.91 kWh/m^3), and the O&M cost is almost half (104 to 196 RWF/m^3).

Therefore, the proposed Central Main is the most efficient way to transmit the water from the Nzove to the Remera. Further study is necessary for determining the construction availability of the routes, land availability of the reservoir, actual elevations by the topographical investigations and the cost including that for dealing with interferences along the routes.



Source: JST

Figure 13.10-5 Model for the Water Transmission

Table 13.10-5 Legends and Elevations of the Existing/Proposed Reservoirs

ID	Name	GL	HWL	LWL
NZ	Nzove	1,364	-	1,364
NT	Ntora	1,570	1,572.5	1,568
KM	Kimisagara	1,429	1,429	1,429
KR	Karama	1,563	1,565	1,561
MK	Mont Kigali	1,790	1,792	1,788
GL	Gikondo Low (Proposed)	1,412	1,412	1,412
GP	Gikondo Premiere	1,530	1,532	1,528
RC	Rebero Carrier	1,648	1,650	1,646
KC	Kicukiro (Golf 7)	1,510	1,514	1,510
RM	Remera (Golf 8)	1,524	1,526	1,522
GH	Gahanga	1,579	1,581	1,577
KZ	Kanzenze	1,352	-	1,352
BH	Bihembe (from Karenge)	1,643	1,645	1,641

Source: JST

Table 13.10-6 Comparison of Transmission Energy and O&M costs

Comparison of Trasmission Energy	kWh/m3	Electricity cost, RWF/m3	OM Cost Reference	Chemical Cost, RWF/m3	Maintenance+Salary, RWF/m3	Total OM Cost RWF/m3
To Remera						
(1) Nzove-Ntora-Remera	0.91	135	Nzove	50	11	196
(2) Karenge-Remera	1.40	208	Karenge	54	23	285
(3) Nzove-MontKigali (-Remera)	2.00	298	Nzove	50	11	359
(4) Kanzenze-Gahanga(-Remera)	0.92	137	Nzove	50	11	198
(5) Central Main (Nzove-Kimisgara-Remera)	0.77	114	Nzove	50	11	175
To Kicukiro						
(1) Nzove-MontKigali-(Nyanza)-Kicukiro	2.00	298	Nzove	50	11	359
(2) Kanzenze-Gahanga-Kicukiro	0.92	137	Nzove	50	11	198
(3) Central Main (Nzove-Kimisagara-Gikondo Low)	0.70	105	Nzove	50	11	165
To Gikondo Premier						
(1) Nzove-MontKigali	2.00	298	Nzove	50	11	359
(2) Central Main (Nzove-Kimisagara-Gikondo Low)	0.77	114	Nzove	50	11	175
To Lower Gikondo Sector						
(1) Nzove-Ntora-Remera	0.91	135	Nzove	50	11	196
(2) Nzove-MontKigali (-Remera)	2.00	298	Nzove	50	11	359
(3) Central Main (Nzove-Kimisagara-Gikondo Low)	0.29	43	Nzove	50	11	104
		*Direct Construction Cost, overhead not included				

Source: JST

13.10.3 Emerging Demand in the East

In the Section **13.4.3** , the JST discussed that the water supply expansion should be considered from the Masaka new WTP, the Nzove WTP via the Remera or the Masoro bas reservoir or the Karenge WTP to meet the emerging demand in the east. One important question is where the most efficient water supply station is to meet the demands in terms of the water transmission energy and other O&M costs. In this section the JST compares the water transmission costs from those three sources.

13.10.3.1 Routes description

The routes are assumed as shown in **Figure 13.10-6**. Note that the JST did not expect that the existing pipeline can be utilized for this purpose because the diameter should be much larger than the existing ones.

a. Remera-Azam bas-Ndera/Rusororo to Kabuga 2 (Red-blue)

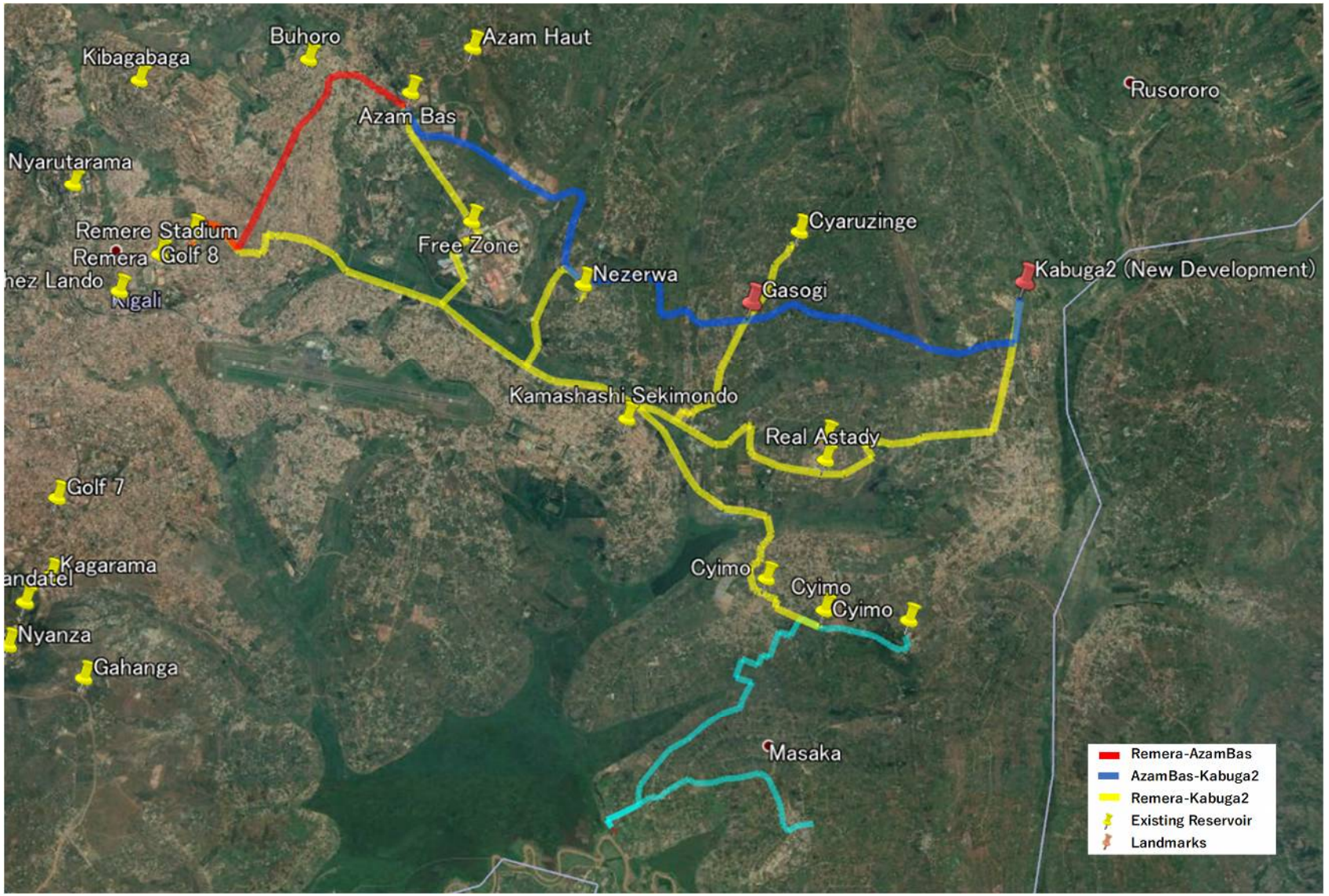
The first route from the Remera is the routes from the existing Azam-bas, via the new roads to be constructed and to the Kabuga 2. The Remera-Azam is the routes where on-going pipeline expansion is planned (**Section 4** "the North Ring", ND400). The routes after the Azam-bas are the new routes as proposed in the CoK M/P. The route traverses through the town called the "Nezerwa" and the "Gasogi" of the Ndera sector and go up to the Kabuga hill area. The endpoint "Kabuga 2" is in the northern part of Kabuga, where the new development is expected as per the CoK M/P. Through this route it is not expected to reach the water to the Masaka area because the route is obviously out of the way compared to the existing Karenge route. Note that the latter part of the route (shown in blue) can only be constructed after the new road is constructed.

b. Remera-Existing Karenge Routes to Kabuga 2 (Yellow)

The other route from the Remera assumes the same route as the northern pipeline from the Karenge-Bihembe-Remera pipeline (SP300). In this case, the JST assumed that the water can be also transmitted to Cyimo (the middle one at the existing small water reservoir, up from the city center). The endpoint is the Kabuga 2, as same as the **a**.

c. Masaka new WTP (Light-blue)

The route starts from the proposed Masaka WTP to the top of the Masaka Mountain. The comparison with the other route was conducted based on the route up to the middle Cyimo reservoir.



Source: JST

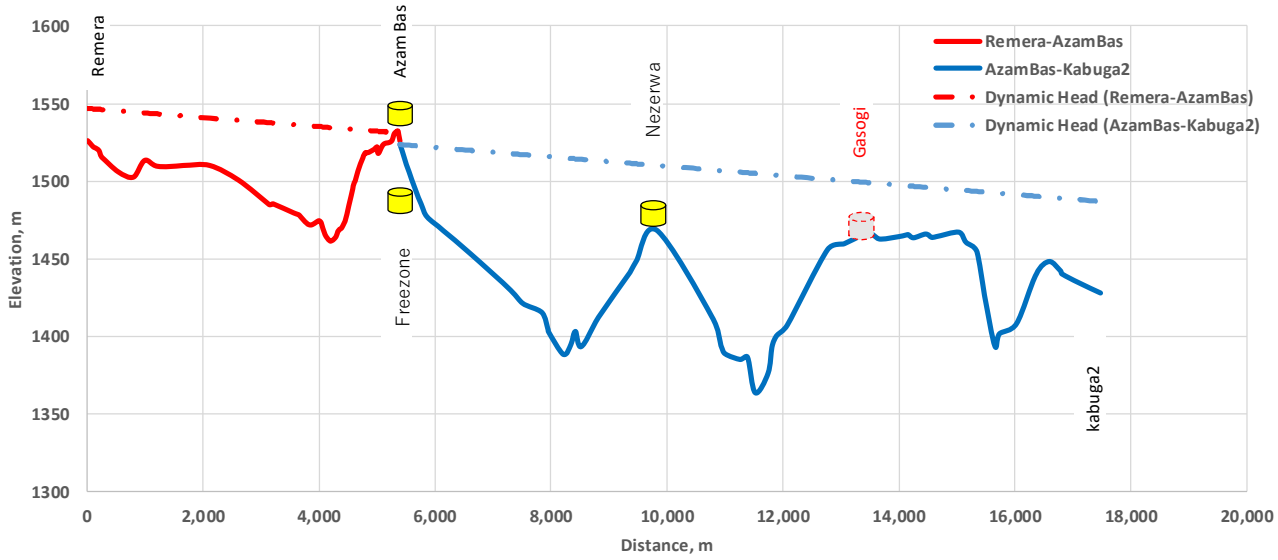
Figure 13.10-6 Transmission Routes to Meet the Eastern Demands

13.10.3.2 Comparison

Longitudinal profiles along the routes and the simulated hydraulic profiles are shown in **Figure 13.10-7** and **Figure 13.10-8**. Note that the Dynamic Head at each figure shows 3 per-km (3 m head-loss for a kilometer).

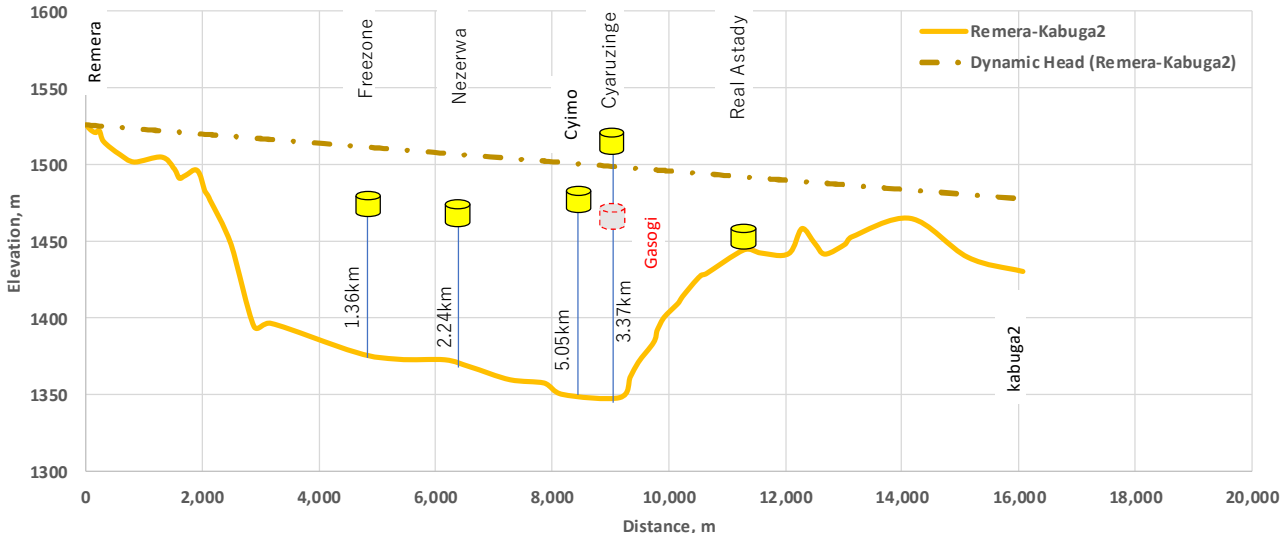
The Case (a) shows that water is necessary to pump up from the Remera to the Azam bas because the ground-level of both reservoirs are almost the same. The water from Azam bas can be transmitted to the Kabuga 2, the endpoint of the line, by gravity. Note that the water cannot be reached to Cyaruzinge, the existing reservoir in the Ndera, by gravity. A new transit reservoir is necessary near the new city center of this region, namely at Gasogi.

The Case (b) also showed that the water could be transmitted from the Remera to the end, as well as the existing middle of the Cyimo reservoir at the Masaka.



Source: JST

Figure 13.10-7 Hydraulic Profile of Remera-Azam bas-Ndera/Rusororo to Kabuga 2 (a)



Source: JST

Figure 13.10-8 Remera-Existing Karenge Routes to Kabuga 2 (b)

Table 13.10-7 shows the O&M cost comparison for supplying water to the Masaka area. The electricity cost for the Masaka is estimated from the necessary energy to pump up the elevation gap from the source to middle Cyimo (134 m) and the loss at the distances (5.5 km). The result showed that both the electricity cost and the estimated O&M cost is the lowest for supplying water from the Masaka WTP. The second-lowest is the option from the Nzove, which assumed utilizing the Central Main which the JST proposed under **Section 13.10.2** . The water from the Karenge is significantly costly than those two options.

Note that this only discusses the cost efficiency from the three options. The other aspects of the water resources such as availability, quality, and various risks are described in **Chapter 10**.

Table 13.10-7 O&M Cost Comparisons to Supply Water for Masaka

Comparison of Transmission Energy	kWh/m^3	Electricity cost, RWF/m^3	OM Cost Reference	Chemical Cost, RWF/m^3	Maintenance + Salary, RWF/m^3	Total OM Cost RWF/m^3
To Cyimo (middle at Masaka)						
(1) From Karenge (via Bihembe)	1.40	208	Karenge	54	23	285
(2) Central Main (Nzove-Kimisagara-Remera)	0.77	114	Nzove	50	11	175
(3) From Masaka	0.59	87	Karenge	54	23	164

Source: JST

13.10.3.3 Conclusion

- Water can be supplied from the Remera to emerging demand zones in the Ndera, the Rusororo and the Masaka via the existing north pipeline route, except for the Cyaruzinge in the Ndera where the small booster pumping station is necessary.

- The new route (Remera-AzamBas-Kabuga2) is based on the new road which was proposed in the CoK M/P. This can be an alternative water supply route via the Azam Bas by gravity. It is recommended that the WASAC has a plan to construct the pipeline in order that they could do it alongside the road construction.
- The most energy-efficient route to supply water to the Masaka is that from the newly proposed Masaka WTP.

13.10.4 Upcountry Water Sources for 2050 perspective (Mutobo and Kivu)

Borehole along the Nyabarongo River will be developed as priority water sources by the year 2035 considering the advantage of the borehole as was discussed in **Chapter 10** and **Section 13.4.3** . The Nyabarongo River will be developed as a water source after the year 2035. However, the Kivu Lake and the Springwater from the Mutobo will also be candidates for alternative water sources in the period. The plan and longitudinal section of the expected transmission line from the Kivu Lake to the Nzove and line from the Mutobo to the Nzove are shown in **Figure 13.10-9** and **Figure 13.10-10** respectively.



Google earth

Source: JST

Figure 13.10-9 Plan of Kivu Lake route and Mutobo route

Mutobo Line



Kivu Line



Google earth

Source: JST

Figure 13.10-10 Longitudinal Section of Mutobo Lake route and Kivu route

Hydraulic calculations of both routes are shown in **Table 13.10-8** to **Table 13.10-11** .

Table 13.10-8 Hydraulic Calculation of Kivu Lake route (Q=20,000m^3/d)

Node up	Node dwn	Pump	Elevation		Q	C	D	L	v	i	Δhp	he	Remarks
		m	up	dwn	m3/d		mm	km	m/s	‰	m	m	
Kibu	peak	**600**	1463	2000	200,000	130	**1,200**	**22**	2.05	2.547	56	**7**	Pump up 600m
peak	Nzove		2000	1368	200,000	130	**900**	**53**	3.64	10.337	548	**84**	

Source: JST

Table 13.10-9 Hydraulic Calculation of Mutobo route (Q=20,000m^3/d)*

Node up	Node dwn	Pump	Elevation		Q	C	D	L	v	i	Δhp	he	Remarks
		m	up	dwn	m3/d		mm	km	m/s	‰	m	m	
Mutobo	Nzove		2093	1368	200,000	130	**1,000**	**100.0**	2.95	6.188	619	**106**	Gravity

Source: JST

Table 13.10-10 Hydraulic Calculation of Mutobo route (Q=12,000m^3/d)*

Node up	Node dwn	Pump	Elevation		Q	C	D	L	v	i	Δhp	he	Remarks
		m	up	dwn	m3/d		mm	km	m/s	‰	m	m	
Mutobo	Nzove		2093	1368	120,000	130	**800**	**100**	2.76	7.130	713	**12**	Gravity

Source: JST

Table 13.10-11 Hydraulic Calculation of Mutobo route (Q=10,000m^3/d) *

Node up	Node dwn	Pump	Elevation		Q	C	D	L	v	i	Δhp	he	Remarks
		m	up	dwn	m3/d		mm	km	m/s	‰	m	m	
Mutobo	A		2093	1368	100,000	130	**800**	**60**	2.30	5.089	305		Gravity
A	Nzove			1368	100,000	130	**700**	**40**	3.01	9.751	390	**30**	Gravity

Source: JST
*Note: Previous studies mentioned the availability of Mutobo spring water to Kigali is 10,000m^3/day and 12,000m^3/day while JST assumed more water might be available after the development of the shallow wells.

