REPUBLIC OF RWANDA

WATER AND SANITATION CORPORATION (WASAC)

PROJECT FOR STRENGTHENING NON-REVENUE WATER CONTROL IN KIGALI CITY WATER NETWORK

PROJECT COMPLETION REPORT

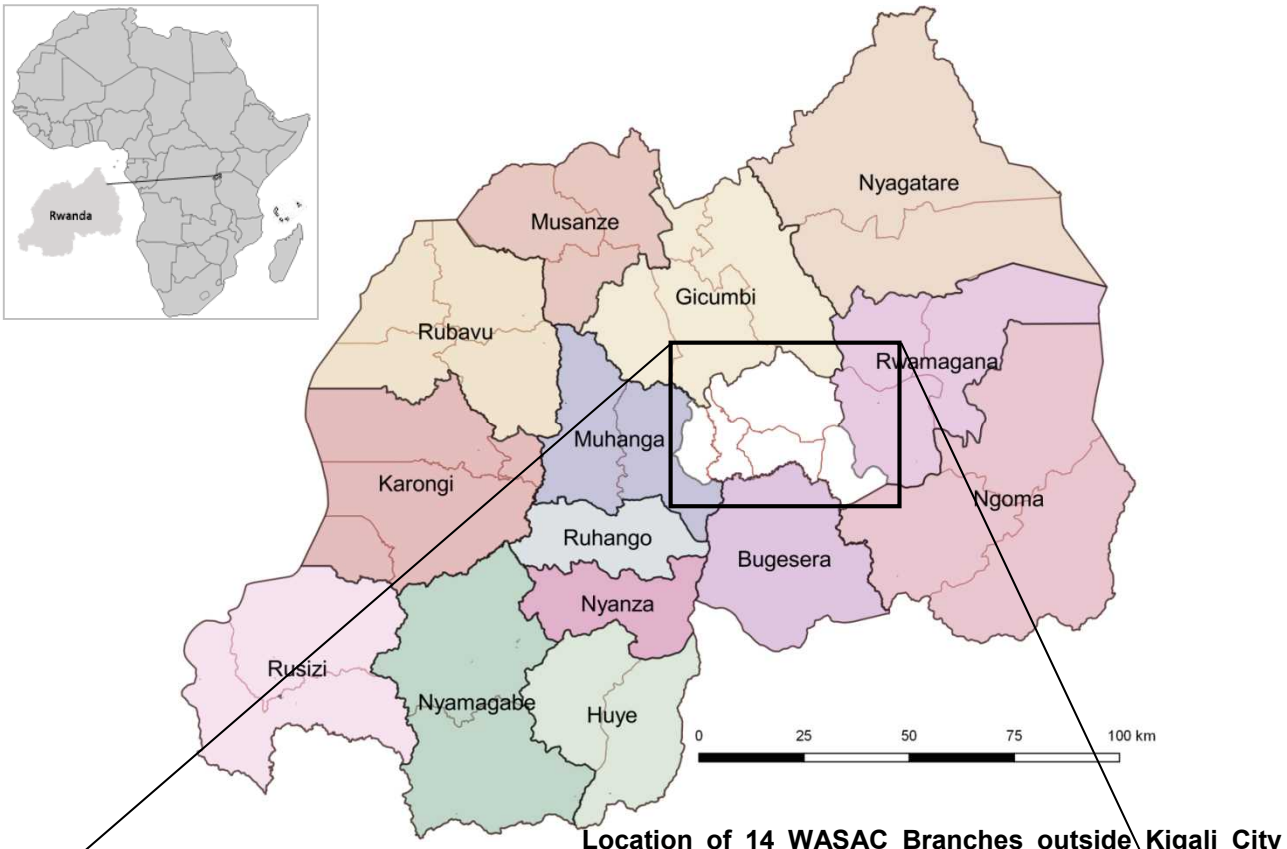
February 2022

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

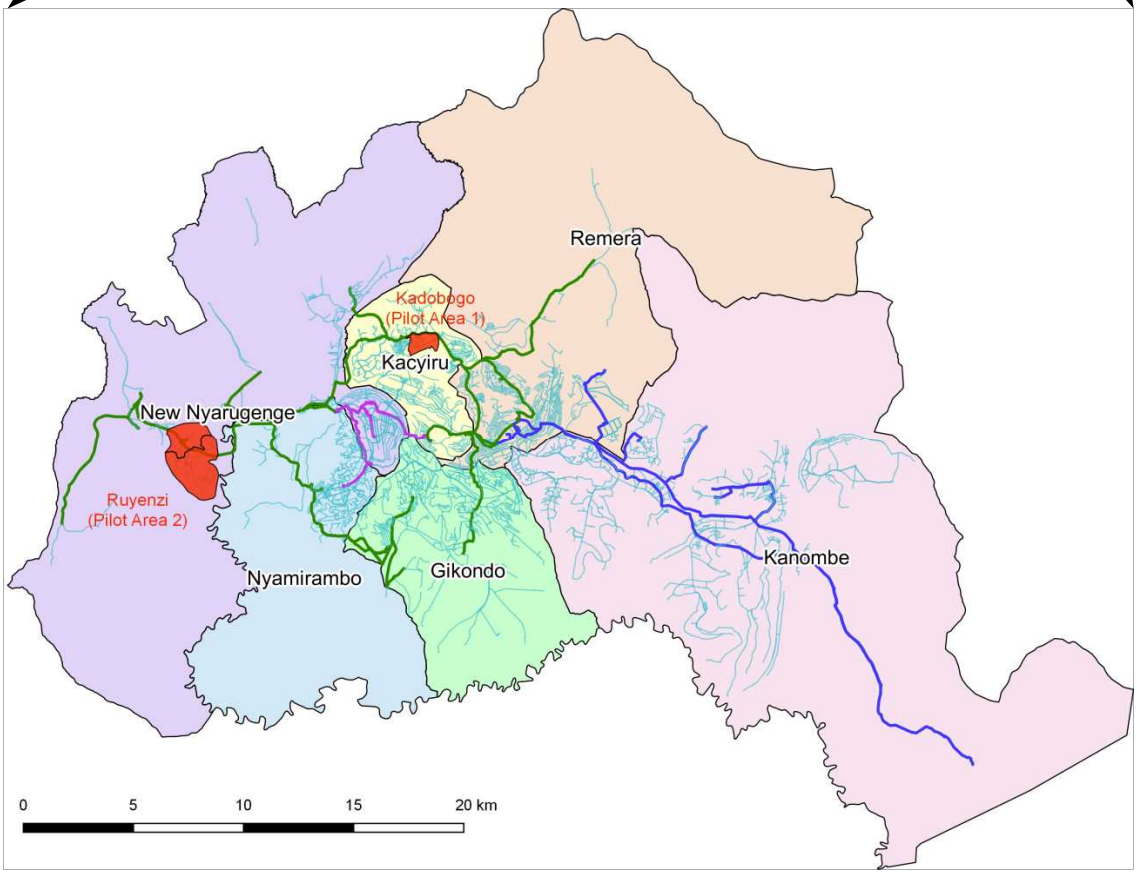
KYOWA ENGINEERING CONSULTANTS CO., LTD.
YOKOHAMA WATER CO., LTD.
KOKUSAI KOGYO CO., LTD.

GE
JR
22-006

Project Area Location Map



Location of 14 WASAC Branches outside Kigali City



Location of 6 WASC Branches in Kigali City and 2 Pilot Project Areas

Project Activity Photos

Project Kick-off Meeting

Steering Committee Meeting

Weekly Meeting

Branch Office Meeting

Workshop of 5YSP for NRW Reduction

Workshop of Water Utility Regional Partnership

Training for Hydraulic Analysis

Training for Water Rate measurement

Project Activity Photos

Training for Leakage Detection

Training for Leakage Detection

Training for Pipe Connection

Customer Meter Survey

1st Training in Japan

2nd Training in Japan

Manhole for Flowmeter in Pilot Area 1

On-site Meter Accuracy Test

Project Activity Photos

Surface Leakage

Underground Leakage

Flow Measurement by UFM

Minimum Nighttime Flow measurement

PRV Installation

Replacement of Distribution Pipe

Kick-off Meeting for Monitoring System Construction

Manhole for Installation of Electromagnetic Flow meter

Project Activity Photos

Data Transmission Facility for Monitoring System

Installation of Flow Meter of Monitoring System

Transmitters of Flow Meter and Pressure Meter

Datalogger and UPS in Pumping Station

Server System in Nyarugenge

Training for NRW Calculation Software

Water Supply Tank for Support to COVID-19 Measures

Operation of Emergency Water Supply by Water Tanker

Table of Contents

Abbreviation

AfDB	African Development Bank
B/C	Benefit Cost Ratio
BoQ	Bill of Quantity
CAPEX	Capital Expenditure
CEO	Chief Executive Officer
CFO	Commercial Field Officer
CMS	Customers Management System
COVID-19	Corona virus diseise-19
C/P	Counterpart
DAC	Development Assistance Committee
DCEO	Deputy Chief Executive Officer
DMA	District Metered Area
DN	Nominal Diameter
DSS	Department of Support Services
DUWSS	Department of Urban Water and Sanitation Services
EDPRS	Economic Development and Poverty Reduction Strategy
EWASCO	Embu Water and Sanitation Company
FV	Float Valve
GIS	Geographic Information System
GPRS	General Packet Radio Service
GSP	Galvanized Steel Pipe
HDPE	High Density Polyethylene
HQ	Head Quarter
ICT	Information and Communication Technology
IWA	International Water Association
JICA	Japan International Cooperation Agency
JICS	Japan International Cooperation System
KEC	Kyowa Engineering Consultants Co., Ltd.
LWB	Lilongwe Water Board
MININFRA	Ministry of Infrastructure
MM	Minutes of Meeting
M/M	Man Month
MP	Master Plan
NPV	Net Present Value