As shown in **Table 13.10-8** , the Kivu Lake route shall traverse through the high mountain. The actual head (the difference of altitude between the lake and the mountain) is at least 537 m and pumps with about 600 m lifting head will be required considering water headloss in the pipeline. A straight route but not along the road is assumed as the shortest route for the lowest cost, in which 22 km pipe with diameter 1200 mm and 53 km pipe with diameter 900 mm is required to be installed for transmission of 20,000 m^3/day of water. However, this route has obviously less advantage than pipe from the Mugesera Lake through the Karenge Water Treatment Plant, in which the actual head of about 360 m with much short pipeline is required. The Kivu Lake route system requires much higher initial cost and operation cost (energy cost) than the Karenge route system, which requires the highest cost in/around the CoK.

On the other hand, water can be transmitted by gravity through the Mutobo route. As shown in **Table 13.10-9** about 100 km pipe with a diameter of 1000 mm is required for transmission of 20,000 m^3/day of water through the Mutobo route, which requires simple water treatment and no pump. The Mutobo route has much advantage than the Kivu Lake route for development.

Thus, initial cost and operation cost for 30 years are compared between the Mutobo spring water system and the Nyabarongo river water system for the capacity of 200,000 m^3/day, 120,000 m^3/day and 100,000 m^3/day respectively.

Table 13.10-12 Cost comparison of River Water Sources and Mutobo Spring Sources

Water Source	Case		A	B	C
	Treatmatn Capacity	m3/d	200,000	120,000	100,000
River Water in Kigali	Construction of Water Treatment Plant	mil $	**100**	**60**	**50**
	Water Treatment Unit cost	Rwf/m3	84	84	84
	Yearly OM Cost	mil $/year	6.3	3.8	3.2
	Present Value of 30 year OM Cost	mil. $/30 year	**71.0**	**42.6**	**35.5**
	Total	mil $	**171**	**103**	**85**
	Number of Inteka well	location	200	120	100
	Construction of boreholes	mil $	**3.60**	**2.16**	**1.80**
Mutobo Spring Water	Diameter of transmission pipe	DN	1,000	800	800 / 700
	Unit rate for pipe installation	$/m	1,500	1,200	1,200 / 1,000
	Length of transmission route	km	100	100	55 / 45
	Pipeline Construction Cost	mil $	**150**	**120**	**116**
	Yearly OM Cost	mil $/year	0.30	0.18	0.15
	Present Value of 30 year OM Cost	mil. $/30 year	**3.39**	**2.03**	**1.69**
	Total	mil $	**157**	**124**	**119**

Source: JST

As inferred from the comparison, the Mutobo springs will have a financial advantage to the Nyabarongo Surface-water when the capacity of 200,000 m^3/day is considered while the Nyabarongo River water system has a financial advantage when the capacity is 12,000 m^3/day or 10,000 m^3/day. It can be concluded significant financial advantage of the Mutobo spring system is not found when yield capacity is not large. Considering the previous plan for the development of the Mutobo springs for the CoK was not realized due to several difficulties. Availability of yield capacity, instability due to volcanic activities, affects the hydraulical environment and water usage in the Mutobo shall be studied in detail and understanding of residents in the Mutobo area shall be taken before utilizing the Mutobo spring water. Therefore, the development of the Nyabarongo River and the Muhazi Lake will be planned from the year 2035 to 2050 under this Study but it shall be revised when difficulties are clarified and the advantage is found on the usage of the Mutobo spring water.

13.10.5 Impact of Water Loss Reduction

The water demand projection assumed that water loss percentage will be reduced to 35% in 2019, 25% in 2025, 23% in 2035 and 20% in 2050. On the contrary, the NRW percentage is estimated to be 38%[1] as of the 2018/2019 fiscal year-end, according to the WASAC's annual report. The current level of NRW is not in accordance with the Five Years Strategic Plan of NRW reduction. For fear that the NRW reduction will not be on track even in the future, the worst-case scenario–NRW will remain at the current level at 38%–was simulated in **Table 13.10-13** and **Table 13.10-14.**

This result implies that;

- The impact of water loss on supply capacity is estimated to be 34,400 m^3/day in 2025, 82,700 m^3/day in 2035 (Day Average), and 310,000 m^3/day in 2050 (Day max). This means NRW reduction measures are worth producing another WTP.
- Regional impact particularly on the Karenge supplying Area–Ndera, Rusororo, Masaka, Gahengeri, Muyumbu and Nyakaliro sectors (ID: 6, 9 and 11)–sums up to 7,100 m^3/day in 2025 and 21,900 m^3/day in 2035. This amount may be even underestimated since the water loss in those areas has not yet accurately been calculated and will be more than 38%.
- The cost for the failure to reduce water loss is significant and emergent as was estimated to be 26.9 MUSD as CAPEX and 4.7 MUSD/year as OPEX in 2025 and will reach 42.8 MUSD/year as OPEX in 2050.

Therefore, NRW reduction through reconstruction of distribution systems is one of the top priority issues to be tackled at the early stage of the Masterplan implementation. The impact of water loss on supply capacity is estimated to be 34,400 m^3/day in 2025, 82,700 m^3/day in 2035 (Day Average), and 310,000 m^3/day in 2050 (Day max) (**Figure 13.10-11**). The additional investment was estimated to be 26.9 MUSD as CAPEX and 4.7 MUSD/year as OPEX in 2025, and the OPEX will reach 42.8 MUSD/year in

[1] The water loss percentage is assumed to be the same level as NRW percentage.

2050 if there is no improvement in the NRW reduction. Comprehensive evaluation should be conducted project-wise. Yet, this implicates that taking NRW reduction measures are worth investing, gaining similar effect as constructing another WTP.

Table 13.10-13 Estimated Loss at the Worst-case Scenario of Water Loss Reduction Failures

ID	Supply Area	Main Supply Scheme	**Water Demand if Water Loss remains 38% until 2050, m^3/day**				
			Day Average				Day Max
			2019	2025	2035	2050	2050
0	Remote	Independent Water Supply	3,100	4,900	8,700	20,600	27,000
1	North-West	Nzove-Kanyinya	3,100	4,900	8,700	19,400	25,000
2	North	Nzove-Ntora	16,800	30,400	63,600	151,000	196,000
3	Central West	Kimisagara	15,700	20,700	31,200	46,500	60,000
4	South-West	Nzove-Karama	4,200	7,300	16,200	37,400	49,000
5	South (a)	Mont-Kigali	6,300	12,200	26,200	69,700	91,000
6	East	Karenge	3,100	8,500	22,400	65,800	86,000
7	South (b)	Kanzenze-Gahanga	12,600	24,300	59,900	161,300	210,000
8	South (c)	Kanzenze-Bidudu	1,000	1,200	5,000	18,100	24,000
9	Masaka	Masaka	4,200	7,300	23,700	114,800	149,000
10	Central East	Mixed	29,400	47,400	87,300	169,000	220,000
11	New East	Mixed (Remera-Karenge)	11,500	24,300	64,800	185,800	242,000
a. Total (Water Loss=38%)			**111,000**	**193,400**	**417,700**	**1,059,400**	**1,377,000**
b. (Ref) Total in main projection (Water Loss; 35% in 2019 to 20% in 2050)			106,000	159,000	335,000	821,000	1,067,000
Difference (a-b)			**5,000**	**34,400**	**82,700**	**238,400**	**310,000**

Source: JST

Table 13.10-14 Estimated Cost for Compensation for the Worst-case Scenario

Year	Method	Difference of Water Loss*, m^3/day	Unit Construction cost* ,USD/ m^3/day	As CAPEX, MUSD	Unit Production Cost**, RWF/m3	As OPEX, MUSD/year
2019	Day Average	5,000	953	4.8	342	0.7
2025		34,400	782	26.9	342	4.7
2035		70,000	576	40.3	342	9.7
2050		238,400	576	137.3	342	32.9
2050	Day Max	310,000	576	178.6	342	42.8

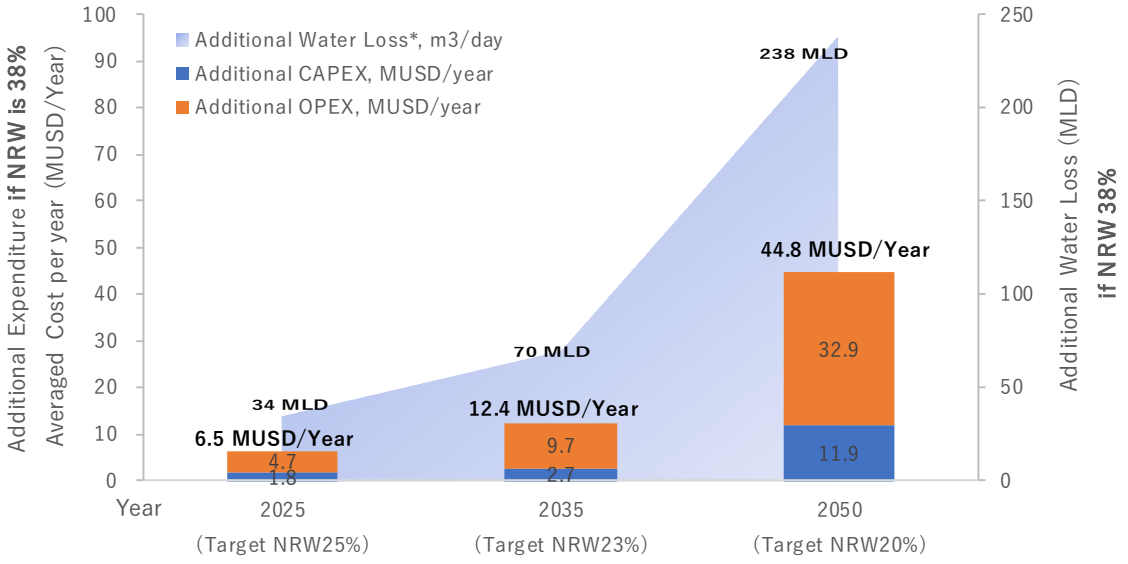
* (Worst-case; Water Loss=38%) - (Main Scenario; Water Loss decreases from 35% in 2019 to 20% in 2050)

** Current USD in 2019, pure construction cost excluding engineering cost, miscellaneous, and contingencies. Estimated from the data of recent projects in Rwanda and adjacent countries.

*** Based on WASAC 2018/2019 Annual Report (Aggregated average of Nzove, Kimisagara, and Karenge)

Note: Inflation and price escalation on materials/energies are not considered.

Source: JST



Source: JST

Figure 13.10-11 Economic Loss by NOT Achieving NRW reduction Target

13.10.6 Other Technical Consideration

Other technical consideration for the transmission and distribution systems are summarized in **Figure 13.10-12**.

(1) Transmission Route from the Karenge WTP to be expanded (Usage of Reservoir at the Bihembe)

When new pipe is installed along the same route with the exiting transmission line, pumping up from the Nyabubare reservoir (at EL+1566 m) to the Bihembe reservoir (at EL+1642 m) will be required in addition to pumping up from the Karenge WTP to the Nyabubare reservoir. When detour route is selected, pumping up from the Nyabubare reservoir to the Bihembe reservoir will not be required, but a longer transmission pipe is required. If water is pumped up to the Bihembe reservoir, water will be transmitted directly to the high area in the CoK such as the northern Rusororo and the northern Ndera, but the pressure for some distance will be very high. Another option is to recover surplus energy (of potential energy at the Bihembe) using small scale generator at low area. These options will be compared during the Feasibility Study considering several factors such as energy efficiency and installation cost. The efficient method of using the new Bihembe reservoir with a capacity of 500 m^3 will also be studied.

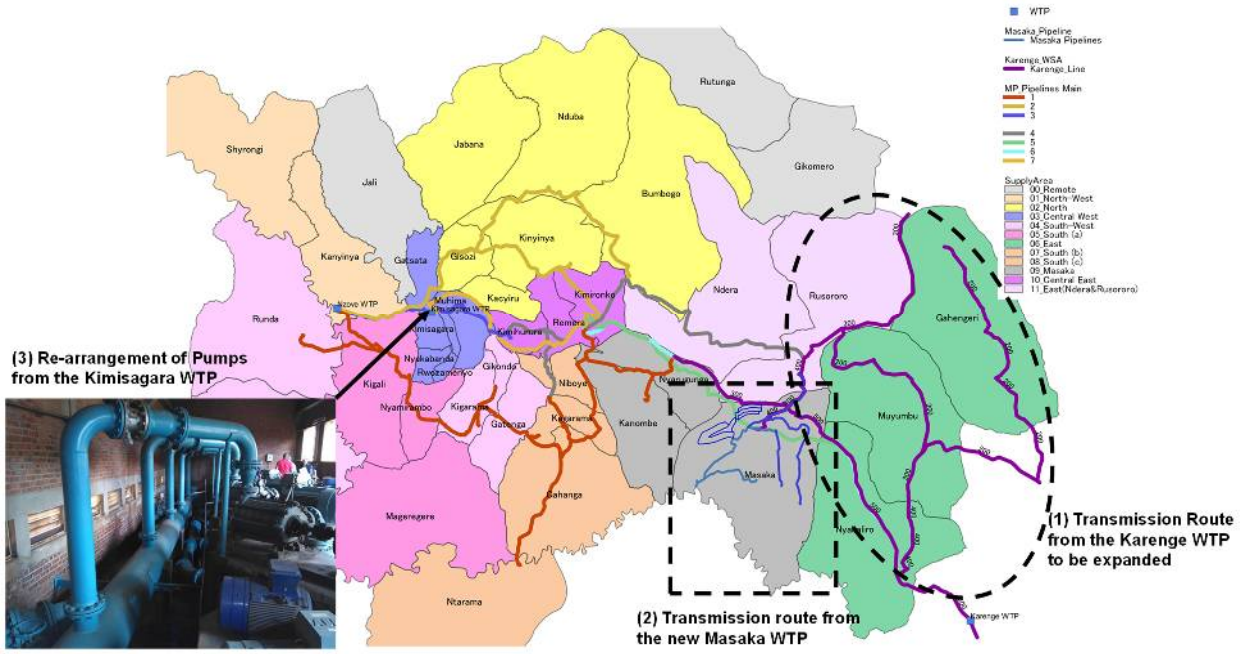
(2) Transmission route from the new Masaka WTP (Usage of the Masaka Cyimo High Reservoir)

A new reservoir with capacity of 500 m^3 at the Masaka Cyimo High (at EL+1564m) will soon be constructed. Instead of pumping up all of the treated water to the High Reservoir from the new Masaka

WTP, it will be energy efficient to pump up to the new reservoir being planned at lower elevation and boost the limited volume to the High reservoir. Location of new reservoir and pipe route will be planned during the Feasibility Study considering initial and running costs.

(3) Re-arrangement of Pumps from the Kimisagara WTP

All the pumps at the Kimisagara WTP are connected with a header pipe and water is transmitted/ distributed mainly in three directions. Therefore, some pipes have unnecessarily high water-pressure and pump energy is not effectively used. It will be planned to install pumps having different water head and to re-arrange header pipe for efficient improvement of energy and reduction of leakage during the Feasibility Study.



Source: JST

Figure 13.10-12 Schematic of Other Technical Considerations for Water Transmission

13.11 TECHNICAL CONSIDERATION: WATER TREATMENT PROCESS

In order to select advanced treatment processes properly, the following aspects have been considered:
1) Efficiency against target treatment compounds
2) Adverse byproduct formation
3) Economic efficiency (including both construction costs and O&M costs)
4) Resources requirement (land requirement and O&M levels etc.), and
5) Environmental sustainability of the considered alternative
6) Others

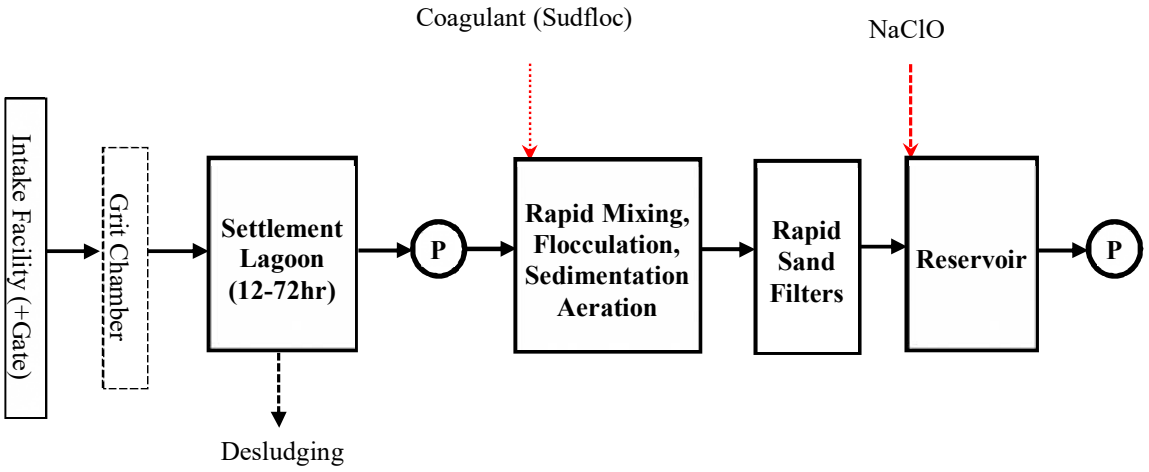
13.11.1 Nyabarongo River

For the raw water of the Nyabarongo River, treatment targets are considered to be high turbidity during the wet season (max. in 10,000-20,000 NTU), Fe and Mn. To remove these compounds (especially high turbidity), settlement lagoon and two-stage sedimentation can be proposed. **Table 13.11-1** presents comparison results of high turbidity treatment methods and shows that settlement lagoon may be a better choice if enough land is available because low coagulant dosage and stable raw water intake can be achieved even during sediment flushing of the Nyabarongo-II dam. The treatment processes for settlement lagoon and two-stage sedimentation are shown in **Figure 13.11-1** and **Figure 13.11-2**, respectively.

Table 13.11-1 Comparison of High Turbidity Treatment Methods

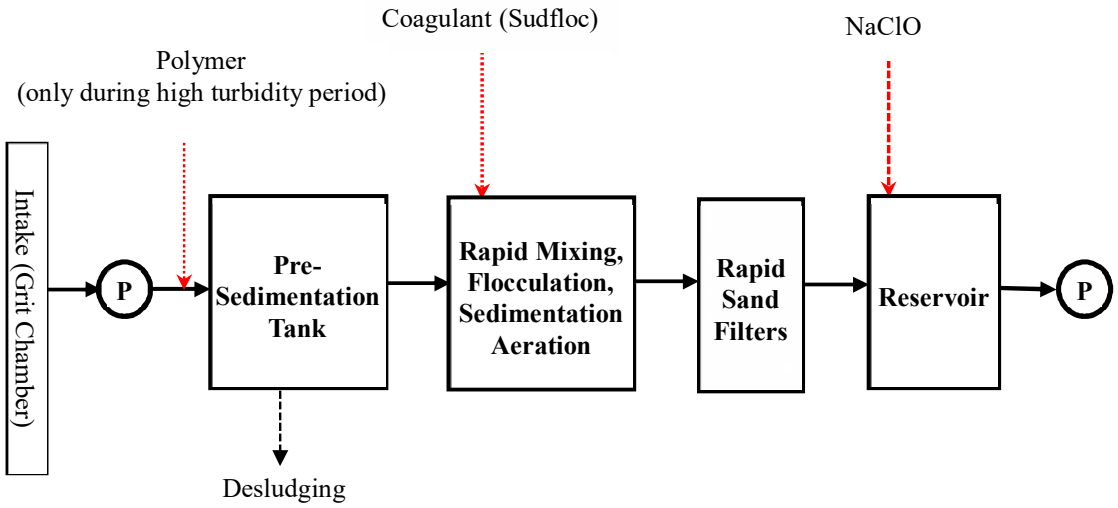
Item	Option-1: Settlement Lagoon	Option-2: Two-stage Sedimentation
Efficiency	Middle-High (depending on retention time)	High (polymer addition at high turbidity)
Removal other pollution matters	Yes (NH_3, organic matters and some heavy metals etc.)	Yes (NH_3, organic matters and some heavy metals etc.)
Byproduct formation	No	Impact of polymer
Capital costs	Middle (but coagulant dosage can be reduced)	Middle (but coagulant dosage can be reduced)
O&M costs	Low (natural sedimentation)	Middle (polymer dosage at high turbidity)
Land requirement	Large (depending on retention time)	Small
Required O&M level	Low	Middle-High (Dosage control, sludge discharge etc.)
Environmental issues	Sediments final disposal	Final disposal of the sediments with polymer
Others	• Reduction of Fe and Mn by natural oxidation • Reduction of coagulant dosage • Land availability	• Reduction of coagulant dosage
JST recommendation	○1)	○2)

Source: JST
HRT: Hydraulic Retention Time
When enough land is available, Option-1 is recommended. If not, Option-2 is recommended.



Source: JST

Figure 13.11-1 Treatment Flow Chart of High Turbidity Treatment (Regulating Reservoir)



Source: JST

Figure 13.11-2 Treatment Flow Chart of High Turbidity Treatment (Two-stage Sedimentation)

13.11.2 Mugesera Lake

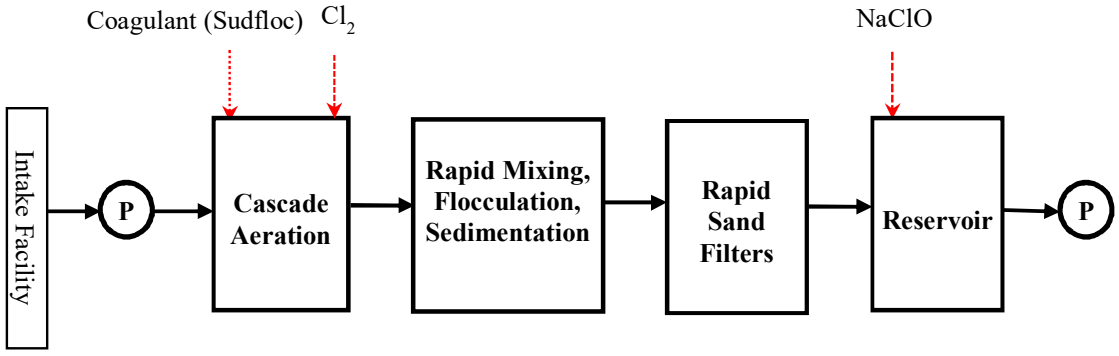
For raw water of the Mugesera Lake, the treatment target is considered to be algae with low turbidity (approx. 20 NTU). To remove algae, except convention sedimentation (existing treatment process), dissolved air floatation (DAF) and pre-chlorination can be proposed.

Table 13.11-2 presents comparison results of algae treatment methods and shows that DAF may be a better choice considering removal efficiency and byproduct formation. The treatment processes of convention sedimentation and DAF are showed in **Figure 13.11-3** and **Figure 13.11-4**, respectively.

Table 13.11-2 Comparison of Algae Treatment Methods

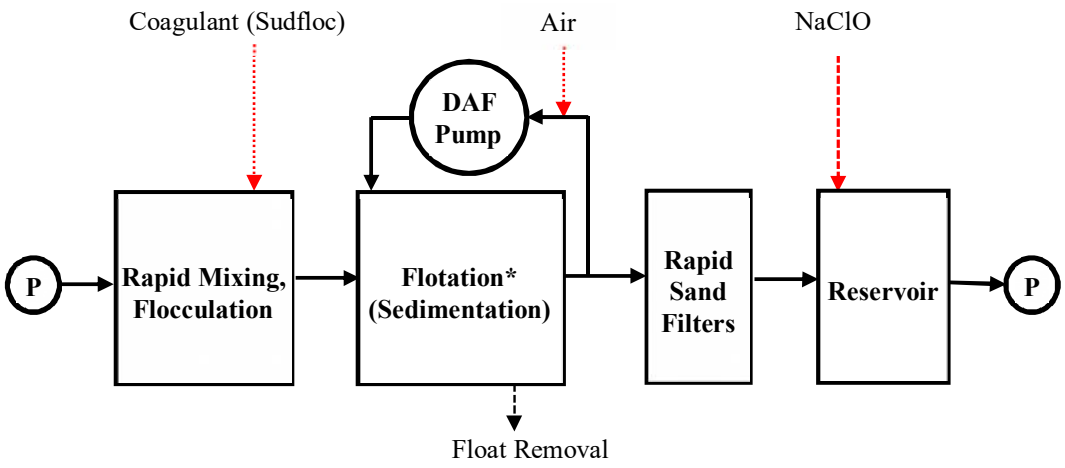
Item	Alternative-1: Convention Sedimentation	Alternative-2: Pre-chlorination	Alternative-3: Dissolved Air Floatation (DAF)
Efficiency	Low (low settling velocity of floc)	High	High
Removal other pollution matters	Yes (NH_3 and organic matters etc.)	Yes (NH_3, Fe, Mn, etc.)	Yes (turbidity, NH_3, Fe, Mn, and organic matters etc.)
Byproduct formation	No	Yes (THMs, increase of dissolved cyanotoxins if toxins producing algae existing)	No
Capital costs	Middle	Low (chlorination dosage system)	Middle (DAF pump and float removal system)
O&M costs	Middle (coagulant consumption)	Low (chlorine consumption)	Middle (coagulant consumption, power consumption for DAF pump, but coagulant dosage can be reduced)
Land requirement	Middle	Very small (only chlorination equipment)	Small
Required O&M level	Low	Low	Middle-High
Environmental issues	No	No	No
Others	• Existing treatment method • Difficult to deal with eutrophication of the lake	• Suitable for algae without toxins. • To removal byproducts or toxins, granular activated carbon (GAC) may be necessary.	• Advanced technology • Effectiveness of DFA needs to be confirmed.
JST recommendation	△ (Low efficiency of algae removal, which may cause short filter running)	△ (Byproducts or toxins formation)	○ (High efficiency of algae removal. However, farther investigation is necessary.)

Source: JST
THM: Trihalomethanes



Source: JST

Figure 13.11-3 Treatment Flow Chart of Algae Treatment (Conventional Sedimentation)



Source: JST, *: If it is necessary, the flotation tank can be combined with sedimentation tank.

Figure 13.11-4 Treatment Flow Chart of Algae Treatment (DAF)

13.11.3 Groundwater

For groundwater, the main treatment targets are considered to be high Fe and Mn (max. in 15 mg/l and 3 mg/l respectively). To remove Fe and Mn, aeration with sedimentation, contact oxidation and high-rate biological oxidation can be proposed. **Table 13.11-3** presents comparison results of Fe and Mn treatment methods and shows that high-rate biological oxidation process may be a better choice for the WTP construction. The treatment processes are shown in **Figure 13.11-5**, **Figure 13.11-6**, respectively.

Table 13.11-3 Comparison of Fe and Mn Treatment Methods

Item	Alternative-1: Aeration with Sedimentation	Alternative-2: Contact Oxidation	Alternative-3: High-rate Biological Oxidation
Efficiency	Middle (limited Mn removal due to low oxidation rate for Mn)	Middle-High (limited Mn removal due to high concentration of Fe)	High (both Fe and Mn can be removed effectively by iron bacteria)
Removal other pollution matters	Yes (turbidity, part of NH_3 and organic matters etc.)	No	Yes (NH_3, odor and organic matters etc.)
Byproduct formation	No	No	No
Capital costs	Middle	Middle	Middle-High (blowers and nozzles)
O&M costs	Middle (power consumption for aeration, coagulant and chlorine)	Middle (power consumption for aeration, coagulant and chlorine)	Middle (power consumption for aeration, coagulant and chlorine)
Land requirement	Middle-High (long detation time for coagulation and sedimentation)	Middle (app. 120 m/d)	Small (filtration rate: 240 to 380 m/d)
Required O&M level	Middle (coagulant dosage, sludge discharging of sedimentation tank etc.)	Middle (coagulant dosage and filters' backwash control etc.)	Middle (DO control, coagulant dosage and filters' backwash control etc.)
Environmental issues	No	No	No

Item	Alternative-1: Aeration with Sedimentation	Alternative-2: Contact Oxidation	Alternative-3: High-rate Biological Oxidation
Others	Basically, same as the existing treatment method at Kanzenze WTP, but intermediate chlorination is applied to improve catalysis of manganese sand.	Basically, same as the existing treatment method at Nzove 1 WTP, but intermediate chlorination is applied to improve catalysis of manganese sand.	• Advanced technology • It is recommended when enough land is not available.
JST recommendation	△ (aeration can not be controlled, higher concentration of Mn than that of Kanzenze and more land is required)	△ (aeration can not be controlled and more land is required)	○ (aeration can be controlled, both Fe and Mn can be removed effectively by iron bacteria and less land is required)

Source: JST

Source: JST

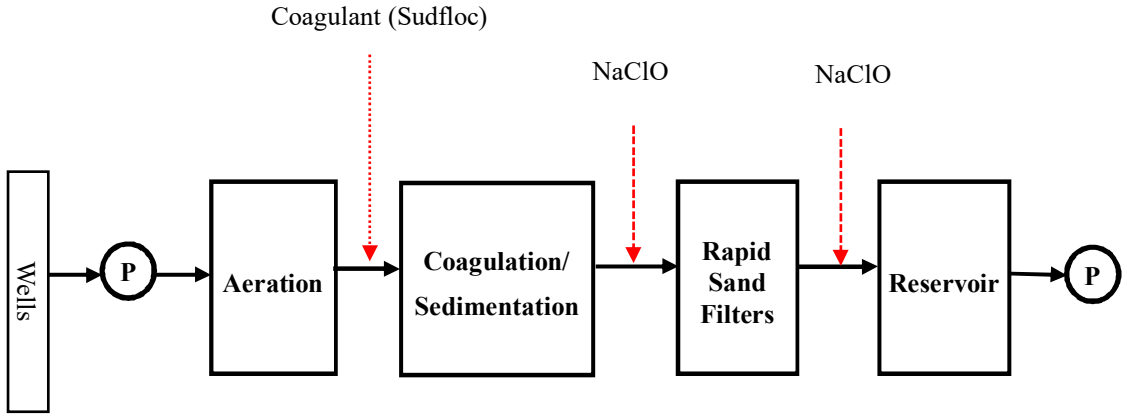
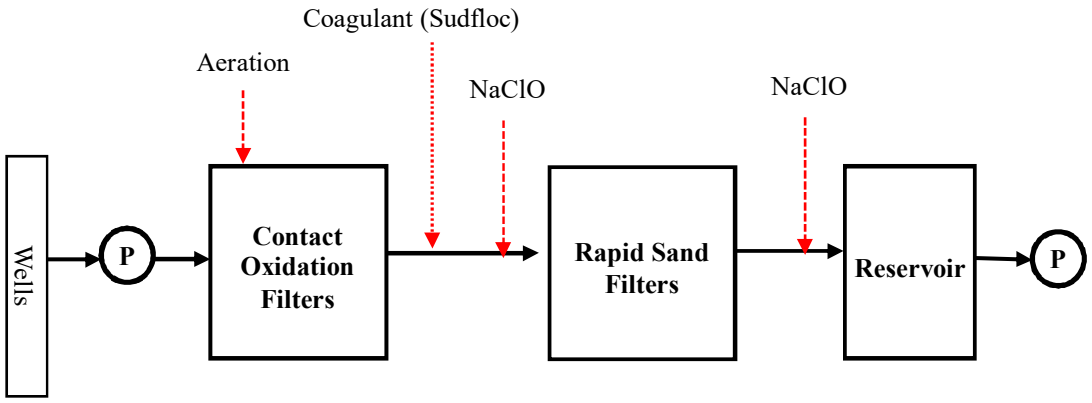
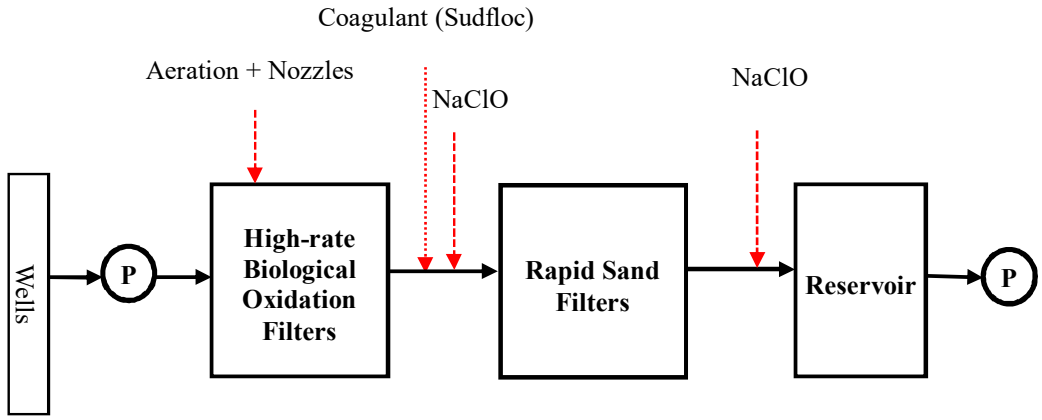


Figure 13.11-5 Treatment Flow Chart of Aeration with Sedimentation



Source: JST

Figure 13.11-6 Treatment Flow Chart of Contact Oxidation



Source: JST

Figure 13.11-7 Treatment Flow Chart of High-rate Biological Oxidation

CHAPTER 14 THE 15-YEAR INVESTMENT PLAN

14.1 OBJECTIVES

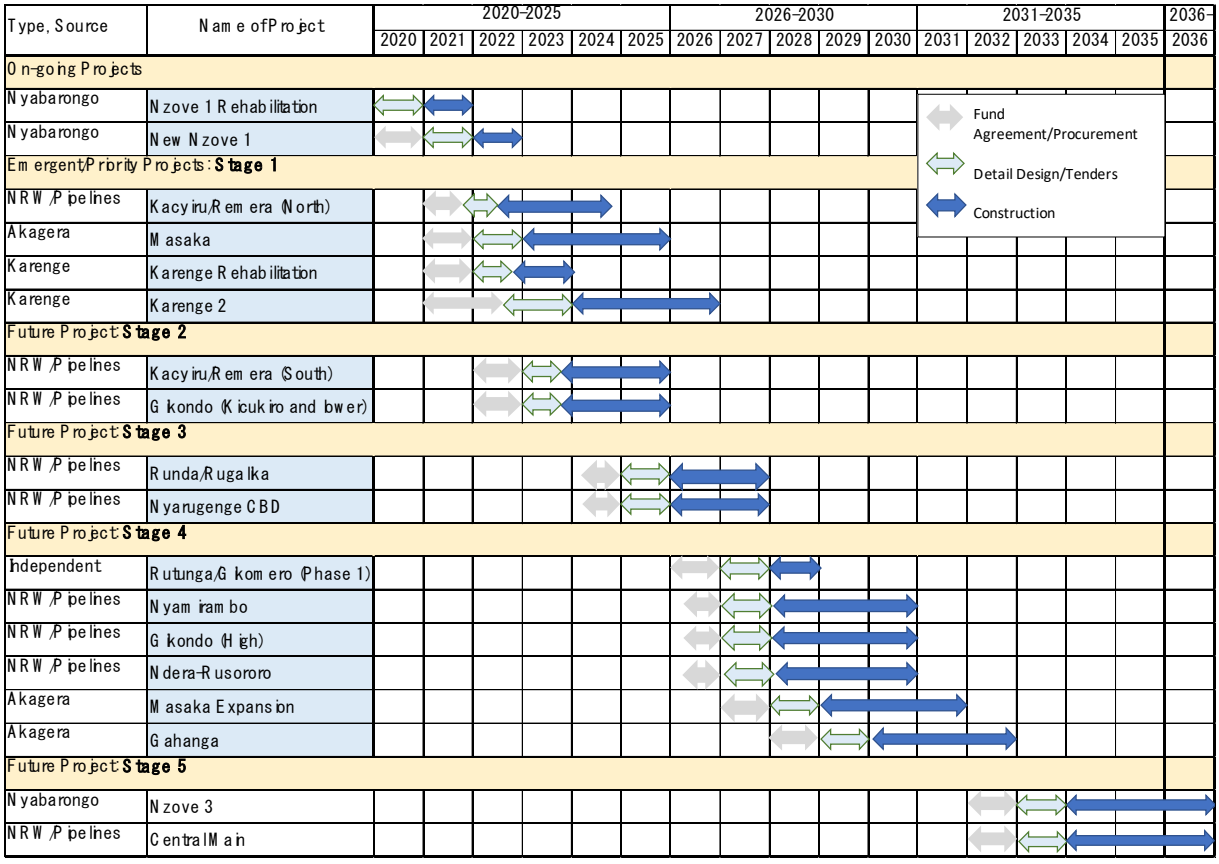
The 15-Year Investment Plan is the investment plan to achieve the master scenario.

14.2 FORMULATION PROCESS

The possible projects for the 15 years investment plan were first listed out in the long list as in attached **Appendix-23** during the IT/R. Then, the urgent and promising projects in the 2035 perspective was short-listed to formulate the 15 years investment plan. The details of the short-listed projects are shown in the **Appendix-24** Project Identification sheet. The projects were sorted out in a priority order and in line with the Master Scenario, to make the 15 Year Investment plan was then submitted in the KWSMP and approved in the JCC.

14.3 15 YEAR INVESTMENT PLAN

The Plan is divided into five (5) stages apart from the On-going projects shown in **Figure 14.3-1**. The stage 5 is aimed at the target after the year 2035 and is not included in the evaluation of 15-Year Investment Plan shown in **Chapter 9**.



Source: JST

Figure 14.3-1 Implementation Schedule for 15-Year Investment Plan

14.4 PROJECTS AND INVESTMENT STAGING

Stage 1 (Procurement from 2021, Completion in 2026): Emergency Project (NRW reduction project phase 1: the Ntora-Remera), the rehabilitation and expansion of the Karenge WTP and the Construction of the Masaka WTP.

(1) NRW/Pipelines (Phase 1) Kacyiru/Remera (North)

The area includes the Gisozi, Kinyinya, and a part of the Remera (the Nyarutarama), which is the supply area of the Ntora-Remera transmission pipeline. The topography is relatively simple, and the system is not very old. The areas can be portrayed as a model for good practices on pressure control and can be disseminated to the other areas.