NRW	Non-Revenue Water
OJT	On-the-Job Training
OPEX	Operating Expenditure
PDCA	Plan-Do-Check-Act
PDM	Project Design Matrix
PIP	Performance Improvement Plan
PN	Nominal Pressure
PO	Plan of Operation
POC	Point of Connection
PP	Power Point
PRV	Pressure Reducing Valve
PT	Public Tap
PVC	Polyvinyl Chloride
Qmnf	Minimum Nighttime Flow
R/D	Record of Discussions
RURA	Rwanda Utilities Regulatory Authority
RWF	Rwanda Flan
SAT	Site Acceptance Test
SC	Steering Committee
SCADA	Supervisory Control And Data Acquisition
SSD	Support Service Department
SUSWAS	Sustainable Water Services in Rwanda
UFM	Ultrasonic Flow Meter
USAID	United States Agency for International Development
USD	United State Dollar
VAT	Value Added Tax
WAN	Wide Area Network
WASAC	Water and Sanitation Corporation
WP	Work Plan
WURP	Water Utility Regional Partnership
5YSP	Five-Year Strategic Plan
5YSBP	Five-Year Strategic Business Plan

Chapter 1. Outline of the Project

1.1 Basic Information of the Project

The following table shows basic information about the Project.

Table 1.1 Basic Information about the Project

Contents	Summary of the Project
1. Country	Rwanda
2. Title of the Project	Project for Strengthening Non-Revenue Water (NRW) Control in Kigali City Water Network
3. Duration of the Project	Original: August 2016 to July 2019 Amendment: to July 2020, to December 2020, to December 2021 Final Amendment : to September 2022
4. Implementing Agency	Water and Sanitation Corporation (WASAC)
5. Target Area	4 branches of WASAC in Kigali city (Nyarugenge, Gikondo, Kacyiru, Nyamirambo)
6. Activities on PDM	
1) Overall Goal	WASAC conducts NRW reduction measures as planned for Kigali city.
2) Project Purpose	WASAC's capacity is enhanced to conduct NRW reduction measures as planned for Kigali city.
3) Outputs	【Output 1】 Planning capacity of NRW reduction of WASAC is enhanced.
	【Output 2】Basic knowledge, skills and technique on NRW control are acquired by WASAC.
	【Output 3】 WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.
	【Output 4】4 branches in Kigali establish the system to measure NRW rates accurately.
7. Other Activities	Support to strategically respond to COVID-19 Water Utility Regional Partnership (WURP)

1.2 Background of the Project

The Republic of Rwanda (hereinafter "Rwanda") established a long-term development plan called "VISION 2020" in 2000 to announce its aim to develop the country into a middle-income country by 2020. Regarding the water resource development and water supply, the plan is aimed at improving the water supply coverage of 52% as of 2000 (according to the definition provided by the Rwanda Ministry of Infrastructure (hereinafter "MININFRA")) to 100% by 2020. The Economic Development and Poverty Reduction Strategy 2 (EDPRS II) brought forward the goal to attain the water supply coverage of 100% by 2018.

The ratio of people who use the improved water resources is 87% in the urban area and 72% in the rural area (WHO/UNICEF Joint Monitoring Programme, hereinafter, "JMP," 2015), relatively higher in the former than in the latter. At the same time, Rwanda is experiencing a rapid urbanization. In Kigali City, in particular, the urban population growth rate is expected to reach 4.1% to 5.8% by 2025 (Kigali City Master Plan, 2013). Water service has not caught up with this rapid population growth. Furthermore, shortage of water resources and a great deal of water leakage are causing water to be supplied only for a short time, eight hours on average, and making constant restriction or stop of water supply unavoidable.

Therefore, the Water and Sanitation Corporation (hereinafter "WASAC") in charge of water service under the supervision of MININFRA implemented a plan to double the quantity of water supply by the end of 2017 from the 2015 level to secure sufficient water for Kigali, by constructing a new water treatment plant and expanding an existing water treatment plant through public-private partnerships.

However, Kigali, despite its limited water resources, had a high Non-Revenue Water (NRW) rate of 25% to 38% in 2015 (result of JICA Detailed Planning Survey in January 2016). Therefore, WASAC urgently needed to undertake measures for NRW reduction. Since Kigali has about half the piping length of the urban water supply network in the entire country (2,400 km), making the city a model for NRW reduction across Rwanda would allow WASAC to scale the beneficial effect to other cities. It would also help improve the fiscal management of WASAC as a whole.

Under these circumstances, the Government of Rwanda requested the Japanese government to support the implementation of the Project in June 2015 with the aim of strengthening WASAC's technical capacity to reduce NRW. In response to the request from the Government of Rwanda, JICA conducted the Detailed Planning Survey in January 2016 to confirm the necessity of this Project and the relevance of the request, and agreed with WASAC on the framework of cooperation on February 3rd, 2016. Based on the findings of the survey, WASAC and the JICA Rwanda Office signed and exchanged a Record of Discussions (R/D) on March 30, 2016.

1.3 Project Design Matrix (PDM)

The Project was implemented as per the Project Design Matrix (PDM) and Plan of Operation (PO) set forth in the Record of Discussions (R/D). The following is an outline of the R/D as amended four times in the process of project implementation. All versions of the R/D can be found in Attachment 1 to this Report.

(1) Overall Goal, Purpose and Outputs of the Project

Table 1.2 Project Design Matrix (PDM)

Output, Purpose of the Project	Objectively Verifiable Indicators	Means of Verification
【Overall Goal】 WASAC conducts NRW reduction measures as planned for Kigali city.	NRW rate of Kigali city（year 2022/23 25%）	Annual report of WASAC
【Project Purpose】 WASAC's capacity is enhanced to conduct NRW reduction measures as planned for Kigali city.	1：5YSP for NRW reduction is approved by the Minister of Infrastructure. 2：Annual action plan regarding NRW reduction of each branch is reflected in annual action plan of WASAC 3：The management at WASAC recognizes the effects of NRW reduction, and approves the budget of each branch for implementing annual action plan for NRW water reduction	1：5YSP for NRW reduction approved by the Minister of Infrastructure 2：Annual action plan of WASAC 3：Budget of WASAC
【Outputs】 Output 1. Planning capacity of NRW reduction of WASAC is enhanced.	1：5YSP is reviewed and updated, taking into account of the results of the Pilot Project. 2：All the project achievements are shared by WASAC and other concerned parties by holding seminars.	1：Records of the project 2：Records of the project
Output 2. Basic knowledge, skills and technique on NRW control are acquired by WASAC.	1：More than 300 trainees receive training. 2：WASAC human resource development plan includes training programs prepared by the project.	1：Records of the project 2：Records of the project
Output 3. WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.	1：NRW rates are reduced at each pilot area as follows: Pilot Area 1: from 37% to 20% and Pilot Area 2 from 68% to 25%. 2：Action team members share experiences at workshops regarding implementation of the pilot projects. 3：The action team prepares a completion report of the pilot project.	1：Records of the project 2：Records of the project 3：Survey plans for locations outside the pilot project
Output 4. 4 branches in Kigali establish the system to measure NRW rates accurately.	1：NRW rate of each branch is periodically monitored and reported in PIP (Performance Improvement Plan) every month.	1：Records of the project

Note: The indicator figures were determined during the first amendment of the R/D.

(2) Project Activities by Output

Table 1.3 Activities in the Project (in accordance with the amended R/D)

Project Activities
【Activities for Output 1】
1.1 A management team is organized to prepare 5-year Strategic Plan (5YSP) for NRW reduction.
1.2 The management team assesses NRW reduction measures currently conducted by WASAC for Kigali city and other secondary cities (14 branches outside Kigali city), and identifies problems.