(2) Masaka New Water Treatment Plant (Phase 1: 20,000 m^3/day, Phase 2: 20,000 m^3/day, Phase 3: 40,000 m^3/day Phase 4: 40,000 m^3/day)

Water demand growth on the eastern side of the city is urgent and large (i.e., Masaka, Ndera, Rusororo). The construction during Phase 1 is aimed at the first phase (Approx. 20,000 m^3/day, to be reviewed during F/S) to meet the emerging demand in this area. Due to the insufficiency of the current supply capacity, residents in this area are facing difficulties to access safe and steady water supply service. It is more efficient to utilize water source at Masaka near the demand area instead of conveying water from other existing WTPs. New transmission pipes and distribution reservoirs and reinforcement of the distribution network are required for the water supply expansion.

a) Well fields and WTP: Construction of new water source and WTP (Phase 1: 20,000 m^3/d, Phase 2: 20,000 m^3/d)
b) Transmission pipelines and reservoirs: Clearwater transmission pipeline to Masaka (L=6 km, ND500 x2) Reservoir, Block distribution reservoirs (3 nos.), Clearwater transmission pipeline and a reservoir in Ndera (L=6km, ND400)
c) Construction of distribution network in Masaka Area

(3) Rehabilitation and Expansion of Karenge WTP and Transmission & Distribution Facilities

- The intake pumps are damaged, overloaded and vulnerable to the flooding risk. The intake pumps are below the flood level of Mugesera Lake and can be affected by water during the rainy season. An old raw water intake pipe (ND300) is damaged and is not working properly.
- The existing WTP in under over-load operation; being forced to operate 15,000 m^3/day while its capacity is only 12,000 m^3/day. Incidental maintenances of pumps and resulting water supply interruption is a serious problem since they are fully operated with no standby.
- Demand in the eastern area is as large as 52,000 m^3/day in 2025, and 89,000m^3/day in 2035 only for Ndera, Rusororo, Masaka and upcountry three sectors. It is necessary to make the most of the already acquired water rights for 48,000 m^3/day as permitted by RWFA.

a) Rehabilitation of intake facility

- Rehabilitation of Raw Water Transmission pipes (ND300)
- Relocation of the pump house and upgrading the capacity of pumps and motors
- Expansion of WTP capacity from 15,000m^3/d to 18,000 m^3/d

(Filtration Basins, Clear Water Reservoirs)

b) Expansion of Karenge WTP and forwarding infrastructures

- Expansion of Intake and WTP for 36,000 m^3/d

(Intake pumps, Treatment facilities, Clearwater reservoirs and pumps

- Construction of New Transmission Pipelines (ND700, L= 33 km)

Stage 2 (Procurement in 2022, Completion in 2025): Investment on the NRW reduction by reconstruction of the distribution systems (construction of distribution reservoirs and pressure/flow monitoring systems and replacement of pipelines) in the prioritized zones (Phase2: the Kacyiru/South, the Runda Rugarika, the Masaka Kanombe).

(1) NRW/Pipelines (Phase 2) Kanombe/Masaka

Reconstruction of the Masaka existing systems through the Karenge 1 system. Major system construction should be done in the Masaka WTP F/S in order that the system design is along with the Masaka New Water Source.

(2) NRW/Pipelines (Phase 2) Runda Rugarika

The area includes existing and newly developing areas in the Runda and the Rugarika sectors. Setting small reservoirs, reconstruction of incapably small diameters and replacement of the supply pipes along with their expansion are the key considerations for the system.

Stage 3 (Procurement in 2024, Completion in 2027): Investment on the NRW reduction mainly by reconstruction of the distribution systems in the prioritized zones (Phase3: the Ndera Rusororo, the Kicukiro).

(1) NRW/Pipelines (Phase 3) Kacyiru/Remera (South)

The area includes the Kacyiru, the Remera, the Kimironko and the Kimihurura. An old and complicated system where the pipelines from the Ntora, the Remera, the Kimihurura, Kicukiro is tangled. The system's reconstruction should focus on hydraulic separation and NRW reduction rather than the new reservoir construction.

As an improvement measures for the energy, re-arrangement of pumps from the Kimisagara WTP should be also included under this rehabilitation project.

(2) NRW/Pipelines (Phase 3) Gikondo

The area includes the distribution systems from the Kicukiro reservoir and the Nyanza reservoir. Hydraulic separation considering the elevation, is the key consideration.

Stage 4 (Procurement from 2026, Completion in 2032): Last phase of NRW reduction project to transform the distribution system to NRW 23%. Two WTP expansions, the Masaka expansion, and the New Gahanga WTP should be developed to meet the additional demand in the east. New WTP development should also be considered to meet the growing demand in the remote. The water demand in the Target year 2035 will be met following development under this stage.

(1) Independent water supply (Rutunga/Gikomero)

Remote sectors (the Rutunga and the Gikomero) need independent Water Supply Schemes (WSS) by this target year. Each capacity is total of the sector estimated from the CoK M/P and needs to be examined according to the actual development in those sectors. The existing supply capacities in those sectors are neglected in this statement because they are rather small when compared to the demands.

Feasibility Study is necessary to compare the water supply from a. Masaka WTP, b. New water sources from the wells and c. Muhazi Lake. It is also necessary to transit and integrate the new system with the district-based water supply operated by the private operator.

(2) NRW/Pipelines (Phase 4) Nyamirambo, Ndera-Rusororo, Nyarugenge CBD

Nyamirambo: The area includes the Kimisagara-Rwezamenyo-Nyakabanda to the Mount-Kigali, where pipes are not capable and possibly suffering from high NRW ratio. This should also include the reconstruction of existing small-scale water sources (the Mburabuturo).

Ndera-Rusororo: Mainly focus on the reconstruction of the FTZ and the FTZII supplying system and strategic construction of main distribution systems through a new road from the Masoro to the Kabuga.

CBD: The CBD and adjacent areas include the Nyarugenge, the Muhima, and the Gitega sectors, where the pipes are aged and tangled. Extensive replacement of water supply pipes (e.g., Galvanized pipes and fittings) along with the PVC distribution mains and distribution sub-mains with small diameters. The Kimisagara: Small reservoirs and pressure control through the block system are necessary to be constructed.

(3) Masaka Expansion (Phase 2: Approx. 20,000 m^3/day)

Expansion of the Masaka Water Treatment Plant (Phase 2: Approx. 20,000 m^3/day) should be considered in line with the development in the vicinity area (Masaka, Nyarugunga, Ndera and Rusororo Sectors). The development under this phase 2 is considered as a simple expansion of the wells, treatment facilities and transmission pump capacity.

(4) Gahanga (Phase 1: 40,000 m^3/day)

Water supply facilities on the left side of the Nyabarongo River. Water source development (groundwater (subsurface water)) accompanied by its related RW transmission pipes and treatment facilities.
New water source and water supply facilities
- Water Well Field
- Water Treatment Plant

Forwarding infrastructures (Transmission and Distribution Pipes)

Stage 5 (Procurement in 2032, Completion in 2036): This stage is to meet further demand after 2035. The Nzove 3 and the Karenge 3 should be developed to meet the growing demand. The Central Main should be constructed to transmit the water from the Nzove to the eastern part of the CoK.

The Stage 5 goes beyond the evaluation period until 2035 while it needs preparation for the demand right after the 2035.

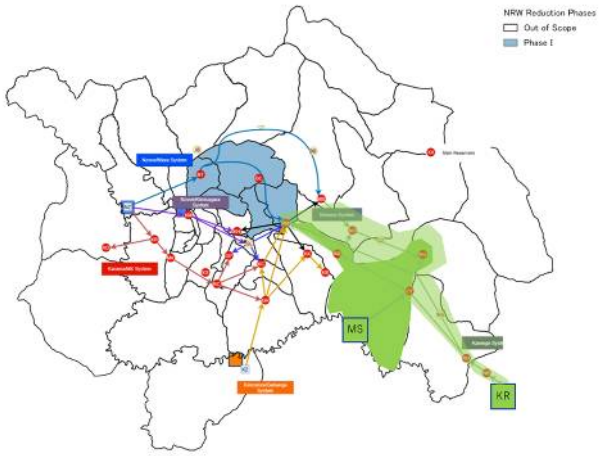
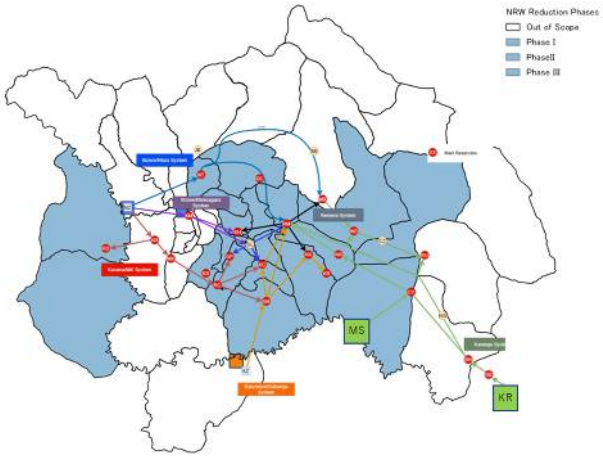
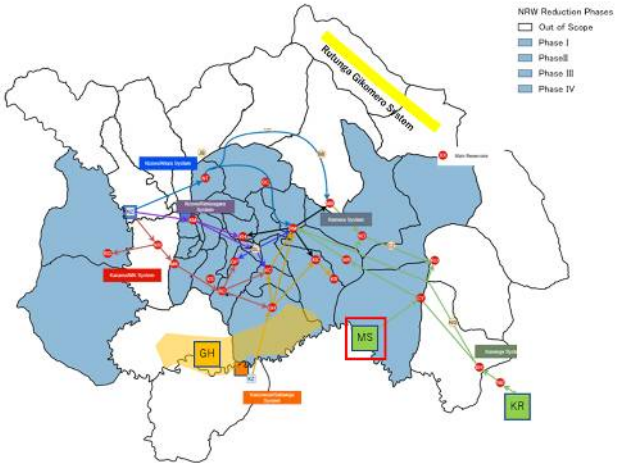
(1) Central Transmission Main

The availability of the potential water source in the middle- and down-stream of the Nyabarongo River is limited. Under this circumstance, transmission from Nzove to the eastern side of the city should be considered. The existing transmission route through Nzove and Mont-Kigali to Remera is inefficient. This is because they are transmitted from the high elevation mountain as well as the route is diverted from the city center and thus is a long way to the eastern area

- Transmission Pipeline (Nzove-Kimisagara-Remera) (18.4 km, ND 800-1,000 mm)
- Transmission Pumping Stations and Pumps (Nzove H=70m, Kimihurura H=125m)
- Distribution Reservoirs (Kimisagara, Kimihurura)

(2) Nzove 3

Expansion of the Nzove Water Treatment Plant (Approx. 40,000 m^3/day as was planned in the F/S of Nzove rehabilitation project) should be considered in line with the development of the Central Transmission Main because of the lack of current water conveyance capacity from the Nzove.

Stage 1 Investment 	Stage 1 (Procurement from 2021, Completion in 2026): Emergency Project (NRW reduction project phase 1: The Ntora-Remera), the rehabilitation and expansion of the Karenge WTP and the Construction of the Masaka WTP.
Stage 2 and 3 Investment 	Stage 2 (Procurement in 2022, Completion in 2025): Investment on the NRW reduction mainly by reconstruction of the distribution systems (Phase2: the Kacyiru/South, the Runda Rugarika, the Masaka Kanombe). Stage 3 (Procurement in 2024, Completion in 2027): Investment on the NRW reduction mainly of the replacement of pipelines in the prioritized zones (Phase3: the Ndera Rusororo, the Kicukiro).
Stage 4 Investment 	Stage 4 (Procurement from 2026, Completion in 2032): Last phase of NRW reduction project to transform the distribution system to NRW 23%. Two WTP expansions, the Masaka expansion, and the New Gahanga WTP should be developed to meet the additional demand in the east. New WTP development should also be considered to meet the growing demand in the remote. The water demand in the Target year 2035 will be met during the development under this stage.

14.5 COST PRINCIPLES

The costs for the projects were estimated under the pre-feasibility accuracy basis, not considering the specific routes or the site specificity of the plants and the pipelines. The cost principles are shown in **Table 14.5-1** and **Table 14.5-2**.

Table 14.5-1 Principles on Cost Estimate as per Facilities

Facilities	Approaches
Water Treatment Plant	The cost was estimated from the past WTP construction project in Rwanda and adjacent countries. The cost for water source development is included in the WTP construction cost since it is deemed to be not significant; large structures such as the dams are not included in the development plan.
Transmission Mains	The cost was estimated from the length of planned routes in the GIS multiplied by the Unit price of the pipelines. The cost includes materials, equipment, labor, construction overhead.
Distribution Mains and Sub-mains	Pipeline length was estimated from the existing pipelines considering the diameter size.
Customer Water Meters	The cost was estimated from the number of new customer connections.
Customer Connections	Length estimated from the actual length per customer connection and proportionally increased as the number of connections.

Source: JST

Table 14.5-2 Principles on Cost Estimate as per the Cost Items

Cost Items	Description
Construction Cost	All price as adjusted for June 2020.
Indirect Cost (Construction Overhead)	Assume 30% of direct construction costs.
Consulting Services	Assumed 10% of the construction cost.
Physical Contingency	Cost included in the estimated cost: Assumed 10% of each construction cost and the consulting service.
Tax and Levies	Not included.
Procurement Administration Cost	5% of the sum of construction cost, consulting services and land acquisition cost.
Land Acquisition Cost	Assumed 50 USD/m^2 multiplied by the estimated land area.

Source: JST

14.6 INVESTMENT PLAN

(1) Capital Expenditure (Capex)

The project costs are shown in **Figure 14.6-1**.

Note that the Capital Maintenance Expenditure (CapManEx) is included in the capital expenditure mainly in the form of the project cost of the NRW reduction project. The minor CapManEx such as the replacement of pumps and motors, pipe repairs, and replacement of pipes with small diameters are included in the Operational Expenditure

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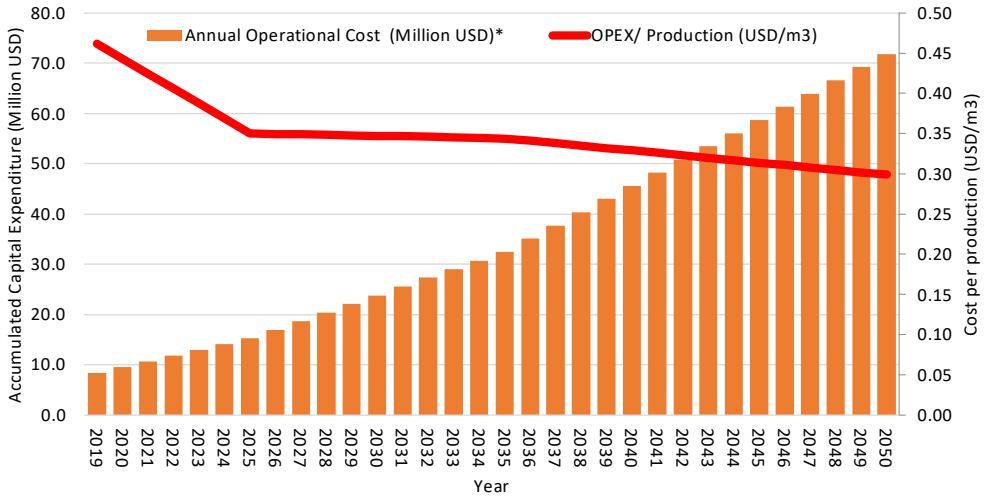
Figure 14.6-1 Accumulated Capital Expenditure for 15-Year Investment Plan

(2) Operational Expenditure (Opex)

The operational cost will significantly decrease along with the NRW reduction up to 2025. The cost is kept low at USD 0.32 /m^3 up to 2035. Further improvement can be materialized on completion of the Central Main after 2035 and can be decreased to low as USD 0.30 / m^3 (**Figure 14.6-2**).

Cost principles: Chemical cost, salaries and maintenance costs are based on the yearly averaged cost of each WTP administrative area (the Nzove, the Kimisagara and the Karenge) of WASAC (WASAC Annual Report 2018/2019). Electricity costs are calculated assuming the pump head which was calculated based on the pipeline routes and elevation differences. The topography is based on the WASAC's GIS data or Google Earth. Electricity tariff is fixed at the current average tariff paid by WASAC (148.68 RWF/kW).

The incremental O&M cost by the 15-Year Investment Plan was estimated for the financial evaluation purpose as shown in **Table 14.6-1**. The O&M costs for the new projects (Karenge, Masaka, Rutunga/Gikomero) are small compared to the total O&M cost because the existing and on-going production covers large part of the production facility. The result is transferred to **Chapter 9** for the evaluation.



Source: JST

Figure 14.6-2 Annual Operational Expenditure towards 2050

Table 14.6-1 Incremental Operational Cost by the Projects Listed in the 15-Year Investment Plan

New Production Facilities	O&M Cost (million RWF)												
	2024	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**Total**
Karenge Rehabilitation	340	340	340	340	340	340	340	340	340	340	340	340	
Karenge 2			3,395	3,395	3,395	3,395	3,395	3,395	3,395	3,395	3,395	3,395	
Masaka		1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240	1,240	
Masaka Expansion							1,240	1,240	1,240	1,240	1,240	1,240	
Rutunga/Gikomero (Phase 1)							373	373	373	373	373	373	
Gahanga										3,182	3,182	3,182	
Total	340	1,580	4,975	4,975	4,975	4,975	6,589	6,589	6,589	9,771	9,771	9,771	70.90

Source:JST

Table 14.6-2 Cost of the 15-Year Investment Plan

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14.7 PRIORITY PROJECT

The shortlist of the projects was drafted in accordance with the determination at JCC held on 13th February 2020, as shown in **Table 14.2-1**.

NRW Reduction for Ntora-Remera Area: Pressure control and pipe renewal and A05 *NRW reduction project through pipe renewal and pressure control* are combined and will be proposed in the Masterplan as an integrated project which should be implemented in a phased manner.

Construction of Masaka WTP and Clear Water Transmission & Distribution Facilities and Rehabilitation *and Expansion of Karenge WTP and Transmission & Distribution Facilities* are selected for the F/S in this study. The capacity and phasing plan should be reviewed in the F/S. *Capacity development for Sustainable Use of Water Resources and Water Supply Facilities* was shortlisted under those projects. *Kigali Central Transmission Main* are shortlisted without the priority since it is regarded as not an urgent project because the expansion at Nzove until 2035 will be limited to on-going projects.

Table 14.7-1 Shortlist and Priority of Development Projects

Priority	ID/ Project Name	Remarks (Possible Financial Sources)
1	**NRW reduction project through pressure control and pipe renewal**	A part of the project will be proposed to Japan's Grant Aid
2	**Construction of Masaka WTP and Clear Water Transmission & Distribution Facilities**	Subject to F/S
3	**Rehabilitation and Expansion of Karenge WTP and Transmission & Distribution Facilities**	Subject to F/S
4	Capacity development for Sustainable Use of Water Resources and Water Supply Facilities	Subject to request for Japanese Grant Aid
-	Kigali Central Transmission Main	WASAC is aware of its necessity. However, due to constraints including budgetary limitation and difficulty in land acquisition, WASAC intends to postpone it in future

Source:JST

CHAPTER 15 ECONOMIC EVALUATION AND FINANCIAL CONSIDERATION ON THE 15-YEAR INVESTMENT PLAN

15.1 ECONOMIC EVALUATION

The economic evaluation is carried out for the projects described in the **Chapter 14** based on the conception presented in **Table 15.1-1**. The objective of economic analysis is to assess a project from an economic viewpoint of a country by applying a cost-benefit analysis. All project components are aggregated in one component for this analysis; accordingly, the consolidated single "Economic Internal Rate of Return (EIRR)" as well as "Benefit-Cost Ratio (B/C ratio)" and "Net Present Value (NPV)" are calculated.

Table 15.1-1 Conception for Economic Evaluation

Standard Items for Evaluation		Conception
1. Project Costs (Capex + Opex)	1) Financial Cost	• The cost is estimated basically at the market price • The details are presented in the previous chapter
	2) Economic Cost	• The above financial cost is converted to economic cost by utilizing the 'Conversion Factor (CF)'. • Finally, the economic cost is applied for economic evaluation. • The land cost is generally disregarded in the economic cost. • See the details presented in the following clause 9.1.1.
2. Benefits		• Beneficiaries "Willingness-to-Pay" • Full capacity operation is assumed after the year of work completion. • See details presented in the following clause 9.1.2.
3. Opportunity Cost of Capital		• Generally, the range between 10% and 12% is used for economic evaluation. • Set at the lower rate of 10% in this analysis by considering the nature of the projects from the point of view of basic human needs. • Referred to the same rate as applied in the "Sustainable Water Supply and Sanitation Program, 2017, AfDB".
4. Evaluation Time Horizon		30 years starting from the 1st operation year for a component that is to be year 2024

Source: JST

15.1.1 Economic Cost

As shown in **Table 15.1-1**, two types of project cost exist, they are, Financial Cost and Economic Cost. Firstly, the former cost is estimated at market price basis. Secondary, the former cost is converted to the latter cost by applying the conversion factor as presented in **Table 15.1-2**. It should be noted that land is regarded in the financial cost but disregarded in the economic cost because it is deemed as an idle asset.

Table 15.1-2 Assumptions for Economic Cost Calculation

Items	Assumptions	Remarks
1.Foreign Exchange Rate	I US$ = RWF 923	National Bank of Rwanda: average of medium rate as at end of month during 6 months from October 2019 up to March 2020.
2 Conversion Factor (CF)	1) Foreign portion cost: 0.8924 2) Local portion cost: 0.884	Guideline of MINECOFIN
3. Economic Life	1) Water Treatment Plant: 45 years	Weighted average years of the below Composition: Facilities 85% — 50 years; Machinery & Equipment 15% — 15 years Life
	2)Pipeline: 40 years	-
4. Replacement cost	50% in every 15 years	Machinery & Equipment
5. Salvage Value	The residue value of capital cost calculated from the above economic life is salvaged at the last year of evaluation time horizon.	

Source: JST

The cost is composed of 1) capital costs (Capex), and 2) operation and maintenance cost (Opex). **Table 15.1-3** presents the economic costs of Capex and Opex that are utilized for economic evaluation of this project.

Table 15.1-3 Capex and Opex converted to Economic Costs (billion RWF)

Costs		WTP	NRW/Pipeline	DSM&PR(1)	Customer water meters	Total
Capex	Economic Cost	99.65	132.78	53.42	16.04	301.89
	(ref) Financial Cost	117.51	157.85	60.03	18.03	353.42
Opex (2)	Economic Cost	62.40	-	-	-	62.40
	(ref) Financial Cost	70.90	-	-	-	70.90

Note: (1) DSM&PR= Distribution Sub-mains and pipes for replacement (2) Opex represents incremental operational cost for the new water production facilities covered by the 15-Year Investment Plan (Karenge rehabilitation and expansion, Masaka, Rutunga/Gikomero and Gahanga)
Source: JST

15.1.2 Benefits

Incremental water-served beneficiaries generated by the project that are represented in monetary basis are regarded as project benefits. To calculate the monetary benefit for the MP, an affordability-to-pay (ATP) is used based on the household income as shown in **Table 15.1-4**.

It is obvious that the benefits are generally computed from the willingness-to-pay (WTP) of beneficiaries as well as the reduction of various costs necessary for getting water, as a substituting way for the cost reduction. The socio-economic survey was conducted in this study to gather this information. However, the number of location and interviewee were limited, which reveals difficulties in acquiring a useful data for the study as is usual with such survey. Accordingly, the JST determined the application of ATP for this study. It is noted for such cases that the “Project Appraisal Manual of International Bank for Reconstruction and Development (IBRD)” mentioned the utilization of ATP as a substituting way for

WTP and cost reduction.

(1) Residential

The project benefits are determined by applying the following methodology.

Benefits	Incremental No. of beneficiaries with Projects (X) ATP of beneficiaries (RWF/beneficiary)

The ATP is estimated based on the parameters as presented in **Table 15.1-4**.

Table 15.1-4 Parameters to estimate Benefits of Residential Beneficiaries

Items	Assumptions	Remarks
1.Household size	4.0 persons: Kigali 4.4 persons: adj. 7 sectors	EICV-5, 2016/17
2.Household income		
1) Kigali Urban	286,000 RWF/month	• Kigali City MP: Av. 262,000 RWF/month in 2018 • To adjust the income with CPI: 9% in two years
2) Kigali Rural	30% of Urban	Assumed based on the Socio-economic Survey conducted by JST
3) Adjacent 7 sectors: urban	70% of Kigali urban	
4) Adjacent 7 sectors: rural	70% of Kigali rural	
3. ATP	4% of household income	Referred to "Project Appraisal Manual, IBRD

Sources: JST

(2) Non-residential & Industrial

The project benefits are determined by applying the following methodology

Benefits	Incremental m^3 of beneficiaries with Projects (X) ATP of beneficiaries

The ATP is estimated at 840 RWF/m^3 based on the following:

- Average of both non-residential tariff and industrial tariff
- Referred to RWF 840 as the vending price to private operators

15.1.3 Results of Economic Evaluation

The economic evaluation is carried out on the basis of the above economic costs and benefits. From the evaluation, the projects are concluded to be economically feasible as the EIRR of the projects exceed 10% of the opportunity cost of capital (see **Table 15.1-1**) as described below. Details are presented in **Appendix-25**.

- EIRR : 12. 0%
- NPV : 23,080 million RWF
- B/C : 1.11

The minimum variation that makes the EIRR to attain over 10% is studied as follows.

✓ Benefits: if decreased by more than 10.0%, the EIRR goes down below 10%.
✓ Capital costs: if increased by more than14.0%, the EIRR goes down below 10%.

< Sensitivity Analysis >

Table 15.1-5 shows the results of the sensitivity analysis on the economic evaluation of the project. The benefits are with a slightly higher sensibility than the capex. On the other hand, the capex variation also has a substantial impact on the EIRR; if costs are reduced by 10%, the EIRR results in 13.8%.

Table 15.1-5 Results of Sensitivity Analysis

Variation Items		Benefits				
		+10%	**+5%**	**Base case**	**-5%**	**-10%**
Capex	-10%	16.1%	15.0%	13.8%	12.7%	11.6%
	-5%	15.0%	13.9%	12.8%	11.8%	10.8%
	Base case	14.0%	13.0%	**12.0%**	11.0%	10.0%
	+5%	13.1%	12.1%	11.2%	10.3%	9.4%
	+10%	12.3%	11. 4%	10.5%	9.7%	8.8%

Sources: JST

15.2 FINANCIAL CONSIDERATION

15.2.1 Financial Evaluation

The objective of the financial evaluation is to assess a project from the financial viewpoint of a private/public firm. The financial evaluation is carried out for the projects described under **Chapter 8** based on the conceptions and assumptions as presented in **Table 15.2-1**. All project components are combined as a one component for this analysis; accordingly, the consolidated single "Financial Internal Rate of Return (FIRR)" as well as "Benefit-Cost Ratio (B/C ratio)" and "Net Present Value (NPV)" are calculated.

Table 15.2-1 Conceptions and Assumptions for Financial Evaluation

Standard Items for Evaluation		Conception and Assumptions
1. Project Costs	Financial Cost	Same as presented in Table 15.1-1
2. Revenues		• Incremental revenues generated by the projects • Served demand with the projects after the year of work completion.
3. Opportunity Cost of Capital		Real interest rate of 6.3% is applied, that is generally calculated: = (long-term interest rate) – (expected inflation.) ✓ Yields of 7-years' Rwandan government bond of 2019 quoted at the Rwanda Stock Exchange in 2020: 11.25% ✓ Inflation rate estimated by IMF: 5%
4. Evaluation Time Horizon		Same as presented in Table 15.1-1
5. Economic Life		Same as presented in Table 15.1-2
6. Replacement cost		
7. Salvage Value		

Source: JST

(1) Financial Costs

The financial costs are estimated and presented in **Table 15.1-3**.

(2) Revenues

The revenues generated by the projects are determined by applying the following methodology.

Revenues	Incremental Consumption with Projects (X) Water tariff (RWF/ m^3)

To obtain the revenues as mentioned above, the following assumptions presented in **Table 15.2-2** are considered.

Table 15.2-2 Assumptions for Revenue Generation

Items	Assumptions
1.Incremental consumption	(Entire served demand projected by JST) – (Net supply volume of existing WTPs)
2.Water tariff	To apply the base rate of case-2 presented in Table 9.2-11: 840 RWF/m^3

Source: JST

(3) Results of Financial Evaluation

The financial evaluation is carried out on the basis of the above project costs and revenues. From this evaluation, the projects are judged to be financially feasible as the FIRR of the projects exceeds 6.3% of the opportunity of capital (see **Table 15.2-1**) as described below. Details are presented in **Appendix-26**.

- FIRR : 6.8%
- NPV : 12,520 million RWF
- B/C : 1.04

< Variation for Breakeven Point of FIRR>

The minimum variation that makes the FIRR to attain over 6.3% is studied as follows.

✓ Revenues: if decreased by more than 4.0%, the FIRR goes down below 6.3%.
✓ Capex: if increased by more than 5.5%, the FIRR goes down below 6.3%

WASAC is a concessionaire to operate and maintenance the facilities owned mostly by the GOR. Considering this, a large part of the project cost except O&M costs are to be paid and owned by the GOR. In this context, the FIRR soars to over 6.3% of the opportunity cost of capital.

15.2.2 Project Cost Funding

15.2.2.1 Overall Project Costs for 15 -Year Investment Plan

Table 15.2-3 illustrates the project costs summarized in the 3 periods and the year average of each period as well. The year average cost reaches RWF 25.27billion during 1st period, RWF 27.17 billion during 2nd period and RWF 17.61billion during 3rd period.

Table 15.2-3 Project costs summarized under 3 periods (billion RWF)

Project Components		1st Period	2nd Period	3rd Period
		2020-2025	2026-2030	2031-2035
Total of the Period	1.WTP	55.11	31.20	31.20
	2.NRW/Pipelines	67.58	73.84	16.43
	3.DSM&PR (1)	17.84	18.62	23.57
	4.Customers Meters	5.35	5.59	7.08
	Sub-total	145.88	129.25	78.28
	O&M	1.92	6.59	9.77
	Total	147.80	135.84	88.05
Year Average of the Period	1.WTP	9.19	6.24	6.24
	2.NRW/Pipelines	11.26	14.77	3.29
	3.DSM&PR (1)	2.97	3.72	4.71
	4.Customers Meters	0.89	1.12	1.42
	Sub-total	24.31	25.85	15.66
	O&M	0.96 (2)	1.32	1.95
	Total	25.27	27.17	17.61

Note: (1) Distribution sub-mains and pipe for replacement, (2) Average of 2 years: 2024 and 2025 only
Source: JST

15.2.2.2 Expected Funding Sources

In principle, the funds for the project cost are expected to be funded from 1) WASAC own funds, 2) the GOR budget including external grants and loan and 3) private sectors' participation.

1) WASAC

WASAC is an autonomous legal body that generally enables the company to expand and run the business with an aggressive strategy. However, WASAC engages in a concessional business operation, and the water tariffs of WASAC are regulated by the GOR. It should be noted that due to the enormous entire project costs, WASAC faces substantial business and financial risks as to whether it could recover the entire projects costs and the likes with the tariffs in future. Meanwhile, it is obviously impossible for WASAC to bear all projects cost when taking into consideration the severe financial conditions.

Table 15.2-4 shows WASAC's Cash Flow (CF) during 4 years. Within the amount of the net CF, WASAC can obviously pay the entire O&M costs and also possibly the customers' meters costs, which have to be reflected into the tariffs afterwards. However, the possibility of payment to the DSM&PR costs largely depends on the revenues generated in the future.

Table 15.2-4 WASAC Cash Flow (million RWF)

Cash-flow Items	FY2016/17	FY 2017/18	FY 2018/19	FY 2019/20	4 years' Average
	Actual	Actual	Actual	Budget (1)	
1. Net income before tax	-4,611	-7,334.	-2,610	-1,247	-
2.Adjustment	11,044	9,148	-538	8,334	-
1) Depreciation & amortization	3,424	3,277	3,353	3,353(2)	-
2) Changes in receivables & payables	7,620	5,871	-3,891	4,981(3)	-
3.Net CF from operation activities (=1-2)	6,433	1,814	-3,148	7,087	3,046

Note: (1) Estimates based on WASAC Budget, (2) Assumed to be the same as previous year depreciation, (3) Average of 5 years from FY 2014/15 to 2018/19 to avoid distortion

Source: JST

2) Government

Table 15.2-5 shows the GOR's development budget allocation. The allocation to WASAC is around 4% during two financial years. The allocated amount includes both WASAC's utility budget and the districts' development budget.

Considering the rapid population growth rate and the necessity of water to sustain basic human needs, the allocation budget needs to be raised to 8% to enable all identified projects to be funded.

Table 15.2-5 Development Budget Allocation (billion RWF)

Government Hierarchy		FY2018/19	FY2019/20	FY2020/21	FY2021/22
Development Budget	The GOR (a)	897.1	1,152.2	n/a	n/a
Allocated to:	The MININFRA: inclusive WASAC water sector below	323.4	402.2		
	(WASAC water sector (b)) (1)	36.4	43.2	72.1	95.5
	% of allocated = (b)/(a)	4.1%	3.7%	-	-

Note: (1) The allocation specified for WASAC water sector involves allocations to both WASAC itself and to the Districts.

Source: Budget Estimates of the MINECOFIN, Annex II-5, Budget by Agency, Program and Sub-program

Incidentally, the development budget cannot be met totally by the GOR's own revenue. An additional amount of around 500 billion RWF to 700 billion RWF is needed to be financed to the GOR's budget under foreign/domestic grants and debts as presented in **Table 15.2-6**. This additional budget covers 60% of the country's budget. Meanwhile, it is remarkable to know that the GOR issues bonds and treasuries for long-term financing and list them under the Rwanda Stock Exchange. They have been issued every year since 2014 and as per the Fitch's credit rating their issued securities stand at B+. The rating is rather low, however it should be noted that the GOR has continuously shown an aggressive domestic funding behavior.

Table 15.2-6 Source of Funds for Development Budget of the GOR (billion RWF)

Sources of Funds		FY 2018/19	FY 2019/20	FY 2020/21	FY 2021/22
Grants	Foreign Government	67.9	76.8	89.9	73.1
	Int'l Organization	165.2	183.0	199.2	199.3
	Sub-total	233.1	259.8	289.1	272.4
Debts	Foreign Loan	153.8	198.3	247.4	294.8
	Domestic: Treasury Bonds and Notes	129.1	220.7	98.6	126.2
	Sub-total	282.9	419.0	346.0	421.0
Total		516.0	678.8	635.1	693.4

Source: Budget Estimates of the MINECOFIN, Annex I

3) Private Sector

Private sector is expected to join as a business partner during the project implementation. As in the case of the Kanzenze, PPP for a WTP is possibly considered under a Built-Operate-Transfer (BOT) method. The possibility of private participation will be researched during the F/S study to determine the feasibility of participation of foreign/domestic public/private companies or those having interest in the relevant field.

4) Conclusion

From the above discussion, the funding sources that are expected and recommended at present are shown in **Table 15.2-7**.

Table 15.2-7 Demarcation of Funding Sources

Project Components	WASAC	GOR	Private Sector
1.WTP	-	✓	✓
2.NRW/Pipelines	-	✓	-
3.DSM&PR	✓	✓	-
4.Customers Meters	✓	-	-
5. O&M	✓	-	-

Source: JST

The capex for the WTPs could be financed solely by the GOR including development partners' funds, or some portion of the WTPs could be funded through participation of private entities. The capex for the NRW/pipelines could be financed solely by the GOR as it neither is financially light for WASAC nor suitable as a business proposition to attract private participation. The capex for the DSM&PR could be funded partially by WASAC if it can afford the same through its own cash flow, else it would have to be financed totally by the GOR. The expenses pertaining to customers' meters and O&M could be totally covered by WASAC within its own operational cash flow.

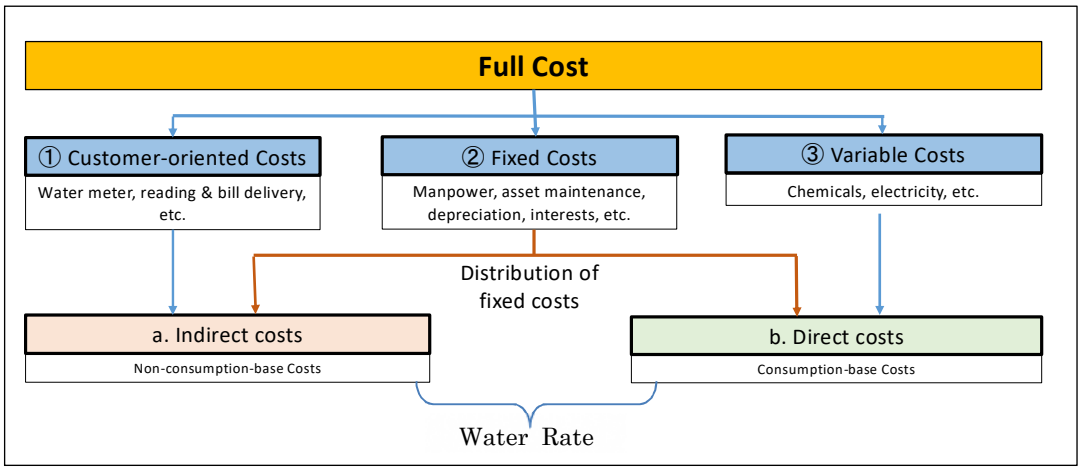
15.2.3 Study on Costing and Rating for Tariff Setting

This chapter studies on a costing and rating model for future tariff setting. The costing contains costs generated by all the branches and the headquarters of WASAC in the country. The rating is projected as

a base rate for tariff setting on the basis of the costing and is billed in terms of m^3. Following two cases are studied in this analysis.

- Case-1 : The GOR pays the Capex and transfers or leases the assets to WASAC
- Case-2 : The GOR pays the Capex and owns the assets, which is a similar form to the present concession

The image of 'Costing and Rating' is illustrated in **Figure 15.2-1** below.



Source: JST based on the Japan Water Works Association

Figure 15.2-1 Image of Costing and Rating

(1) Conception

Table 15.2-8 presents the conceptions and assumptions applied to this study.

Table 15.2-8 Conceptions and Assumptions for the Study

Conception and Assumptions		Remarks
1. Tariff revision		Every 5 years
2. Cost Recovery		That is, to disregard profit margin.
3. Depreciation	Existing assets	The depreciation as of FY 2019/20 is not available at this time. Thus, figures of FY 2018/19 are used.
	On-going projects	WTP: 40 years
	The Projects	WTP: 40 years, Pipeline, etc.: 20 years for rating Note: Disregard the Nzove 3, the Karenge 3 and the Central main pipeline because of their water services in the year of 2037.
4. Additional Capex		No additional Capex is assumed other than this 15-year Plan
5. Recurrent costs		Refer to projection of FY 2019/20 studied under "the Final Costing Model, 2019" of WASAC
		Variable costs such as chemical and electricity are adjusted to lower by 10% considering the difference of projected production between WASAC and the JST.
		In line with the increase (%) of year-wise billed water, physical adjustment by +20% on the said increase is added to 1) salaries/wages for permanent and casual staff, and 2) commercial and administrative expenses
6. Bulk water purchase: the Kanzenze		From the beginning of 2021: supply of 40,000 m^3/day, price of US$ 0.7/m^3
7. Repayment of Loans		To disregard for tariff setting because the depreciation is already considered, and this has to be covered with the generated profit.