Project Activities
1.3 Based on the problems identified by Activity 1.2, the management team proposes methods and procedures to conduct NRW reduction measures by WASAC in the future. 1.4 The management team undertakes inventory surveys in order to identify facilities improvement necessary to conduct methods and procedures proposed by Activity 1.3. 1.5 Based on the results of Activity 1.3 and 1.4, the management team prepares a draft of the 5YSP. 1.6 The management team identifies organizational and institutional changes necessary to conduct methods and procedures proposed by Activity 1.3 and prepares a report. 1.7 The management team prioritizes and schedules the conducts of specific actions of 5YSP. 1.8 WASAC secures budget in accordance with the priorities of Activity 1.7 for the next fiscal year. 1.9 The management team prepares the 5YSP that summarizes the achievements from Activities 1.1 to 1.7. 1.10 The management team holds seminars and presents 5YSP for WASAC and other concerned parties. 1.11 The management team facilitates implementation and the monitoring of the 5YSP. 1.12 The management team drafts the revised New Connection Policy and a Standard Enforcement Policy. In addition, the management team will facilitate training and monitoring of standard compliancy of pipes with the existing pipe standards. 1.13 The management team reviews 5YSP, updates it as necessary, and secures the budget for the next fiscal year. 1.14 Seminars are organized to present all the achievements of the project for WASAC and other concerned parties.
【Activities for Output 2】 2.1 Training materials on NRW control are prepared. 2.2 Training on NRW control is conducted for the management team and WASAC management as necessary. 2.3 On-the-Job Training (OJT) is conducted on the updating of GIS data, using available GIS data base. 2.4 OJT is conducted on hydraulic analysis and pressure management, using available hydraulic models. 2.5 In-room training and OJT on leak detection for the pilot project are conducted with provided equipment. 2.6 In-room training and OJT on repairing leaking pipes and installing service connection for the pilot project are conducted. 2.7 In-room training and OJT on meter reading, billing, and customer services for the pilot project are conducted. 2.8 Training materials on NRW are reviewed and updated. 2.9 Based on feedback of Activities from 2.5 to 2.8, training programs are developed and training courses are planned.
【Activities for Output 3】 3.1 An action team is organized to conduct NRW reduction measures at Pilot Area 1 and Area 2. 3.2 The action team grasps the current situations of Pilot Area 1 and Area 2 through reviewing available maps, customer ledgers, surveys, and other necessary means. 3.3 The action team plans and schedules the implementation of the pilot project for Pilot Area 1 and Area 2. 3.4 The action team hydraulically isolates Pilot Area 1 and Area 2, and installs flowmeters and pressure gauges at the inlets of the Pilot Area 1 and Area 2. 3.5 The action team establishes the baseline NRW rate of Pilot Area 1. 3.6 The action team conducts measure for reducing "Apparent Losses" indicated by the water balance of International Water Association (IWA) for Pilot Area 1. 3.7 The action team measures NRW after conducting Activity 3.6 and examines its effectiveness. 3.8 The action team conducts measure for reducing surface leakage (visible leakage). 3.9 The action team measures NRW after conducting Activity 3.8 and examines their effectiveness. 3.10 The action team conducts measure for reducing underground leakage (invisible leakage). 3.11 The action team measures NRW after conducting Activity 3.10 and examines their effectiveness. 3.12 The Action team conducts measures for reducing high water pressure. 3.13 The action team measures NRW after conducting Activity 3.12 and examines their effectiveness.

Project Activities
3.14 The action team reviews the results from Activities 3.5 to 3.13, and undertakes cost-benefit analysis of NRW for each Activity of 3.6, 3.8, 3.10 and 3.12.
3.15 The action team summaries activities and results from Activities 3.1 to 3.14, prepares the completion report on the pilot project for Pilot Area 1, and submits it to the management team.
3.16 The action team holds a workshop and presents the completion report of the pilot project prepared by Activity 3.15 to WASAC and other concerned parties.
3.17 Action team conducts activities from Activities 3.5 to 3.16 at Pilot Area 2.
3.18 Action team prepares manuals on methods and use of survey equipment learned through the implementation of the pilot project, and holds seminars in order to share them with WASAC and other concerned parties.
3.19 Action team disseminates the manual and use of survey equipment to the activity of whole branches.
【Activities for Output 4】
4.1 Isolation plan of 4 branches prepared by WASAC will be reviewed and revised as necessary.
4.2 Based on the isolation plan prepared by Activity 4.1, exact locations for the installation of electromagnetic flowmeters and pressure gauges are determined by field survey.
4.3 Electromagnetic flowmeters and pressure gauges are procured and installed for isolating 4 branches.
4.4 Chambers are constructed as appropriate.
4.5 System input to each of 4 branches is measured.
4.6. Based on the results of Activity 4.5, NRW rates for each branch are calculated and reported.

Note: The following additions and modifications were made to the items listed in the table above with the first amendment to the R/D (November 7, 2018), as approved at the third session of the Steering Committee (SC) on August 20, 2018.

Additions: Activities 1.11, 1.12, 3.12, 3.13 and 3.19; and the replacement of existing water distribution and service pipes in Pilot Project 1.

Modifications: Determination of indicator values; renaming of 5 Year Strategic Actin Plan as 5 Year Strategic Plan (5YSP); and installation of procured equipment by JICA, and not by WASAC as originally envisaged.

1.4 Progress of the Project Impremention

1.4.1 Overview of Project Activities

Originally expected to continue for three years, the Project was launched in August 2016 with activities for Outputs 1, 2, 3 and 4 undertaken simultaneously as set forth in the PDM. To promote the activities, JICA made available 12 experts specialized in relevant fields while WASAC appointed counterparts from relevant sections in its headquarters and branches to serve as Management and Action Team members. Based on the common understanding of the PDM, the participants proceeded with their respective activities as stipulated therein.

As regards Output 1, WASAC identified problems related to NRW and the current response by the Corporation through surveys and workshops, and developed concrete proposals for new activities based on the findings, with a view to developing a NRW reduction 5YSP for systematic implementation of NRW reduction measures. Following the development of 5YSP, quarterly reports have been prepared to evaluate the performance of each branch on the specified key management items, for monitoring by WASAC management. High pressure management was also conducted along with functional surveys on reservoirs in Kigali. Necessary equipment for 5YSP was procured

including pressure reducing valves (PRVs), float valves (FVs) for reservoirs, test meters for customer meters and water pressure/level measuring instruments.

For Output 2, in-room and field training sessions were held on NRW control, GIS database updating, hydraulic analysis, leak detection, leaking pipe repair and the management of customer meters and water billing. Necessary equipment used for training was also procured including leak detection equipment, pipe repair equipment, and customer meter management equipment. Field training typically included OJT in the Pilot Project to learn skills for Output 3. (Leak detecting equipment was procured by the JICA Headquarters.)

As for Output 3, concrete NRW reduction works were conducted in the Pilot Areas (Area1: Kadobogo and Area2: Ruyenzi) which was created in the zones served by the Kacyiru and Nyarugenge branches to measure effectiveness indicators such as the NRW rate, the minimum night flow and the frequency of leakage repairs. It was also conducted a cost-benefit analysis as a part of the Pilot Project.

In building District Metered Areas (DMAs), surveys on piping networks and the location of customer connection, partial adjustments to piping to ensure hydrological isolation from neighboring areas, procurement of flowmeters to measure water inflow and related equipment such as valves, and placing them inside manholes were conducted. In the DMAs thus created, the NRW rate was calculated by collecting data on monthly billed water consumption and water flow at the influx point to each area.

The activities conducted include customer surveys on water use, testing and replacement of customer meters, water leakage survey/detection, the installation of PRVs for pressure management surveys, and the replacement of distribution/service pipes were conducted. For this purpose, field testing meters to test customer meters, replacement customer meters and equipment for water leakage survey/detection were procured. It was also procured ancillary materials to PRVs for pressure control surveys, and manholes were constructed to install PRVs. New water distribution and service pipes were procured to replace existing pipes.

The activities to obtain Output 4 consisted of ensuring hydrological isolation of four branches in Kigali (Nyarugenge, Gikondo, Kacyiru and Nyamirambo) to build a system for calculating the NRW rate for each branch. Since it was necessary to place flowmeters on the water distribution pipes running across branch boundaries, the manholes to place the flowmeters were constructed by a local constructor after surveys and discussions to determine their locations. Also a monitoring system was designed and developed the technical specifications thereof. The procurement and installation of the equipment of the system were made by Japanese contractor. The bidding procedure in Japan was organized by the JICA Headquarters, whereas the preparation of instructions to bidders was commissioned by JICA to JICS.

Although it was initially planned to entrust a Rwandan contractor with the procurement of equipment, the absence of a successful bidder forced JICA to find a contractor in Japan. It was also planned that the installation of the equipment would be carried out as part of training to be provided by the Project, but it was decided that whole process, including the installation, was entrust to the Japanese contractor, as priority was placed on ensuring the accuracy of system architecture.

Once the system was put in place, guidance on calculation software to measure the NRW rate using the data made available by the system was provided.

In compliance with JICA's contractual requirements, the Project was implemented in two phases: Phase 1 started in July 2016 and ended in June 2017, and Phase 2 covers the period from July 2017 to September 2022. Shown below is a flowchart of project activities (planned and actual).

Fig. 1.1 Flowchart of Project Activities (Actual)

January 2022 Revi.

Project Phase: Phase 1 | Phase 2

Year: 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022

Month: JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB Mar APR MAY JUN JUL AUG SEP

Activities

【Output 1】 Enhancement of Planning capacity of NRW reduction of WASAC

- 1.1 Organizing management team
- 1.2 Assessing NRW reduction measures and identifying problems
- 1.3 Proposing methods and procedures for NRW reduction
- 1.4 Inventory survey for existing facilities
- 1.7 Making of Implementation Schedule
- 1.8 Securing budget for the next year
- 1.9 Preparation of the 5YSP
- Approval by WASAC BORD: April 27
- 1.10 Holding seminar
- 1.10 Holding seminar
- 1.10 Holding seminar at every 20 branch
- 1.10 Holding seminar
- 1.11 Facilitate implementation and the monitoring of the 5YSP
  Customer survey, On-site Meter Test, Meter Replacement, Leakage Repair,
  Float Valve Installation, High Pressure Management
- 1.12 Draft the revised New Connection Policy and the Standard Enforcement Policy
- 1.13 Updating 5YSP/ securing budget for the next year
- 1.4 inventory Survey of the Reservoir in Kigali City
- PRV, FV Installation and Effect Survey
- 1.14 Holding seminars
- 1.8 Securing budget for the next year
- 1.14 Holding seminars

【Output 2】 Acquisition of Basic knowledge, skills and technique on NRW control by WASAC

- 2.1 Preparation of Training materials
- 2.2 Training of management
- 2.3 OJT updating GIS dat
- 2.4 OJT for hydraulic analysis & pressure management
- 2.5 In-room training for leak detection
- 2.5 OJT for leak detection
- 2.6 In-room training on repairing leaking pipes and installing service connection
- 2.6 OJT on repairing leaking pipes and installing service connection
- 2.7 In-room training on meter reading, billing, customer services
- 2.7 OJT on meter reading, billing, customer services
- 2.8 Reviewing and updating of training materials
- 2.8 Reviewing and updating of training materials
- 2.9 Developing training programs/Planning training courses

【Output 3】 Learning how to conduct NRW reduction measures through the implementation of the Pilot Project

- 3.1 Organizing action team
- 3.2 Grasping the current situations of Pilot Area 1& 2
- 3.3 Planning & scheduling the implementation of the pilot project
- 3.4 Hydraulically isolation of Pilot Area 1& 2 and installation of flow meters
- Procuring and Installing Equipment
- Pilot Project 1 : Kadobogo
- Monitoring
- 3.5 Baseline NRW rate
- 3.5 Baseline NRW rate
- Pilot Project 2: Ruyenzi
- Monitoring
- 3.6 Measures for reducing "Apparent Losses"
- 3.6 Measures for reducing "Apparent Losses"
- 3.8 Measures for surface leakage
- 3.8 Measures for surface leakage (visible leakage)
- (visible leakage)
- 3.10 Measures for underground leakage
- (invisible leakage)
- 3.10 Measures for underground leakage (invisible leakage)
- 3.7, 9, 11, 13 NRW rate measurement (Pilot 1 & Pilot 2)
- 3.12 High Pressure Control
- 3.12 High Pressure Control
- Service Pipe Replacement
- 3.14 Reviewing cost-benefit analysis
- 3.15 Preparing Project Completion Report
- 3.16 Holding workshop
- 3.18 Preparing manual
- 3.18 Preparing manual & holding seminars
- 3.19 Dissemination of manual

【Output 4】 Establishment of the system to measure NRW rates accurately in 4 branches in Kigali (Monitoring System)

- 4.1 Reviewing isolation plan of 4 branches in Kigali City
- 4.2 Determination of locations for installation of electromagnetic flow meters and pressure gauges
- 4.3 Preparation of Technical Specification
- 4.3 Preparation of Re-Bid Document
- 4.3 Bidding in Rwanda on Procurement of the Equipment
- 4.3 Bidding in Japan on Procurement of the Equipment
- Interruption by COVID-19
- Kick-off, Survey
- 4.3 Procurement of the Equipment
- Periodical maintenance
- Periodical maintenance
- 4.3 Installation of the Equipment
- 4.4 Construction of the Chamber
- 4.4 Construction of the Chamber
- 4.5 Measuring for system input to each branch
- 4.6 Calculating & reporting of NRW rates for each branch

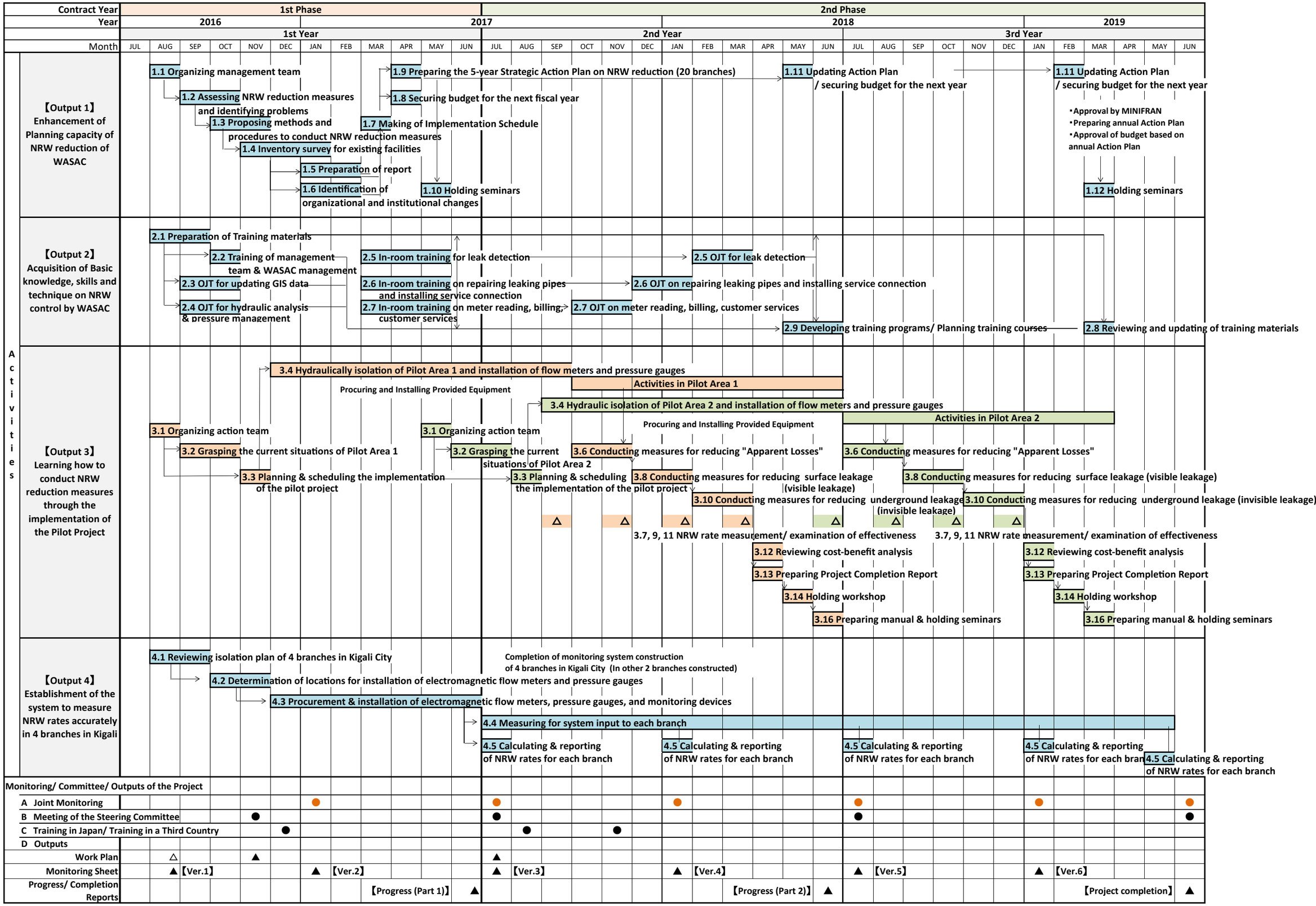
【COVID-19 Support】

- COVID-19 Supporting Activities

Monitoring/ Committee/ Outputs of the Project

- A Joint Monitoring: 1: Sept. 15; 2: March 15; 3:3 Aug. 9; 4: Aug.20; 5: Feb 28; 6: May 20; 7: Nov.19
- Monitoring mission from JAPAN: JICA Project Monitoring Mission; JICA Project Terminal Evaluation
- B Steering Committee (SC): 1st: April 3; 2nd: Octo. 12; 3rd Aug.28; 4th May 22; 5th Feb.4; 6th Apr.27; 7th Nov.25
- C Training in Japan: 1st; 2nd; 3rd
- / Training in a Third Country: Kenya; Malawi; 18th March; 26th February; Prohibition of Traveling Overseas
- D Outputs
- Work Plan: 【Ver.1】; 【Ver.2】; 【Ver.3】; 【Ver.4】
- Monitoring Sheet: 【Ver.1】; 【Ver.2】; 【Ver.3】; 【Ver.4】; 【Ver.5】; 【Ver.6】; 【Ver.7】; 【Ver.8】; 【Ver.9】
- Progress/ Completion Reports: 【Progress (Part 1)】; 【Progress (Part 2)】; 【Progress (Part 3)】; 【Progress (Part 4)】; 【Progress (Part 5)】; 【Progress (Part 6)】; 【Completion】

Fig. 1.2 Flowchart of Project Activities (Planned)



1.4.2 Changes to the Contents and Period of the Project

In the middle of the project activities mentioned above, the project period was extended to December 2020 following two amendments to the R/D, due mainly to the unexpectedly long time required to select the contractor for the procurement of monitoring system equipment for Output 4, as well as to delays in the procurement of equipment by the contractor and the addition of new activities (procurement of FVs, PRVs and meters for field testing to obtain Output 1, and high water pressure control for Output 3).