Source: JST

(2) Costing

Table 15.2-9 represents the recurrent cost items that are utilized in this study. The overall computed costs based on **Table 15.2-8** are estimated and summarized under 3 periods in **Appendix 27**.

Table 15.2-9 Recurrent Cost Items

Sources of Data/Information	Cost Items
WASAC (1)	1.Chemical products
	2.Electricity cost (VAT exclusive)
	3.Salaries, Wages & Benefits (Casual)
	4.Salaries, Wages & Benefits (Permanent)
	5.Repair & Maintenance Production
	6.Distribution network
	7.Commercial expenses
	8.Administrative Expenses
	9.Depreciation & Amortization Expenses
	10.inance costs
	11.External Water Quality Analysis
	12.Abstraction permit (2frw/m^3)
	13. Repayment of existing loans
JST	1.Kanzanze: Bulk water purchase
	2.Depreciation of existing assets (2)
	3.Depreciation of new assets by the on-going works
	4.Depreciation of new WTP by the Projects
	5.Depreciation of new NRW/Pipelines by the Projects
	6.Depreciation of new DSM&PR by the projects
	7.Depreciation of new assets: water meters
	8.O&M of the Projects

Note: (1) "The Final Costing Model, 2019" of WASAC, (2) FY 2018/19 Financial Statement of WASAC

(3) Billed Water

The following is considered while estimating the county-wide billed water (BW) of WASAC from FY 2020/21 up to FY 2035/36 (**Table 15.2-10**).

Table 15.2-10 Considerations for assuming Billed Water

Year	Billed water generated from	Remarks
Existing	Country-wide of the WSAC	Estimation of FY 2019/2020, to avoid COVID-19 impact, as follows: (BW: from July/2019 to February/2020)+ (BW: March/2020 x 4 months)
	(-) Kigali	Deduct from the above
FY 2020/21 afterwards	(+) On-going projects	The Nzove 1 rehabilitation, and the New Nzove 2
	(+) Bulk water purchase	The Kanzenze
	(+) Kigali under JICA projects	15-Year Investment Plan

Source: JST

(4) Rating for Tariff Setting

Based on the above (2) and (3), the base rates for tariff setting of the first period from year 2020/21 to year 2025/26 was projected as presented in **Table 15.2-11**. WASAC applies a single tariff table equally for the whole country. It is noted that this is a model for WASAC to determine the customer-wise tariff

table at the suitable level by considering the affordability of customers and at the adequate operational profit level of WASAC which is necessary for its business continuity and sustainability.

Table 15.2-11 Results of Study on Rating for Tariff Setting

Cases	Study Items	Unit	2020/21 – 2025/26
-	Billed Water	Ton	294,063
Case-1	Costing	Mil. RWF	266,269
	Base rate for tariff setting	RWF/m^3	910
Case-2	Costing	Mil. RWF	248,125
	Base rate for tariff setting	RWF/m^3	840

Source: JST

The level of the base rate projected above is summarized below.

1. This should be carefully referred to the rate projected by WASAC in 2019 which indicates 736 RWF/m^3.
2. Compared to the above, the base rate for the 1st period, respectively Case-1 910 RWF/$m^3$and Case-2 840 RWF/m^3, is still higher due to the probable head-heavy investment as indicated in **Table 15.2-12**.
3. The case-2, where capex is paid for and the assets owned by the GOR, indicates a lower rate.

Table 15.2-12 Comparison between 15-year Investment Plan and WASAC Projection in 2019

Case	Comparison Items		Projection		Increases	
			15 Years' Plan (1)	WASAC (2)	In figures	By times
-	Billed water	Ton	49,010	35,614	13,397	1.38
Case-1	Costs	million RWF	44,378	26,214	18,164	1.69
	Base rate	RWF/m^3	910	736	174	1.24
Case-2	Costs	million RWF	41,354	s/a	15,140	1.58
	Base rate	RWF/m^3	840	s/a	104	1.14

Note: (1) 6 years' average for the 1st period, (2) 2 years' average for FY 2018/19 and 2019/20

Source: JST

< Recommendation >

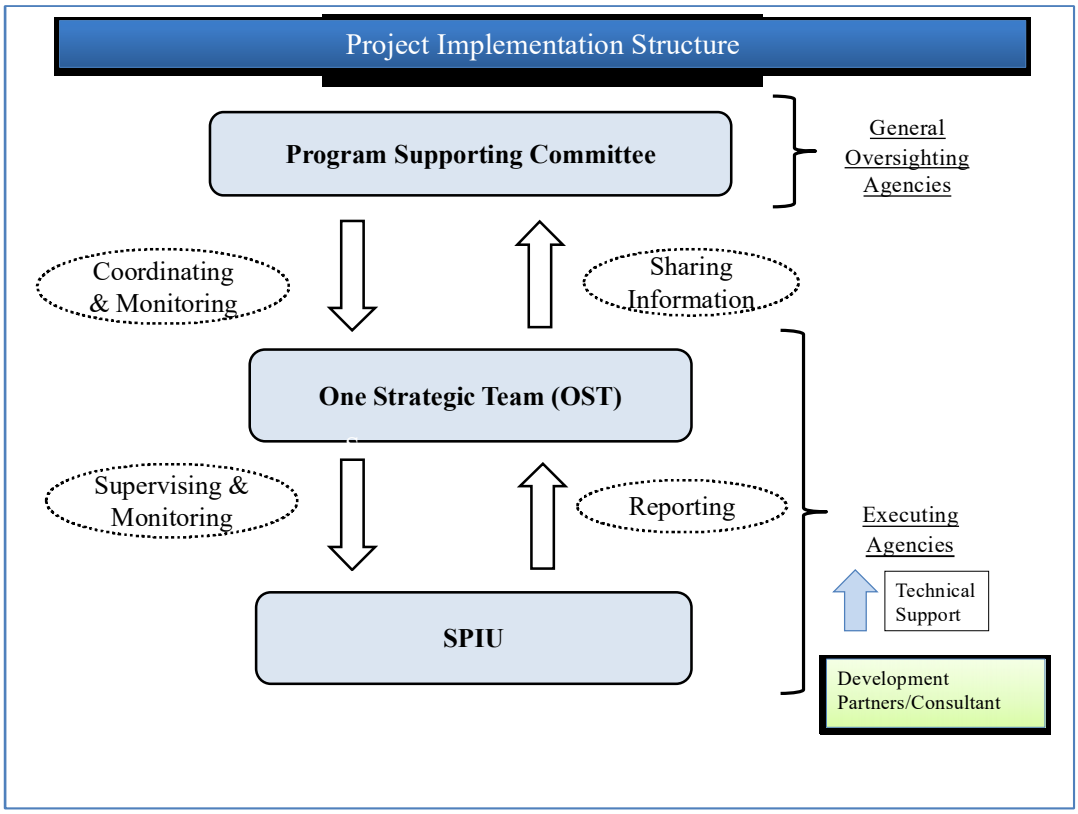
The JST recommends revising the tariff table periodically with an interval of every 3 to 5 years to cope with the increasing number of customers and new facilities and also to maintain a stable operational profit and allocate a fair and equity charge to the satisfaction of its customers.

CHAPTER 16 STRATEGY FOR IMPLEMENTATION

16.1 PROJECT IMPLEMENTATION STRUCTURE

The reliable implementation of the project requires not only the full commitment of all WASAC departments, but also strong cooperation with key government agencies such as ministries and the city of Kigali. Therefore, in addition to the existing department/unit of WASAC, a new Program Supporting Committee and One Strategic Team (OST) will be established.

The overall view of the project implementation system is shown in the **Figure 16.1-1** below.



Source: JST

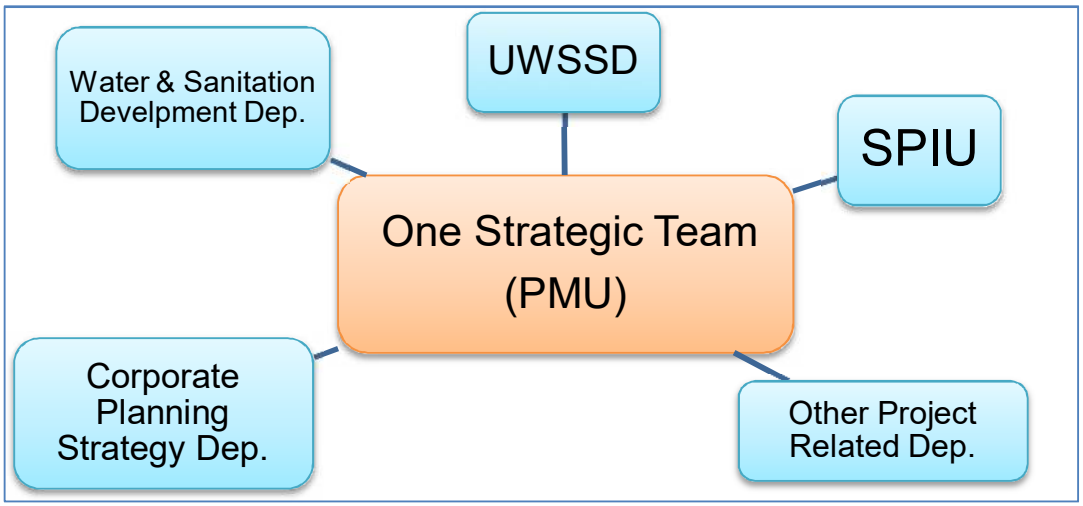
Figure 16.1-1 Project Implementation Structure

- Establish OST that oversees proper project implementation through reports from SPIU.
- Establish Program Supporting Committee consisting of related ministries and agencies and members of the WASAC Control Board. The OST will share the progress of the MP and the committee will assist as needed.
- OST acts as an interface to report the project implementation status to WASAC Managements. In addition, the progress of the entire project will be reported to the Program Supporting Committee quarterly.
- The project implementation entity shall be SPIU.

16.1.1 Establishing One Strategic Team

OST is formulated as a new unit within WASAC. This team works as a unit with a function to identify cross-organizational issues and examine measure to solve issues and develop strategies for commencement/implementation of the long-term investment projects.

This new team unit is composed by CEO, DCEO, UWSSD, Water & Sanitation Development Dept. SPIU, Corporate Planning & Strategy Dept. and other project related Dept as shown in **Figure 16.1-2**.



Source: JST

Figure 16.1-2 Formulation of One Strategic Team

Major roles and member of this OST are stated in the **Table 16.1-1**.

Table 16.1-1 Major Roles and Member of OST

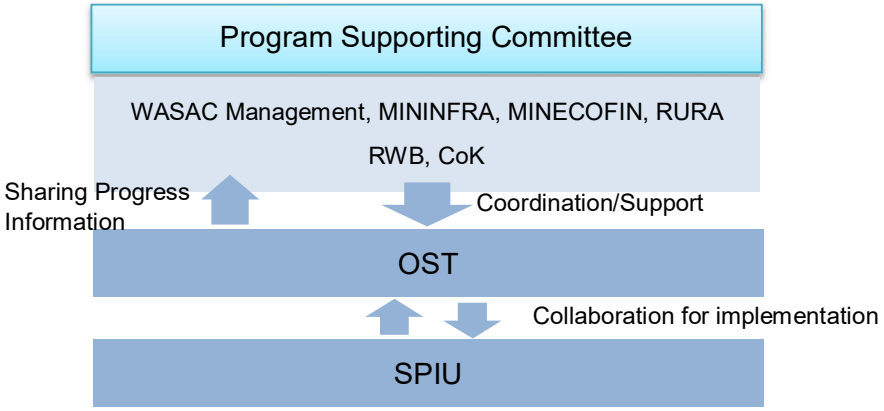
OST member	Role
Program Leader: CEO **Co-Leader:** DCEO **Program Coordinators** • SPIU: 1person • Water & Sanitation Development Dep.: 1person • UWSSD: 1person • Corporate Strategy and Planning Unit: 1person • Representatives of each Dept related to the projects.	• The operation of the entire project will be coordinated by the CEO/DCEO and the implementation status will be reported directly to Program Supporting Committee. • Review and resolve SPIU staffing and implementation requirements for project implementation. • Evaluate the performance of SPIU's Project Manager. Solve problems that go beyond the management and operation authority of SPIU. • Responsible for reporting and negotiating project implementation with government ministries including MININFRA and MINECO FIN. • Develop strategies for commencement/maintenance of the long-term investment projects, including Feasibility Study (F/S) and Detailed Design (D/D) project. • Directors from other dept will be joined based on the project status

Source: JST

16.1.2 Setting up Program Supporting Committee: Coordination with the government ministries and agencies

Coordination with various government ministries such as the MININFRA, the MINECOFIN, the RURA, RWB and the CoK are indispensable for effective implementation of the 15-Year Investment Plan created under the MP.

Therefore, setting up a regular committee consisting of permanent members from WASAC and the related authority including the MININFRA, the MINECOFIN RURA, RWB and the CoK for the MP is important as shown in **Figure 16.1-3**. This committee receives reporting and monitors the progress of the MP.



Source: JST

Figure 16.1-3 Formulation of Program Supporting Committee

Major roles and member of this Program Supporting Committee are stated in the **Table 16.1-2**.

Table 16.1-2 Major Roles and Member of Program Supporting Committee

Committee Member	Role
Committee member from • WASAC CEO/DCEO • MININFRA: 1 person • MINECOFIN: 1person • RURA: 1person • RWB: 1person • CoK: 1person	• Share MP progress with the OST quarterly and the Commission will assist in project implementation as needed. • Coordinate the WASAC project with the large-scale project being implemented / planned in Rwanda. • Share information on project progress or plans with international agencies as needed. • Share water rate development plans, water resource development plans, long-term investment plans at the national level, etc. with OST.

Source: JST

16.1.3 Cooperation with International Development Partners

OST and SPIU will discuss with International Development Partners for implementing an additional technical assistance for capacity development.

16.2 PRIORITIZING ORGANIZATIONAL STRENGTHENING MEASURES

The following organizational strengthening measure should be prioritized among organizational issues for project implementation as is shown in **Figure 16.2-1**. The technical cooperation from Development Partners can be considered for effective implementation of measures.

(1) Forming One Strategic Team

- Forming of one strategic team is necessary to solve cross-functional issues to implement MP as stated in Project Implementation Structure. Moreover, this team also works monitor the activities and achievement of the organizational development throughout WASAC. This team is composed by CEO, DCEO and directors of related department of the following strengthening measures.

(2) Strengthen financial management capabilities

- Preparation of accounting books and financial statements that clarify the division of assets owned by the government and WASAC
- Development of management accounting systems to monitor production costs and financial performance of all related departments

(3) NRW Reduction

- Enhancement of activity to reduce NRW should be continued and enhanced by the improvement of water pressure control and service connection pipes.

(4) Reducing production cost by improving production efficiency

- Improvement of civil/electricity engineering capacity for energy efficiency for water production and operation.
- Development of Standard Operation Procedures (SOP).

(5) Geographic information system (GIS) database construction and utilization

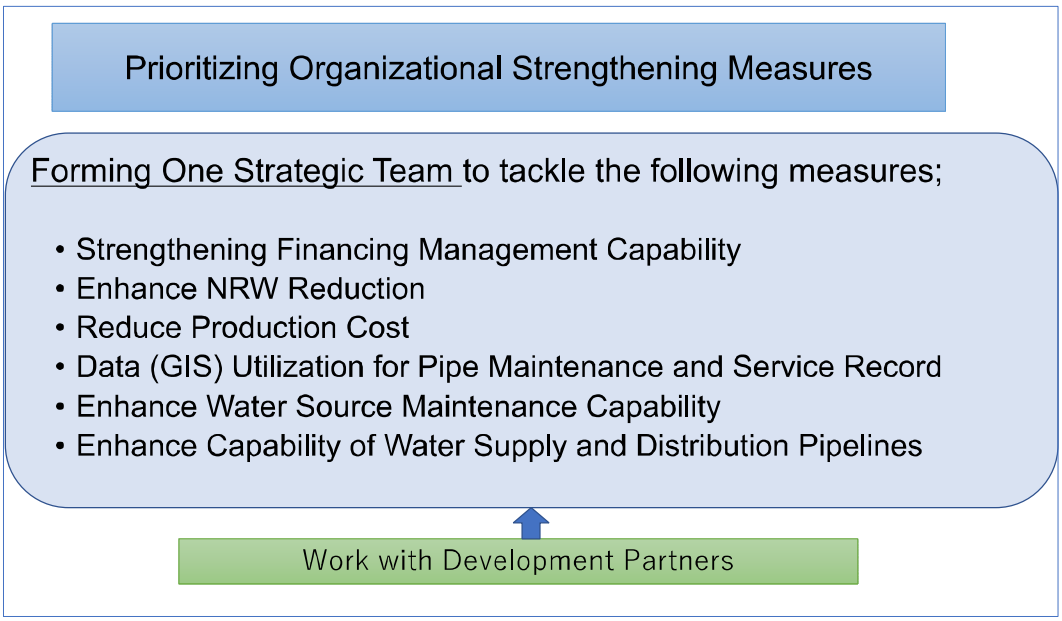
- Creation of GIS database for all areas and utilization of database for maintenance of water distribution pipe network, billing / collection of water charges

(6) Water source maintenance capabilities

- Procurement of equipment for maintenance of water sources and wells and management of groundwater resources
- Development of standard manual for the monitoring and management of wells and surface water resources

(7) The maintenance capability of water supply and distribution pipelines

- Creation of standard work procedure manuals for pipeline maintenance work
- Creation of quality standards for equipment and materials required for pipeline maintenance



Source: JST

Figure 16.2-1 Prioritizing Organizational Strengthening Measures

16.3 FINANCIAL SUPPORT FOR LOW-INCOME CUSTOMERS BY THE GOVERNMENT/COK

For increasing the connection rate to future water supply services, it is essential to promote connection to low-income groups. At present, there is no financial support, such as subsidy system, for low-income people to obtain a stable water supply.

- Establish a support loan / subsidy system for low-income people. The subsidy for water bill payment will be dispatched by the government/CoK.

16.4 DEVELOPMENT PARTNERS

In order to realize all projects itemized in the 15-Year Investment Plan toward 2035 as well as the ones toward 2050, huge investment is inevitable. However, it cannot be covered by single finance source. Therefore, it is important to consider how to draw interest of the potential development partners for their investment on the potential projects (e.g., what is the best mix in terms of type/scale of the projects; whether to go for loan or grant). **Table 16.4-1** outlines major development partners that are presently active in Rwanda.