As the infection of the new coronavirus (COVID-19) began to spread globally in early 2020, JICA introduced a travel ban to Rwanda in February 2020, effectively suspending the project activities of the Japanese experts in the country. WASAC made an emergency request to JICA on June 11, 2020 for assistance concerning countermeasures for the COVID-19 pandemic, to which the latter responded positively on July 24. After considering how to provide the assistance, JICA decided to implement the following activities under the Project. Activity 1) below is closely related to the activities for 5YSP listed under Output 1:

1) Procurement of materials and equipment for Reduction of Intermittent Water Supply.
2) Emergency water supply to people with limited access to clean water.

With no end to the COVID-19 pandemic in sight, JICA decided to conduct the “terminal evaluation” of the project remotely between Japan and Rwanda. Based on the findings of a survey started in June 2020, the evaluation results were agreed upon between JICA and WASAC on August 5, 2020.

As the survey team found that it would be impossible to complete the Project by December 2020 due to the impact of COVID-19, it was proposed to extend the project period to December 2021.

JICA continued to take travel ban measures to prevent and help control COVID-19 infection, but due to improvements in conditions, the suspension of travel to Rwanda was lifted on February 26, 2021. This finally resulted in the resumption of local activities in March 2021.

One of the biggest causes of the delayed progress in project implementation was the delay in the construction of the monitoring system listed as an activity for Output 4 due to the impact of the COVID-19 pandemic. The monitoring system was almost completed in September 2021, and the certificate of partial completion was issued to the Japanese contractor on September 9. This was followed by three months of training with NRW rate calculation software at each branch, using the flow data obtained from the monitoring system. The activities for Output 4 were thus completed with the exception of the maintenance period after the construction of the facilities. To ensure enough time for maintenance, the project period was further extended to September 2022.

The 7th session of the Steering Committee (SC) was held on November 25, 2021 to review the whole Project. The table below summarizes the changes in the project period and activities following the amendments to the R/D.

Table 1.4 Summary of Changes in Project Period and Activities due to Amendments to R/D

Amendment to:	Date of R/D Conclusion	Project Period	Reason for Amendment	Decided at:
Original R/D	3/30/2016	August 2016 – July 2019 (3 years)	—	—
1st Amendment	11/7/2018	August 2016 – July 2020 (extended to 4 years)	Delays in the development of 5YSP and the procurement of equipment for the monitoring system; determination of PDM indicator values; addition of new activities	3rd SC meeting 8/28/2018
2nd Amendment	6/15/2020	August 2016 – December 2020 (extended to 4 years and 5 months)	Modification to the equipment installation timeline due to delays in the procurement of equipment for the monitoring system	5th SC meeting 2/4/2020
3rd Amendment	12/23/2020	August 2016 – December 2021 (extended to 5 years and 5 months)	Delayed progress in project implementation due to COVID-19; addition of activities to support anti-COVID-19 measures and the time required for completing the monitoring system	Written request from WASAC 12/15/2020
4th Amendment	12/21/2021	August 2016 – September 2021 (extended to 6 years and 2 months)	Delayed progress in project implementation due to COVID-19; the time required to ensure a sufficient maintenance period for the monitoring system	7th SC meeting 11/25/2021

1.4.3 Meetings

To review progress in the above-listed activities, a regular Project Progress Meeting was basically held on weekends to discuss the progress of the activities in the week, remaining issues and the timeline for the remaining activities, among others. The Meeting also offered useful occasions for seminars and workshops on various activities, where JICA experts and counterparts shared information and deepened friendship and mutual understanding of their respective activities, effectively playing a substantial role in raising their motivation for the continuation of the Project. A total of 101 sessions of the Meeting were held throughout the project period.

A Steering Committee (SC), whose membership included the CEO at WASAC and MININFRA officials, met regularly on an annual basis to manage the overall operation of the Project. A management meeting was also held prior to each SC session to check on the progress in project implementation and remaining issues, with the help of a monitoring sheet developed as a monitoring

tool for the Project. A list of SC sessions is shown in the table below. SC's minutes of meeting (MM) can be found in Attachment 2.

Table.1.5 List of Steering Committee Sessions

Session	Date	Agenda
1st	April 3, 2017 6 months after project launch	・Verification of progress in project implementation and next steps ・Approval of the second work plan (WP2) for Phase 1
2nd	October 12, 2017 At the start of Phase 2 of the Project	・Verification of progress in project implementation and next steps ・Approval of 5YSP ・Approval of WP for Phase 2
3rd	August 28, 2018 At the time of Project Monitoring by JICA headquarter	・Briefing on the result of project monitoring by the JICA Headquarters ・Addition and modification to the PDM activities; determination of indicators ・Approval of project extension; modification to PO
4th	May 22, 2019 At the time of modification to the timeline for Output 4	・Verification of progress in project implementation and next steps ・Approval of modification to the timeline for activities to achieve Output 4; modification to PO ・Approval of additional activities for Output 1
5th	February 4, 2020 At the time of modification to the timeline for Output 4	・Verification of progress in project implementation and next steps ・Approval of project extension; modification to PO
6th	April 27, 2021 Directly after the lifting of travel ban to contain COVID-19	・Verification of progress in project implementation and next steps ・Verification of progress in activities to support measures against COVID-19 ・Approval of modification to PO to terminate the Project
7th	November 25, 2021 At the time of project completion, except the maintenance period for Output 4	・Overall review of the Project ・Verification of progress in activities to support measures against COVID-19 ・Approval of project extension; modification to PO

1.5 System for Implementing the Project

This project was implemented with the organization system shown in Fig. 1.3. A Steering Committee (SC) was provided as the highest level of organization, in order to ensure the smooth implementation of the Project. SC meetings were attended by officials from the Ministry of Infrastructure (MINIFRA). The Management Team was composed of the heads of the organizations associated with NRW reduction and the section heads that implemented the NRW reduction activities, and was headed by the Director of UWSS. The Action Team, led by the Head of Leak Detection and Pressure Management of the NRW Section, tasked with the implementation of NRW reduction, included the heads of the 6 branches of WASAC within Kigali city that are on the frontline of NRW reduction activities, and the heads of various specialist groups and teams of activities at the headquarters.

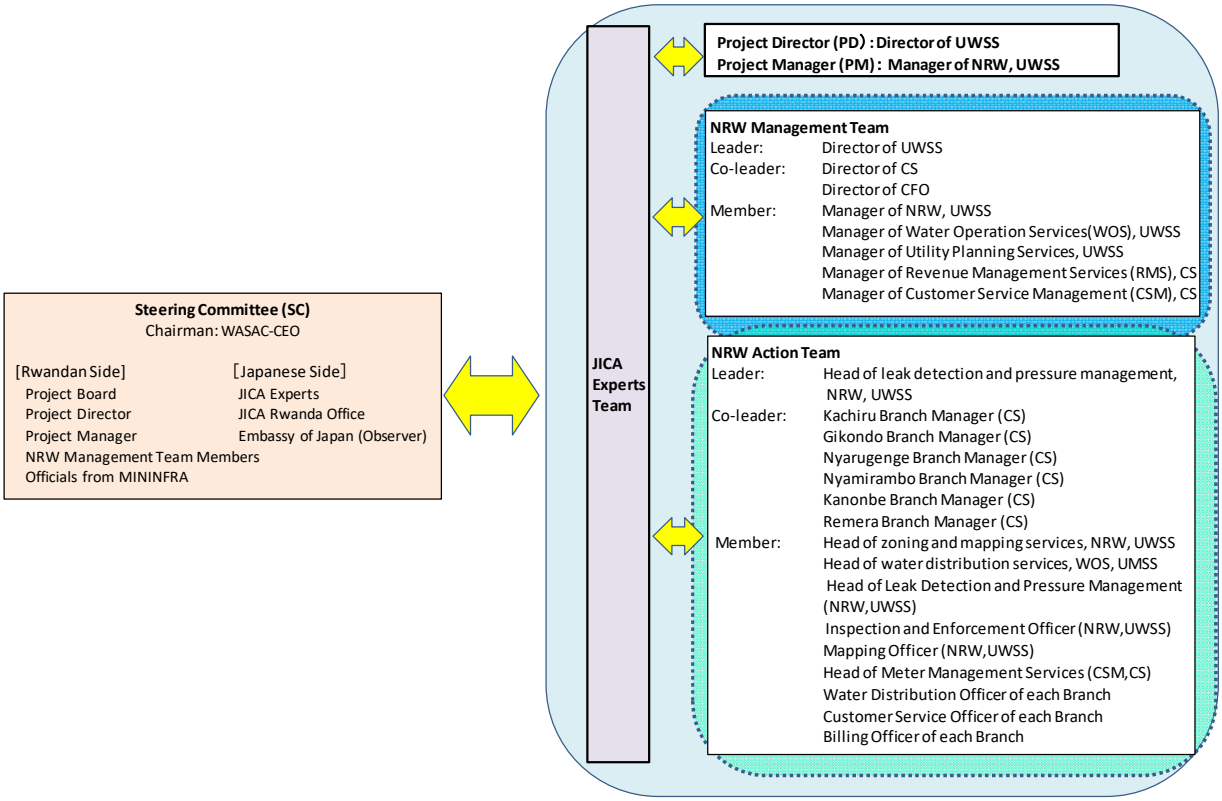


Fig.1.3 Project Implementation System

Attachment 3 lists the counterparts for the Project.

Chapter 2. Results of the Project

2.1 Result of the Project PDM

2.1.1 Input by the Japanese Side

(1) Japanese Experts

Since the beginning of the Project, a total of 12 experts have been dispatched, working for 103.02 man-months in Rwanda. The details are shown in Attachment 3.

1) Working in Rwanda

Table 2.1 Man-Months Worked in Rwanda

No	Field in Charge	Name	Duration		MM
			From	To	
1	Chief Adviser/NRW control	Shigeo OTANI	2016/8/14	2016/12/11	4.00
			2017/1/15	2017/4/6	2.70
			2017/5/1	2017/5/31	1.00
			2017/8/5	2017/10/16	2.43
			2018/3/18	2018/5/16	2.00
			2018/8/5	2018/9/16	1.50
			2018/10/20	2018/11/29	1.37
			2019/1/15	2019/3/9	1.80
			2019/4/15	2019/6/2	1.63
			2019/7/15	2019/11/24	4.43
			2020/1/21	2020/2/15	1.06
			2021/4/28	2021/6/1	1.17
			2021/6/2	2021/7/31	2.00
			2021/11/1	2021/11/29	0.96
2	Adviser/NRW control	Hiroyuki HIGUCHI	2016/8/14	2016/9/27	1.50
			2017/1/15	2017/2/28	1.50
			2017/4/1	2017/6/2	2.10
			2017/8/5	2017/9/17	1.47
			2018/5/24	2018/7/12	1.27
3	NRW Reduction Plan 1（1）	Chiaki SUZUKI/ Hiroyuki YAMAGUCHI/ Toru TOYODA	2016/8/15	2016/9/13	1.00
			2016/11/10	2016/12/27	1.60
			2017/4/1	2017/5/31	2.03
			2017/8/5	2017/9/23	1.67
			2018/1/16	2018/3/1	1.50
			2018/5/9	2018/7/7	1.77
			2018/10/12	2018/12/27	2.57
4	NRW Reduction Plan 1（2）	Hiroyasu YODA	2016/9/7	2016/11/14	2.30
			2017/1/15	2017/4/10	2.87
			2017/11/8	2017/12/22	1.50
			2018/3/18	2018/5/16	2.00
			2018/8/5	2018/10/3	2.00
			2019/2/18	2019/4/6	1.60
5	NRW Reduction Plan 2（1）	Toru TOYODA	2016/8/15	2017/9/28	1.50
			2017/1/15	2017/4/8	2.80
6	NRW Reduction Plan 2（2）	Nobuyuki TSUTSUI	2016/9/18	2016/12/16	3.00
			2017/3/18	2017/5/31	2.50
			2017/8/5	2017/9/3	1.00
			2019/10/12	2019/11/30	1.70
			2021/3/6	2021/4/19	1.50
			2021/8/19	2021/11/16	3.00

No	Field in Charge	Name	Duration		MM
			From	To	
7	GIS	Eita HORISHITA	2016/8/14	2016/11/11	3.00
8	Hydraulic Analysis	Hiroki Oe	2016/8/15	2016/11/12	3.00
9	Leak Detection	Junichi TAKAHASHI	2017/3/3	2017/5/31	3.00
			2017/12/3	2018/2/15	2.50
10	Pipe Repairing and Service Connection（1）	Tokiya MOMOZONO	2017/4/2	2017/6/2	2.07
			2018/2/5	2018/4/5	2.00
11	Pipe Repairing and Service Connection（2）	Hiroshi TAKASHIMA	2017/1/15	2017/4/14	3.00
12	ICT	Marcel Brouwer	2016/9/30	2016/12/10	2.40
			2017/2/13		0.03
			2017/3/1	2017/4/21	1.73
			2017/5/8	2017/5/31	0.80
		Shigeo OTANI	2021/3/6	2021/4/27	1.76
Total MM					103.02

Note: Man Month (MM)

2) Working in Japan

Table 2.2 Man-Months Worked in Japan

No.	Field in Charge	Name	Duration		MM
			From	To	
1	Chief Adviser/NRW control	Shigeo OTANI	2016/8/1	2016/8/5	0.25
			2017/4/17	2017/4/21	0.25
			2018/6/4	2018/6/8	0.25
			2019/6/24	2019/6/28	0.25
			2020/6	2020/12	5.75
			2021/1	2021/1	1.30
			2021/8	2021/9	0.60
6	NRW Reduction Plan 2（2）	Nobuyuki TSUTSUI	2019/9	2019/10	0.85
			2019/12	2020/12	7.10
			2021/1	2021/1	0.50
10	Pipe Repairing and Service Connection（1）	Tokiya MOMOZONO	2016/9/26	2016/9/30	0.25
			2016/10/3	2016/10/7	0.25
			2017/8/1	2017/8/10	0.40
			2017/10/30	2017/11/9	0.40
12	ICT	Shigeo OTANI	2020/4	2020/6	2.50
Total M/M					20.90

(2) Training in Japan and third Countries

A total of 15 WASAC counterparts participated in the three training courses provided in Japan, and 2 persons in Kenya and 5 persons in Malawi as the third country training.

1) Training in Japan

In addition to local project training in Rwanda, training in Japan was designed for WASAC to learn about NRW reduction, one of the greatest challenges for a water service provider, in a country that has achieved a NRW rate of under 10%. Thus, the participants were expected to learn how Japan has met

the challenge in its history of NRW reduction and to observe the skills for maintaining the water revenue rate at a high level. Even if WASAC was not in a position immediately to adopt the advanced Japanese technology, the training could inform WASAC about technical requirements for the future. It was also expected that learning the details of advanced project operations in Japan would raise the motivation for NRW activities among the WASAC participants, thus increasing their commitment to the Project after returning to Rwanda.

For the first and second training courses in Japan, intended for managers, a curriculum was focused on the business management of a water service provider. The third training course, intended for counterparts participating in activities in Pilot Areas of the Project, was more focused on day-to-day practice in the field. The tables below show the list of participants and an outline of the training courses.

Table 2.3 Outline of Training in Japan

No.	Timing	Field of training	Number of trainees	Training themes
1	January 23 to 31, 2017	Management Team	5	- Introduction to water service management and NRW - Outline of water facilities in Yokohama and Kobe Cities and other matters
2	August 14 to 30, 2017	Business affairs and GIS matter	5	- Introduction to water service management and NRW - Customer information management, meter management and reading, and water service management - Examples of how local governments utilize GIS, purposes of use, and other matters
3	Nov. 13 to 30, 2017	Technical matter	5	Introduction to NRW, pressure management, leak detection, distribution management, and other matters

Table 2.4 List of Participants in Training in Japan

	Title	Name
1st training course		
1	Director of Urban Water and Sanitation Services (UWSS)	Methode Rutagungira
2	Manager of Non-Revenue Water (NRW),UWSS	Jean Berchmas Bahige
3	Manager of Customer Service Management, Commercial Services (CS)	Felix Gatanazi
4	Gikondo Branch Manager, CS	Mutamba Jane
5	Nyarugenge Branch Manager, CS	Byamugisha Bernard
2nd training course		
1	Director of CS	Lucien RUTERANA
2	Manager of Revenue Management Services (RMS), CS	Desire KAYIRU
3	Branches coordinator, CS	Johnson MULISA
4	Nyamirambo branch manager, CS	Catherine SARANDA
5	Head of zoning and mapping services, NRW, UWSS	Jean Paul KAYITARE

	Title	Name
3rd training course		
1	Zoning and Mapping Officer, NRW, UWSS	Claudien Mazimpaka
2	Zoning and Mapping Officer, NRW, UWSS	Desire Uwitonze
3	Water Distribution Officer, Remera Branch, CS	NSENGIMANA Damascene
4	Technician of leak detection and pressure management, NRW, UWSS	J.M.V MUGABO
5	Technician of leak detection and pressure management, NRW, UWSS	J.M.V RUTEMBESA

2) Training in 3rd countries

Table 2.5 Training in 3rd Countries

No	Country	Timing	Field of training	Trainees	Training Themes
1	Kenya	May 7 to 10, 2018	Management Team	2	An introduction and discussion of activity on NRW reduction carried out in Kenya (WASREB, MWI, KEWI, NYERI)
2	Malawi	Sept 22 to 27, 2019	Management and Action Teams	5	An introduction and discussion of activity on NRW reduction carried out in Malawi (LWB, EWASCO)

a. First 3rd Country Training Course: Kenya

WASAC was aware of the necessity of mutual learning with other regional countries in Africa about their common challenge of high NRW rates. Kenya, where JICA's Project for Strengthening Capacity in Non-Revenue Water Reduction is ongoing, has a variety of new initiatives including in relation to the project, as well as some of the region's top-rated water utility corporations including that in Nyeri. The purpose of the training course was to learn useful lessons about NRW control from such Kenyan water service providers to help the smooth implementation of NRW reduction activities by WASAC in the framework of 5YSP. The tables below show the list of participants and an outline of the training course.