Table 16.4-1 Major Development Partners in Rwanda

Dev. Partners	Activities in Rwanda in Brief
JICA	Outline of development cooperation to Rwanda[1]: • Purpose of development cooperation for Rwanda: Consolidation of peace in this region and reduction of poverty in this country

[1] Japan's Country Development Cooperation Policy for Rwanda (https://www.rw.emb-japan.go.jp/files/000293362.pdf)

Dev. Partners	Activities in Rwanda in Brief
	• Basic policy of Japanese ODA to Rwanda: Promotion of sustainable growth, poverty reduction and job creation • Priority areas for ODA: ➢ Economic Infrastructure Development (Transportation, Trade Facilitation and Energy) ➢ Agricultural Development (Promotion of Market Oriented and Value Added Agriculture) ➢ Social Service Improvement (Sustainable Safe Water Supply and Sanitation Service) ➢ Human Resources Development for Sustainable Growth and Job Creation (Science and Technology Education and Training) Major recent projects/programs on water/sanitation in Rwanda[2]: • The Project for Water Supply Master Plan for CoK • Project for Rural Water Supply (Phase 3) • Project for Strengthening Operation and Maintenance of Rural Water Supply Systems in Rwanda • Project for Strengthening Non-revenue Water Control in Kigali City Water Network • Grant Assistance for Grassroots Human Security Project in Water and Sanitation Sector • JOCVs in the Water and Sanitation sector • Issue-based Training in the Water and Sanitation sector
AfDB	• Sustainable Water Supply and Sanitation Program – Additional Financing • Sustainable Water Supply and Sanitation Program • The Kigali Bulk Water Supply Project • National Water Supply and Sanitation Masterplans
USAID4F	It supports an integrated program that improves the sustainable management of water in Rwanda. The program builds local capacity to monitor and manage water resources and helps develop water and sanitation services to the public, with a focus on the rural poor.
WB	Since 1970, the World Bank (WB) has been operating 145 projects for a total equivalent amount of USD 4,940.40 million. Amongst them, four projects were related to the water supply sector and all these projects were closed / completed as on Jun 2019.
UNICEF	• Since 1986, it has supported the realization of the rights of every child, especially the most disadvantaged. Guided by the SDG principle 'leaving no one behind', • The UNICEF's country program for Rwanda has seven main components, namely, (i) Child Health, (ii) Nutrition, (iii) Early Childhood Development, (iv) Education, (v) Child Protection, (vi) Water, Sanitation and Hygiene (WASH), and (vii) Social Policy.
DFID	• Rwanda Growth and Poverty Reduction Grant (GPRG) • General Budget Support to the Rwanda-Second Three Year Phase
KfW	• Water Supply for 8 rural Communities / Kigali, Phase I & II • Water Supply for Bugesera South
Dutch Government' Aid	• The SusWAS Project: PPP-based project that is jointly invested by the Dutch Government and private sectors, focusing on NRW issues on some branches in the CoK. It is carried out by the Vitens Evides International from the Netherlands. • The SCALE Project: Scaling universal access to safe and climate-resilient water services in Rwanda, with a focus on small towns, which is an on-going project as of 2020 based on the partnership agreement amongst WASAC (with finance from the AfDB), the Vitens Evides International and the WaterAid.

Source: JST

To attain the plan towards 2035 and 2050, the GOR is recommended to get financing from the development partners in case of any difficulty for securing the same within the governmental budget.

- Primarily, the ordinary lines for long-term loans with preferential interest rates and the following financing schemes are also possible for the water sector, provided they meet the eligibility requirements.
- Loans through Green Bond Program of the World Bank
- Loans with the Climate Investment Funds (CIF) through the AfDB

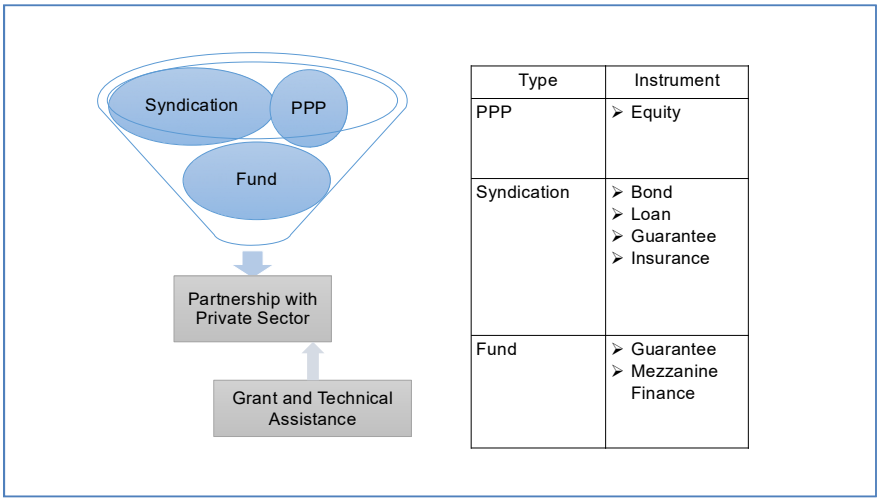
[2] Rolling Plan for the Republic of Rwanda (https://www.rw.emb-japan.go.jp/files/000293363.pdf)

- Loans with the Emerging Africa Infrastructure Fund (EAIF) which had financed the Kigali Water Limited, the special purpose vehicle for the Kanzenze Project.

16.5 PRIVATE INVESTMENT IN WATER SECTOR

16.5.1 Need for Investment Promotion by Private Funds in the Water Sector

The government's budget (or debt) will be enormous if the government tries to cover all the investment necessary to expand the water business, including water source development with public funds. Therefore, it is essential to have dependable funding also from the private partner (**Figure 16.5-1**).



Type	Instrument
PPP	➢ Equity
Syndication	➢ Bond ➢ Loan ➢ Guarantee ➢ Insurance
Fund	➢ Guarantee ➢ Mezzanine Finance

Source: JST

Figure 16.5-1 Partnership with Private Sector

➢ **Return & Benefit**

- Utilities collect tariffs and other payments (e.g., connection fees) from customers. Tariffs can, but in practice often do not fully cover operational and maintenance costs and rarely cover capital expenditure. Improvements in operational efficiency can create more cash flow to invest in service expansion and increase the customer base and revenues.
- Improved access to water and sanitation services produces a range of valuable benefits for individuals, communities and the environment, including a reduction in adverse health outcomes, increased educational attainment (especially for girls) and enhanced labor productivity.

➢ **Risk**

- Currency risk (due to mismatch revenue and debt servicing currency), operating risk (weak performance of utilities), credit risk (inability of counterparty to honor contractual arrangements).
- Due to the long-lived and capital- intensive nature of water and sanitation infrastructure as well as under-investment in maintenance, performance risks may arise due to aging infrastructure, leakage and obsolescence of technologies. As water distribution infrastructure is underground and services can continue despite high levels of leakage, such degradation can go undetected for years, as

rehabilitation and maintenance needs climb significantly.

16.5.1.1 Public Private Partnership (PPP)

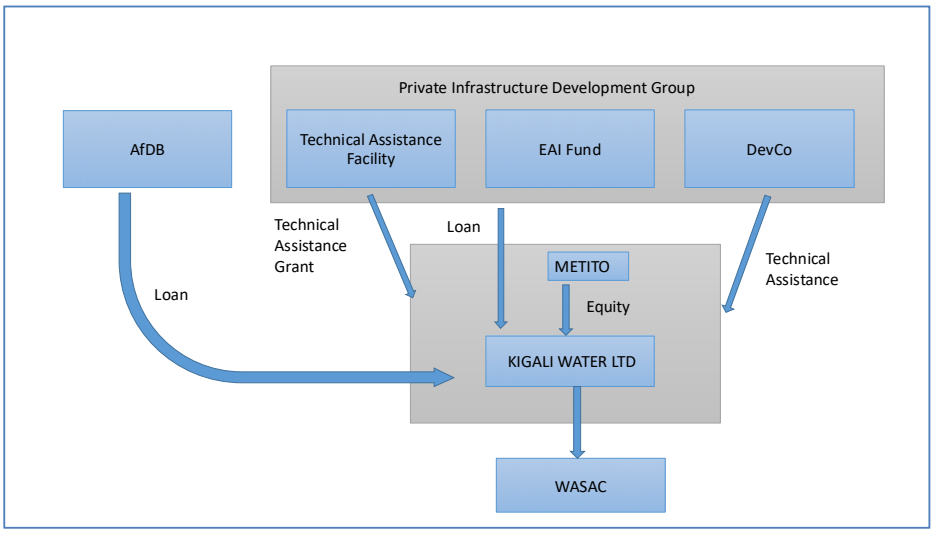
Entry into the water supply business by PPPs (Public-Private Partnerships) and successful water PPPs are usually designed around a mix of funding sources.

In addition to funding, efficient business operation can be expected by introducing technical equipment and products that are competitive in the market by private businesses. PPPs have proved to be an important tool in the sustainability of systems, strengthen financial viability, and boost quality of service in an otherwise monopolistic water and sanitation sector.

- **The Kigali Bulk Water Supply Project**

  The Kigali Bulk Water Supply Project is a Public-Private Partnership Project amongst WASAC, the Metito (a private company) and the IFC. The project aims at construction and operation of new water sources and water treatment plant at the Kanzenze. It is a Build-Operate-Transfer (BOT) project with a contract between WASAC and the Metito and (initially) is coordinated and funded by the IFC. The construction for the project started in November 2017 and is on-going as of 2020. The operation period is 25 years, and the assets are set out to be transferred to WASAC after the completion of the operation period by the operator. Financing Structure is depicted in **Figure 16.5-2**.

- DevCo, a facility managed by the IFC and funded by PIDG, provided initial financial support and technical assistance to the government of Rwanda to cover the legal, financial, technical and environmental feasibility assessments of the project.
- The Emerging Africa Infrastructure Fund (EAIF) provided USD 19 million as senior debt and USD 2.6 million as junior debt. The EAIF also crowded in the African Development Bank funds amounting to USD 19 million as junior debt.
- PIDG's Technical Assistance Facility provided a USD 6.25 million grant to cover upfront capital costs and avoided an increase in water tariffs as a result of the project.



Source: JST

Figure 16.5-2 Kigali Bulk Water Financing Structure

Lessons learned from the Kigali Bulk Water Supply Project are summarized as follows;

- The project initially had included the transmission and distribution facilities, but the component was transferred to other AfDB funded projects. The arrangement was agreed because "greater efficiency could be achieved by allocating (it) to be WASAC". The project cost by PPP was reduced from 79 MUSD to 61 MUSD by this arrangement.
- Currency negotiations led to significant delays. Currency risk was not only the cost-raising factor but also a delay factor for this scheme.
- Tariff of PPP contract (Approx. 680 RWF/m^3) is much higher than the current production cost (271-482 RWF/m^3, Kimisagara and Karenge in the year 2018). WASAC's average tariff to the customer (736 RWF/m^3, 2019/2020 budget) barely covers the tariff of PPP. Electricity costs and tariffs are the major risks in raising the cost since it is borne by WASAC as agreed in the contract.

16.5.1.2 Social Bond

There is potential to mobilize commercial investors through bond investment.
Social Bonds are any type of bond instrument where the proceeds will be exclusively applied to finance or refinance in part or in full new and/or existing eligible Social Projects.

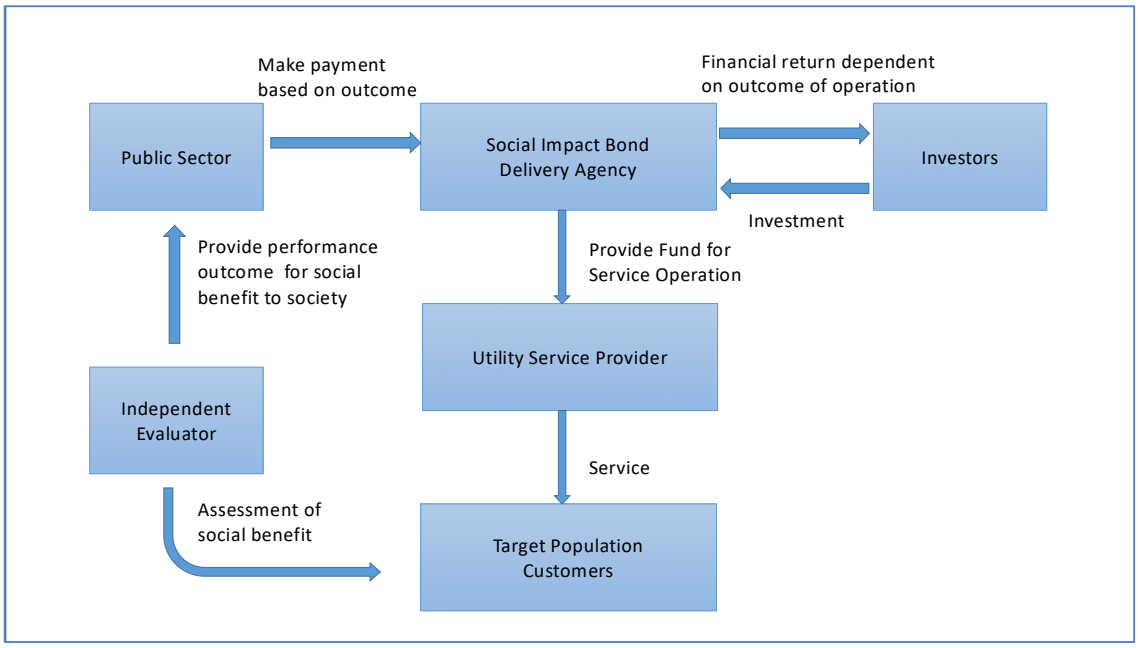
➢ **Sustainability Awareness Bond (SAB)**

The EIB recently launched its Sustainability Awareness Bond (SAB), which it announced in April 2018. The new bond product aims at supporting the global goals by contributing to the development of a sustainable financial system through the financing of water and wastewater projects.

➢ **Social Impact Bond (SIB)**

SIB is a scheme that combines performance-based payment by the government and business operators and utilization of private funds and is one of the methods of performance-based outsourcing contracts together with performance-based payment (**Figure 16.5-3**).

Outsources administrative services to private NPOs and companies, conducts business based on the funds from private fund providers, and the government pays fund providers only when the project achieves the results agreed in advance.

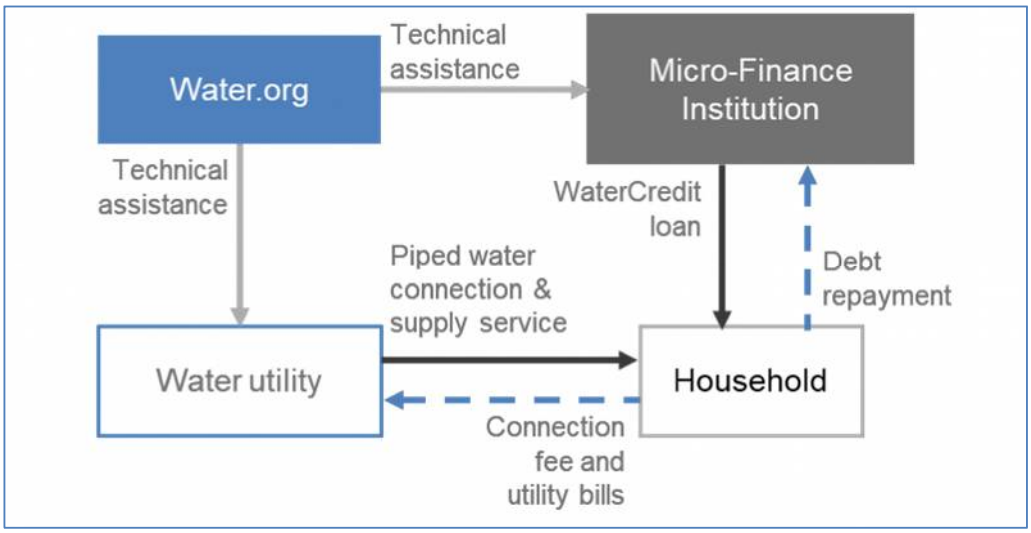


Source: JST

Figure 16.5-3 Social Impact Bond Structure

16.5.1.3 Microfinance Loan with Technical Assistance

Non-governmental organizations (NGOs) may use donations to blend technical assistance and grants with commercial financing to increase access to water and sanitation. Water.org, through the provision of technical assistance and small grants to microfinance institutions (MFIs) fosters the creation of new loan products Water Credit Loan suited to the needs of water and sanitation projects and low-income households (**Figure 16.5-4**).



Source: OECD

Figure 16.5-4 Water Credit Loan Financing Structure

16.5.1.4 Guarantee

The use of guarantees is particularly effective in mobilizing commercial finance across sectors through the mitigation of financial risk resulting in lower cost of capital.

16.5.2 Possibility of Application to the Projects listed in 15-Year Investment Plan

Table 16.5-1 shows the possible financial sources for the projects listed in the 15-Year Investment Plan. From the knowledge hitherto, the application of PPPs is limited to the bulk water supply project as the existing Kigali Bulk Water Supply. However, WASAC is open for any proposal of the partnerships with the private sectors to challenge other forms which will be found effective and feasible.

Table 16.5-1 Possible Financial sources of the Projects listed in 15-Year Investment Plan

Type, Source	Name of Project	Possible Financial Sources			
On-going Projects		GoR	Grant	Loan	PPP
Nyabarongo	Nzove 1 Rehabilitation	✓			
Nyabarongo	New Nzove 1	✓			
Emergent/Priority Projects: Stage 1					
NRW/Pipelines	Kacyiru/Remera (North)	✓	✓		
Akagera	Masaka	✓	✓ *	✓	Bulk Supply
Karenge	Karenge Rehabilitation	✓	✓		
Karenge	Karenge 2	✓		✓	
Future Project: Stage 2					
NRW/Pipelines	Kanombe/Masaka	✓	✓	✓	

Type, Source	Name of Project	Possible Financial Sources			
NRW/Pipelines	Runda/Rugarika	✓	✓	✓	
Future Project: Stage 3					
NRW/Pipelines	Kacyiru/Remera (South)	✓	✓	✓	
NRW/Pipelines	Gikondo	✓	✓	✓	
Future Project: Stage 4					
Independent	Rutunga/Gikomero (Phase 1)	✓	✓	✓	
NRW/Pipelines	Nyamirambo	✓	✓	✓	
NRW/Pipelines	Ndera-Rusororo	✓	✓	✓	
NRW/Pipelines	Nyarugenge CBD	✓	✓	✓	
Akagera	Masaka Expansion	✓		✓	Bulk Supply
Akagera	Gahanga	✓		✓	Bulk Supply
Future Project: Stage 5					
Nyabarongo	Nzove 3	✓	✓	✓	
NRW/Pipelines	Central Main	✓	✓	✓	

Source: JST

16.6 DEVELOPING LOCAL PRIVATE SECTORS FOR BETTER CONSTRUCTION AND PROCUREMENT

WASAC needs to increase the number of staff dramatically in the future if all the tasks are executed by itself since water supply system will expand to meet future water demand. It is recommended for WASAC to consider outsourcing of some works in addition to improvement of efficiency of the organization. Considering unavailability of reliable private sectors to outsource some of the works at present, it is required for WASAC to develop local private sector for several works. Required system for outsourcing shall also be created.

16.6.1 Service Connection

Among several works, it is especially recommended to develop private sectors for service connection as the number of connections are planned to increase dramatically in the future. Service connection is outsourced in several countries. Considering WASAC's past experience of failure in usage of private sectors for service connection, it is recommended to develop capable private sectors and to introduce a registration system of reliable contractors.

16.6.1.1 Designated Contractor System

In order to avoid outsourcing works to unreliable private sector, it is recommended to introduce a system of designated contractor for service connection.