The two participants from WASAC (the Managers of Water Operation Services and NRW, respectively) were very much inspired by the training course, with lots of learnings from workshops with Kenyan water service providers and site visits. Indeed, the experience brought home to WASAC the effectiveness and importance of mutual learning with its regional neighbors.

Table 2.6 Outline of Training in Kenya

Date	Description
May 7, 2018	Visit to Water Services Regulatory Board - NRW standard and guidelines - Assessment of 56 water utilities performance = annual impact report - Reward for best performer water utility
May 7, 2018	Visit to the ministry of water and irrigation - Presentation of water sector in Kenya with emphasis on WRM

Date	Description
May 8, 2018	Workshop with Kenyans water utilities at KEWI - NRW unit structure, NRW rate - NRW reduction strategy: (DMA, meter replacement policy, meter testing Big customers meters, pressure management, protective equipment, quality of pipes, new connection works)
May 9, 2018	Visit Nyeri Water and Sewerage Co. Ltd - Good performance over 10 years (NRW less than 20%) - NRW unit 15 staffs including metering, leak detection, PM, DMA management - -5% of their meter tested yearly based on consumption tend and age - - Disconnection method (seal) - Regular follow up of big customers readings/ meter sealing/ calibration every 6 months

Table 2.7 List of Participants in Training in Kenya

	Title	Name
1	Manager of Non-Revenue Water (NRW),UWSS	Jean Berchmas Bahige
2	Manager of Water Operation Services, UWSS	Innocent Gashugi

b. Second 3rd Country Training Course: Malawi

Following the establishment of a regional cooperation structure among three water service providers (WASAC, LWB and EWASCO), the first workshop under the structure was held in Kigali for six days (four working days), from November 4 to 9, 2018. On that occasion, it was decided that the second workshop, to be organized by the Lilongwe Water Board (LWB), would be held in Malawi to announce the result of the agreed-upon Performance Improvement Plan (PIP) and to share other cases.

As information sharing and mutual learning among utilities was one of the components of JICA's Project for Strengthening the Capacity of NRW Reduction for Lilongwe Water Board in Malawi, four other water service providers in Malawi and the Yokohama City Waterworks Department, a participant in the project, attended the workshop in addition to the three members water suppliers (WASAC, LEB and EWASCO).

Table 2.8 Outline of Training in Malawi

Date	Description
Sept 23	Courtesy call to LWB and JICA
Sept 24	Workshop - Briefing on participating utilities (WASAC, EWASCO, LWB, BWB, NRWB, SRWB, CRWB, Yokohama City Waterworks Department, WASAMA, WUAs) - Announcement of the result of PIP - Successful/unsuccessful cases of NRW reduction
Sept 25	Site Visit - LWB Call Center - Tank Monitoring System (iMosysis)

Date	Description
	- Online mobile billing solution (bilu Pompo) - Prepaid Water Meter - Meter lab. Workshop - DMA/PRV site visit - City Center (capital Hill)
Sept 26	Workshop and Wrap-up meeting

Table 2.9 List of Participants in Training in Malawi

	Title	Name
1	Manager of Non-Revenue Water (NRW), UWSS	Jean Berchmas Bahige
2	Head of IT Business Applications	Alexander Bimenyimana
3	Head of Metering Services	Felicien Niringiyimana
4	Head of Leak Detection & Pressure Management	Desire Ntamuturano
5	Head of Financial & Commercial	Dickson Njiru

(3) List of Equipment Provided for the Project

The following equipment was provided for implementation of the project activities and was handed over to WASAC by November 19, 2021. The list of handed-over documents can be found in Attachment 4.

- Equipment for activity of Output 1 (equipment to support 5YSP activities)
- Equipment for activity of Output 2 (equipment for training)
- Equipment for activity of Output 3 (equipment for constructing Pilot Areas)
- Equipment for activity of Output 4 (equipment for building the monitoring system)
- Equipment for project operation (copier)
- Equipment to support measures against COVID-19 (reduction in intermittent water supply, emergency water distribution by water trucks)

Table 2.10 List of Equipment Provided

Item	Output	Equipment	Description	Qty.	Procured by	Date of Handover
1	2	E&M for training on pipe repairing and service connection	Pipes, piping materials and tools	1 set	KEC	2019/2/28
2		Leak detection equipment	Ultrasonic flowmeter, leak detector, etc.	1 set	JICA	2019/2/28
3		Survey equipment	Portable GPS receiver, test meter, etc.	1 set	KEC	2019/2/28
4	3	Equipment for establishing Pilot DMA	Customer meters, mechanical flowmeter, valves, etc.	1 set	KEC	2019/2/28
5		PRV piping materials	Pipe connectors for PRV installation	1 set	KEC	2019/2/28
6		Materials for service pipe replacement	PVC and deformed pipes	1 set	KEC	2019/2/28

Item	Output	Equipment	Description	Qty.	Procured by	Date of Handover
7	1	Equipment for high pressure management and reservoir management	PRV 12sets, Float valves 10sets, pipes and piping material	1 Unit	KEC	2020/11/26
8		Materials for pressure management	Pipes and piping material for Bypass	1 Unit	KEC	2020/11/26
9		Portable test meters	DN15, 26sets	1 Unit	KEC	2020/5/21
10		Water Level Sensor and Datalogger	Water Level Sensor, Datalogger	3 sets	KEC	2020/11/26
11		Pressure sensor and Datalogger	Pressure sensor, Logger, Data Collector	3 sets	KEC	2020/11/26
12	Cov19 response activities	Engine Pump and Bulk Water Meter	Pump (DN80mm,55m3/hr, H20m) Meter (Waltman type, DN50mm, PN16)	23 sets	KEC	2021/11/19
13		Procurement material for Reduction Intermittent Water	Pipe and fittings for network repair	1 Unit	KEC	2021/11/19
14			Service pipe	1 Unit	KEC	2021/11/19
15			FV	1 Unit	KEC	2021/11/19
16	4	Monitoring System for hydraulic isolation of 4 Branches	Valve and pipes, Joint, Electro-magnetic flowmeter, Mechanical flowmeter, Electro Magnetic flowmeter, water pressure transmitter, data logger, Server, etc.	1 Unit	JICA	Warranty Period until September 2022
20	—	Equipment for project operation	Vehicle (minibus)	1 Unit	JICA	Returned to JICA on 2022/11/26
			Vehicle (pickup)	1 Unit	JICA	
			Multifunctional photocopier	1 set	KEC	2021/11/19

Note: KEC (Kyowa Engineering Consultants)

(4) List of Facilities Provided for the Project

Table 2.11 List of Facilities Provided

Lot	Item	Contents	Quantity	Executor	Status	Handing over to WASAC
Lot 1	Chambers for Pilot Areas	3 chambers for Pilot Area1 1 chamber for Pilot Area 2	1 set	Consultant	May. 2017, Sept, 2018 Completed	Completed
Lot 2	Chambers for Monitoring System	23 chambers for monitoring system	23 sets	Consultant	Feb. 2019 Completed	Completed
Lot 3	Monitoring System	Data measuring and transmission facilities at 28 sites Data receiving and processing server at HQ	1 set	Contractor	Nov. 2021 Completed except manhole 3, 7 19	Not yet

(5) Operational Cost

The Japanese side assumed the following costs:

a. Costs assumed by the consultant:
   - Personnel and travel costs for experts
   - General operating cost (employment of local staff, vehicles, consumables, communications, etc.)
   - Equipment cost (equipment for project activities to obtain Outputs 1, 2 and 3, equipment to support measures against COVID-19)
   - Subcontracting cost (construction of chambers for the monitoring system, water transportation by water trucks)
   - Counterpart training cost in Japan

b. Costs assumed by JICA
   - Contracting cost for the procurement of monitoring system equipment
   - Equipment procurement cost (equipment for water leakage survey/detection)
   - Vehicles for project operation

2.1.2 Input by the Rwandan Side

(1) Rwandan Counterparts

The Rwandan side assigned the Project Director responsible for overall administration and implementation of the Project and the Project Manager. A list of counterparts from respective departments is shown in Attachment 3.

Table 2.12 Responsible Counterparts for Output Activities

Output	Name	NRW section lower organization
Output 1	Jean Berchmas BAHIGE	Manager of NRW, UWSS
Output 2	Celestin MWAMBUTSA	Head of water distribution services, WOS, UWSS
Output 3	Désiré NTAMUTURANO	Head of leak detection and pressure management, NRW, UWSS
Output 4	Jean Paul KAYITARE	Head of zoning and mapping services, NRW, UWSS

(2) Facilities provided for the Project

- Office space and furniture for Japanese experts
- Training room and storage house for procured equipment

(3) Operational Cost

- Cost for counterparts participating in training in Rwanda and abroad (travel, per-diem allowance, accommodation)
- Cost of building the Pilot Project Areas (equipment and material cost)

2.1.3 Performance of Activities Pertaining to the Expected Outputs

(1) Activities Relating to Output 1

[Enhancement of planning capacity of WASAC in NRW reduction]

The 5YSP for NRW reduction was formally approved by the WASAC Board of Directors on April 27, 2018. A 5YSP monitoring team consisting of five members was appointed on September 3, 2018. The monitoring of the implementation status of 5YSP was ensured by the submission of activity reports by the branch offices on a quarterly basis. The team actually began its activities in FY 2018/2019, one year behind schedule.