For realizing the designated contractor system, authorized plumber system will be required to be introduced at first.

a. Authorized Plumber:

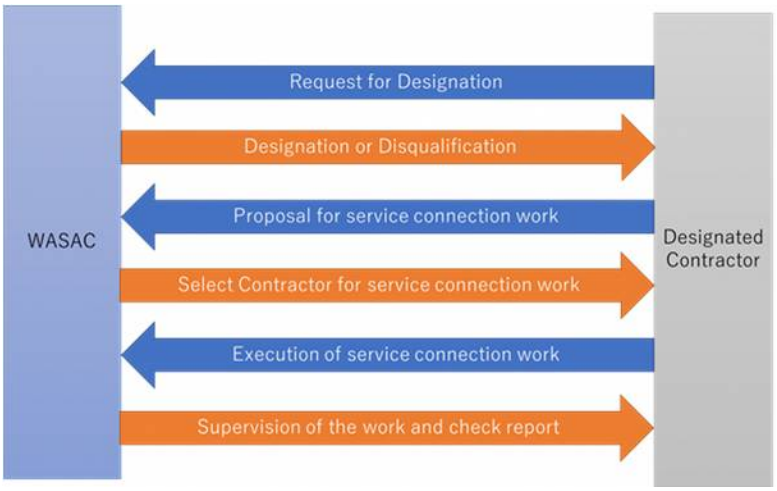
Authorized Plumber shall be responsible for the service connection work including materials used and also recording their work. There are several requirements for "authorized plumber", such as certain experience levels, finishing training, passing test to be provided and registration. Registration system for authorized plumber shall be decided through a detailed study.

Recommended license scheme of designated contractors for service connection is summarized below while details shall be carefully studied before introduction of the system.

b. Recommended License Scheme of designated contractors for service connection works

- Only designated contractors can work for service connection.
- Basic Requirement
  - Registration of Authorized Plumber to supervise or take responsibility of connection work and sign the record of connection
  - Possession and usage of proper equipment such as pipe cutter, file, threading, pipe wrench, spanner, dewatering pump, and water pressure testing equipment
- The license will be disqualified when required and shall be renewed periodically.

Capable and reliable private sector shall be registered as designated contractors when the system is established. The designated contractors shall be responsible for the material and installation of service connection under supervision and control of WASAC. When service connection is outsourced to private sector, it will be easier to control leakage reduction by avoiding poor quality of material and installation. Relationship between WASAC and the Designated Contractors are summarized in **Figure 16.6-1**.



Source: JST

Figure 16.6-1 Relation between WASAC and the Designated Contractors

16.6.1.2 Initial Steps for developing Private Sector

Actions required to be undertaken by WASAC before and after introduction of the designated contractor system are listed below.

a. Until introduction of the designated contractor system, WASAC needs to
- Decide criteria/standard of materials and installation of house connection. It is required to prevent customers to procure inexpensive and low-quality pipes and thereby improve installation
- Select/list up suppliers for quality material
- Prepare water ledger sheets for service connection with GIS incorporation
- Provide trainings to plumbers and certify qualified plumbers

In order to develop reliable private sector, it is required to increase the number of skilled plumbers who can become qualified plumbers. It is recommended for WASAC to provide education, seminar and on-site training to increase the number of skilled plumbers. Continuous follow-up training to the qualified plumbers will also be required. Utilizing international contractors for expansion works shall also be considered for rendering the requisite trainings.

Required actions for WASAC to undertake after introduction of designated contractor system are listed below.

b. When designated contractor system is introduced, WASAC needs to
- Register designated contractors for service connection
- Disqualify the contractors if the quality of material and installation is poor
- Monitor and control the work of the contractors through direct supervision and usage records

Knowledge required to be acquired by WASAC to execute new tasks are listed below

c. WASAC shall be required to acquire
- Basic knowledge for reviewing standards for service connection materials
- Basic knowledge for designing and reviewing plumbers' qualification system
- Knowledge for registration and disqualification of designated contractors

16.6.2 Other Services to be Outsourced

It will be expected to outsource other services, such as meter reading and maintenance of float valves, pipe repair and replacement, customer relation (call center) and maintenance of equipment.

16.6.2.1 Meter Reading

If installation of smart meters is not enhanced, outsourcing of meter reading will be required, considering the dramatic increase of house connections. In this case training and education on meter

reading will be required to be given by WASAC while development of local private sectors will be much simple compared with the case of service connections. Once installation of smart meters is enhanced meter reading system will be changed and outsourcing of meter reading will not be required.

16.6.2.2 Maintenance of Float Valves

Since construction of numerous distribution reservoirs equipped with float valves are planned, number of float valves will be dramatically increased through development of the distribution block system in the future. The float valves are prone to malfunction due to continuous fluctuation of water level. Therefore, periodical checking and repair or replacement of float valves is required to avoid overflow from the reservoirs. When maintenance is outsourced to reliable contractors along with the responsibility of water loss due to malfunction of float valves, NRW due to overflow will be reduced with a limited number of WASAC staff. It will be possible to select private sectors for the maintenance without introducing special system. Contract for outsourcing the maintenance of float valves shall be carefully managed considering termination if required but it is not necessary for WASAC to provide education and training.

16.6.2.3 Pipe Repair and Replacement

The local private companies for pipe repair and replacement will be nominated based on the experience of the company and its personnel in addition to its financial reliability. These contractors will be selected through tendering for a bulk contract bundling several amounts of the work through the year. These contracts will improve the capacity of those local company to do the quality works through the supervision and instruction by the WASAC NRW team, partly backed up by the developing partners.

16.6.2.4 Customer Relation (Call Center)

There are several examples for outsourcing of customer relations in other countries, especially call center functions whenever any water supply system is being expanded. Rules and regulation for outsourcing will be required to be prepared.

16.6.2.5 Maintenance of Equipment

Maintenance of electrical and mechanical equipment will be outsourced to supplier or other specialized companies. In addition, several maintenance works such as removal of soil from sedimentation tanks can be outsourced whenever it is required. These contractors may be selected through tendering or by direct appointment, whichever is adequate.

16.7 DISTRICT OWNED FACILITIES AND PRIVATE OPERATORS

As regulator, the RURA (Rwanda Utilities Regulatory Authority) has the following criteria for giving licenses to the service provider. By acquiring a certain scale of operation, the operator can serve as a stable and quality water supplier.

- Running dedicated laboratory and hiring laboratory staff to ensure quality of the water,
- Having several water sources to ensure stability of supply.

However, apart from the RURA's intent, countless unauthorized water suppliers occupy the market. At present, following 3 major companies are licensed authorized service providers. But they cannot cover the entire region. Therefore, regional water supply business run by the authorized water supplier has many gaps which are duly being filled up by countless unqualified water suppliers.

- WASAC (Urban)
- Regie Associatives Des Usagers Des Points D'eau Gasabo Ltd. (Rural)
- Paak Kam (Rural)

So far, the qualified water suppliers' capacity for supplying water is not enough to fulfil the demand of the region. Therefore, if there are no problems with water quality, no proactive reasons are envisaged to withdraw the unauthorized water suppliers. However, increase of the water supply capacity of WASAC through implementation of the 15-Year Investment Plan shall surely cause an impact on the other water supply operators. To avoid unnecessary conflict between the other water supply operators, WASAC should ensure implementation of the 15-Year Investment Plan in a timely manner.

16.8 KEY PERFORMANCE INDICATORS

The strategy for water supply facilities shall be monitored and enhanced by targets and key performance indicators (KPIs). Proposed KPIs are as presented in **Table 16.8-1**. The KPIs and the target value should be finalized with the One Strategic Team and the Program Committee.

Table 16.8-1 Proposed targets and key performance indicators

KPI	Target in 2050	Target in 2035	Present status	Data Source
Operating Ratio	TBD	TBD	TBD	WASAC Annual report
Electricity Consumption per m3 water produced (kWh/m^3)	TBD	TBD	TBD	WASAC UWSSD
Water supply capacity (Daily average, m^3/day)	TBD	TBD	TBD	WASAC Annual report
Length of Pipeline Rehabilitated	TBD	TBD	TBD	WASAC Annual report (New Indicator)
Average Supply Hours	24 hours	16 hours	8 hours	WASAC Annual report
Percentage of Households with Severe Water Shortages*	0%	0%	TBD	UWSSD GIS Section (New Indicator)
Non-Revenue Water (%)	20%	23%	38.8 (2018)	WASAC Annual report
Number of Leakage Repair	TBD	TBD	TBD	NRW Reduction Team
Percentage of Population with an Access to Piped water supply (population, %)	100%	92%	85%	EICV

* Definition: the water supply restriction for more than four (4) days a week (supplying water only for three days a week), and the no-supply -days continue for three (3) successive days

Source: JST

CHAPTER 17 RECOMMENDATIONS

17.1 KEY RECOMMENDATIONS:

Key recommendations for the KWSMP is itemized as follows:

1. The establishment of the One Strategic Team (OST) within WASAC and Program Supporting Committee in cooperation with the MININFRA, the RURA and the MINECOFIN are key factors to enhance the implementation and monitoring of the Masterplan. The OST and the Program Supporting Committtee are not only just an implementation unit but also serve as the long-term planning facilities to gain the sustainability of the utility. The 15-Year Investment Plan and KPIs for the monitoring are subject to review and approval by the OST and the Program Supporting Committee.

2. WASAC should implement the improvement measures for strengthening the organizational and institutional aspects including followings as detailed in **Appendix 19**.
    - Forming One Strategic Team,
    - Strengthen financial management capabilities,
    - NRW Reduction,
    - Reducing production cost by improving production efficiency,
    - Geographic information system (GIS) database construction and utilization,
    - Water source maintenance capabilities,
    - Maintenance capability of water supply and distribution pipelines.

    In addition, among the improvement measures itemized in the above, (i) Establishing One Strategic Team for the purpose of attending cross-organizational problems, and (ii) Strengthening financial management capabilities in order to materialize the projects itemized in the KWSMP will be a groundwork of the other activities. In this context, the JST believes that the above (i) and (ii) are the most priority aspects among the improvement measures. **Figure 17.1-1** presents categorization and priority order of organizational strengthening measures

Fields that needs to be strengthened		*Priority*
Category	*Individual aspects to be strengthened*	
Framework for implementation of the "utility turnaround strategy" is established and WASAC is enabled to solve cross-organizational problems.	Establishing One Strategic Team == Establishing a cross-organizational team for the sake of materializing the KWSMP as well as monitoring the progress and status of achievement	A
Financial management capability to implement the M/P is enhanced.	Strengthening financial management capabilities == Preparation of accounting books and financial statements for clear demarcation of assets between the government and WASAC == Development of management accounting systems to monitor production costs and financial performance of all concerned departments	A
Capacity of efficient implementation of NRW reduction is enhanced.	Reduction of NRW == Enhancement of activity to reduce NRW through pressure control and service connection pipes.	B
Water supply facilities are cost-effectively operated.	Reducing production cost (e.g., costs for energy and chemical) by improving production efficiency == Improvement of engineering capacity (e.g., civil/mechanical/electrical/water quality) for energy efficiency for water production and operation.	B
	GIS database construction and utilization == Creation of GIS database for all areas and utilization of database for maintenance of water distribution pipe network, billing/collection of water charges	B
	Enhancing water source maintenance capabilities == Strengthening monitoring and management capacity for water source (including ground water and surface water)	C
	Enhancing maintenance capability of service connections == Preparation of manuals and standards for improving quality of service connection works and materials	B

Source JST

Figure 17.1-1 Categorization and Priority Order of Organizational Strengthening Measures

International cooperation for capacity building with the development partners is necessary in this regard.

3. WASAC/MININFRA should take an initiative role for the implementation of 15-YIP to expand and reconstruct the infrastructure through the quality investment and distribution block system. The quality investment is necessary in terms of the materials, construction control, and safety measures to achieve the goal for the water supply expansion and efficiency in a long-term perspective.

4. In order for WASAC to tackle the critical issues including NRW reduction and intermittent supply, comprehend the current status, and evaluate the effect of the measures that have been taken, WASAC

should consider introducing a smart flow and pressure monitoring system. Smart management and monitoring using digital transformation technologies should be highlighted including the introduction of smart water meters with automatic meter reading techniques and utilization of GIS for the policy determination.

5. WASAC/MININFRA should start a discussion with the concerned organizations including RWB in order to facilitate obtaining water use permissions for the required water resources itemized in the 15-Year Investment Plan as well as the Masterplan.

6. The establishment of water sources monitoring system is needed. Especially, in order to avoid overexploitation of aquifer and identify the influence caused by pumping, water level monitoring boreholes should be constructed in the wellfield and regular monitoring of groundwater level is recommended.

7. In order for WASAC to be prepared for possible future crises (such as a pandemic case likewise Covid-19), WASAC should keep on its effort on developing and improving its financial status so that WASAC can maintain stockpiling essential materials for its O&M (e.g., coagulant and disinfectant used for water treatment). In addition, as proposed in the BCP prepared under the Study, an appropriate inventory management will help WASAC to monitor the status of possession (shortage/ needs) of essential materials.

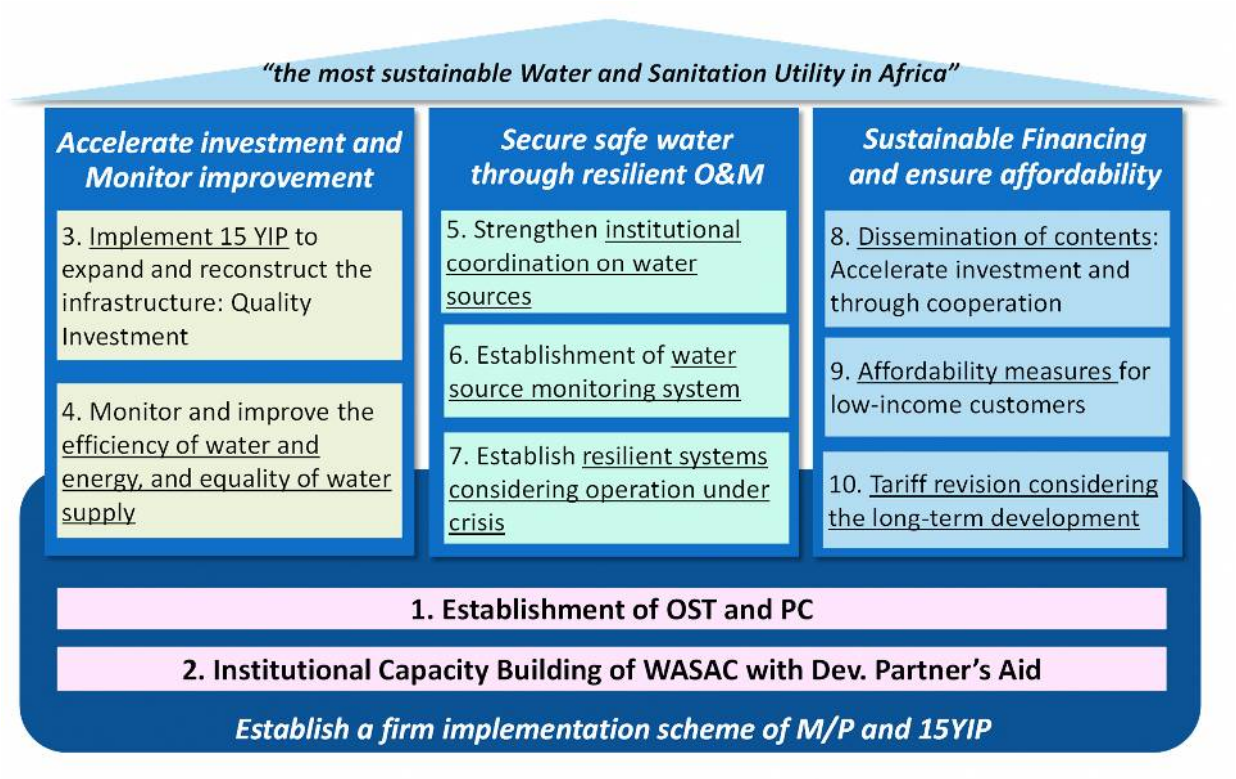
8. It is recommended that WASAC/MININFRA should widely and actively disseminate the content of the 15-Year Investment Plan to the potential investors including development partners and private investors at the right occasions. In addition to the Sector Working Group that is organized by MININFRA to share the content of the water and sanitation projects with the concerned parties, setting up a platform where concerned parties can exchange such information regularly/continuously could be an option to seek funding sources. Launching and putting such activities on track may be supported by the intervention of the central government and/or technical assistance program by the development partner's aid. In addition, such information should be given to existing private operators as well in order to mitigate the impact on their businesses as a part of social consideration.

9. In order for WASAC to increase the service ratio as planned in the Masterplan, it is necessary to take the low-income groups into WASAC's service as a user. Accordingly, it is recommended that WASAC/MININFRA, RURA, and other authorities including central government organizations and regional government bodies to work on the possible pro-poor measures such as subsidies, loans, self-reliance, job gain, housing, health, alternative access to water, alternative water source protection and so forth support for facilitating low-income groups to be a self-sustainable economic entity.

10. WASAC should discuss with MININFRA and RURA on the revision of the tariff table periodically with an interval of every 3 or 5 years in line with the increase of the number of customers and new

facilities, so that WASAC can maintain a stable operational profit, and allocate a fair and equity charge to the satisfaction of its customers, which will contribute to securing funds for appropriate O&M of water supply facilities in the long run.

Figure 17.1-2 illustrates the above key recommendations.



Source: JST

Figure 17.1-2 Key Recommendations

17.2 OTHER RECOMMENDATIONS:

Other recommendations are as follows:

11. Considering that the benchmark year of the 15-Year Investment Plan is 2035, it is recommended that The Kigali Water Supply Masterplan should be reviewed before 2030 (ten years from the preparation of the Masterplan). Note, however, that in case the governing policies, relevant plans and/or official surveys are updated (e.g., national water resource master plan, national water supply master plan, city master plan, national census, EICVs, WASAC's policies including 5 Years Strategic Business Plan), the revision of the Masterplan should be examined based on the result of the review of magnitude of revisions having been done in those governing policies/plans/surveys.

12. It is recommended that WASAC/MININFRA should keep close communication with the concerned authorities including EDCL to monitor the progress of large-scale dam projects including Nyabarongo

II Multipurpose Development Project that could potentially impact to the future projects listed in the 15-Year Investment Plan as well as the Masterplan.

13. Borehole management should be conducted to sustain the yield. In order to protct the yield, proper management of discharge rate by groundwater level moninoring shoud be conducted. In order to protect borehole, investigation and rehabilitation of boreholes should be carried out regularly. In addition, the equipment for the investigation and rehabilitation of borehole such as borehole camera and rehabilitation tools should be procured and used.

14. It is recommended that WASAC/MININFRA should start to take necessary actions for land acquisition for the potential project sites listed in the 15-Year Investment Plan as well as the Masterplan.

Box 5. Accelerating Innovation: Water Business Platform

Public Private Partnerships (PPPs) are a broad concept that the private sector can incorporate the vitality and speed of businesses into the public-led infrastructure utility. Business opportunities of water business are normally not visible to the business entities and start-ups because of its monopoly nature as the infrastructure. The invisibility of the business slows down the participation of the business start-ups as well as the technological innovation. Some utilities in Japan and the developing countries has their "platforms" to activate the opportunity for the business participation with the water services. The platforms are normally permanently installed association/committee (with several persons in charge), being a one-stop facility to discuss and enhance the opportunities for business involvement.

Although WASAC has actively and openly discussed with the private sectors for future business opportunity, the discussion has been often ad-hoc and dealt with as a sideline. As a result, WASAC may have wasted their personnel resources in vain or meddled by the unmatured proposals. In addition, it has been rare that the small businesses or the start-ups proposed the water business because they simply did not have a prior information and ideas. As the ICT technology that we most expect tends to run by a start-up, it is necessary to open the gate publicly to welcome them.

Therefore, it is recommended to facilitate the innovation and business participation from private sector, not only in terms of enlarging the scale of the projects as the Kigali Bulk Water Supply, but also enhancing the participation of the small start-ups. Establishment of the business platform may contribute to accelerate such forms of PPPs.



Photo. An example of Water Business Conference at a utility in Asian Country