5YSP was to be amended in light of the insights gained through project activities at the completion of the activities for the two Pilot Projects (Output 3). A workshop on the amendment of 5YSP was held on July 25, 2019. In the workshop, the items and monitoring indicators in the Implementation and Monitoring Plan were revised based on the outputs of the Pilot Projects in the Pilot Areas and the results of monitoring of the implementation of 5YSP for one year. In the second year, the revised Implementation and Monitoring Plan was used in the implementation and monitoring of 5YSP. Furthermore, 5YSP was to be amended based also on the knowledge acquired in the water balance monitoring of all the branches in Kigali (Output 4) by isolating the water network for these four branches. However, the full hydrological isolation of the branches has not been achieved as of January 2022.

The New Connection Policy and Requirement for Water Distribution and House Connection were developed in January 2019. Assistance will be provided to the promotion of the awareness creation and monitoring of the observance of the existing pipe standards. The table below shows the implementation timeline for 5YSP and the actual NRW rates.

Table 2.13 Implementation Timeline for 5YSP

Financial year July to June	5YSBP	Target value of 5YSBP (%)	Implementation Year of 5YSP	Proposed NRW rate (%)	Actual NRW rate (%)
2018/19	Year 1	35	Year 1	35.0	36.9(38.8)
2019/20	Year 2	32	Year 2	34.4	40.3(41.9)
2020/21	Year 3	30	Year 3	30.0	42.2(43.3)
2021/22	Year 4	28	Year 4	28.0	-
2022/23	Year 5	25	Year 5	25.0	-

Note: NRW rates in Kigali, (the figures in parentheses are the national NRW rates);
5YSBP (5-Year Strategic Business Plan)

While the following activities were conducted, measures were taken to deepen the understanding of WASAC for implementing 5YSP and instructions were provided to WASAC on how to select priority

work, formulate a work plan, and work out details of work to deal with problems specific to each branch.

- Monitoring based on monthly work reports from the branches
- Instructions on activities of the branches based on the monitoring result
- Spread of the activity outputs of the Project to the branches
- Enhancement of instruction and monitoring systems (organizational strengthening of the NRW Section)

The following sections describe the actual performance of the activities.

1.1 A management team is organized to prepare 5YSP for NRW reduction.

The counterparts from WASAC were officially appointed by the CEO, and the Management Team and Action Team were formed in August 2016. Subsequently, however, three CEOs resigned during the project period, and the deputy CEO is currently acting as CEO. Transfer and retirement of WASAC staff also impacted the work of the Management and Action Teams.

1.2 The Management Team assesses NRW reduction measures currently conducted by WASAC for Kigali city and other secondary cities (14 branches outside Kigali city), and identifies problems.

Regarding NRW reduction measures, questionnaire surveys and site visit surveys for related sections of the WASAC HQ and 20 branches were conducted. Afterward, through the discussions in a series of workshops root causes of NRW were analyzed as it concerned WASAC.

Table 2.14 Process for Identification of Issues Relating to NRW Reduction Measures

	Item	Period	Details
1	Distribution of questionnaires to the 20 branches and related sections in HQ	Aug. – Sept. 2016	Organization, outline of water supply facilities, customer information, NRW percentage, flowmeters, water leakage survey equipment, pipe repair equipment, water theft, water meters, etc.
2	Analysis of questionnaires	Sept.-Oct. 2016	-
3	Seminar	November 8, 2016	Questionnaire results
4	Field surveys and reporting and issue identification at PIC	Sept. 2016 to Mar. 2017	Confirmation of questionnaires, visits to facilities, interviews with branch managers, operators, etc., sharing survey results and issues as required at PIC meetings
5	NRW strategic action plan workshop	Mar. 13 & 20-22, 2017	NRW reduction plan: Workshop on identification of issues

1.3 Based on the problems identified by Activity 1.2, the Management Team proposes methods and procedures to conduct NRW reduction measures by WASAC in the future.

From the information obtained in Activity 1.2 and the survey of 6 branches within Kigali city and the existing water supply facilities (field surveys, questionnaires, GIS, bilied water consumption data), the issues were identified, and the countermeasures and orders of priority as of November 2016 were summarized. Thereafter a workshop was held, based on the wishes from the WASAC side for more detailed survey of the issues and causes. The causes of the identified issues were analyzed, and the methods of dealing with each of these issues were discussed.

Table 2.15 Process for Analysis of Causes of NRW and Development of NRW Reduction Measures

	Item	Period
1	Workshop to analyze causes, formulate measures, and select components	April 5-6, 2017
2	Workshop to compare and combine the issues identified by JICA specialists and the issues and measures identified by WASAC	April 21, 27-28, 2017
3	Workshop regarding the selected components, formulation of order of priority of countermeasures, and establishment of framework	May 5, 15, 19 and 22, 2017
4	Joint seminar (Management Team, Action Team, 6 branch managers), explanation and discussion of framework	May 29, 2017
5	Discussion of contents, Preparation of Draft Final Report	August -September 2017
6	Joint workshop (Management Team, Action Team, 6 branch managers), discussion of Final Draft	October 4, 2017

The methods of dealing with the issues were grouped and five fields (42 measures, 133 specific actions) were decided, forming the main components of the 5YSP. These were classified based on the International Water Association (IWA) water balance table. As well as setting the order of priority of the actions based on the assumed reduction effect, the year of implementation and responsible sections were decided. The framework for the 5YSP was discussed through workshops that were continuously held, and was agreed upon at the joint workshop of the Management Team and the Action Team held on May 29, 2017.

The following table shows an outline of the framework of the activities planned for 5YSP.

Table 2.16 Components of 5YSP for NRW Reduction and Responsible Department

Area	Component	Counter-measures	Responsible Section
Volume of system input (input of water distribution)	1. Accuracy of measurement of quantity of water delivered	1	Non-revenue Water（NRW）
	2. Expansion of quantity produced	1	Utility Planning Services（UP） Water Operations Services（WO）
Commercial losses	3. Customer meters, collection of charges	4	Revenue Management Services (RM) Customer Service Management (CSM)
	4. Customer meter management (each house, public water hydrants, large customers)	3	Revenue Management Services (RM) Customer Service Management (CSM)

Area	Component	Counter-measures	Responsible Section
	5. Illegal connections	2	Non-revenue Water（NRW）
Physical losses	6. Water pressure management	4	Water Operations Services（WO） Non-revenue Water（NRW）
	7. Asset management(renewal)	3	Water Operations Services（WO）
	8. Water leaks and distribution pipe repair	4	Non-revenue Water（NRW） Quality Assurance Services (QA)
Unbilled authorized consumption	9. Unbilled certified measured water quantity	1	Revenue Management Services (RM)
	10. Unbilled certified unmeasured water quantity	1	Water Operations Services（WO）
Basic countermeasures	11. Renewal of GIS data and customer data	2	GIS Team (GIS) ICT Team (ICT)
	12. Planning, design, and implementation	3	Utility Planning Services（UP） Quality Assurance Services (QA) Department of Urban Water and Sanitation Services (DUWSS) Human Resource Services (HR)
	13. WASAC NRW control	3	Non-revenue Water（NRW） Department of Urban Water and Sanitation Services (DUWSS) WASAC (WASAC)
	14. Stakeholder management	4	Water Operations Section（WO） WASAC (WASAC)
	15. Training	2	WASAC (WASAC)
	16. Organizational improvement	3	WASAC (WASAC)
	17. Equipment, appropriate materials	1	Department of Support Services (DSS)
Total		42	

1.4 The Management Team undertakes inventory surveys in order to identify facilities improvement necessary to conduct methods and procedures proposed by Activity 1.3.

Inventory surveys, led by WASAC's GIS team, culminated in the completion of schematic drawings for facilities of some of the reservoirs in October 2017. However, the many inadequacies found in our onsite verification led us to consider that it would be better to conduct another survey as an activity under 5YSP. It was also proposed at the fourth session of the SC to develop an inventory of top priority facilities and ensure necessary equipment repair.

In July 2019, a functional survey on existing reservoirs in Kigali city was started to select the reservoirs requiring urgent response. To prevent the reservoirs from overflowing, float valve equipment was procured and executed installation works on eight sites. Subsequently the following functional surveys were conducted for the remaining reservoirs.

One problem was the discrepancy between the number of reservoirs (158) in Kigali according to the GIS list of WASAC and the number of the existing reservoirs. Another problem was that the structures

and functional state of each reservoir were not exactly known. In addition, there were overflows due to the absence or defect of FVs at many reservoirs. Based on these observations, it was decided to conduct an inventory survey to elucidate the functional state of the reservoirs. The survey of 118 reservoirs was conducted between May and October 2020. Based on the results of the surveys, the list of the reservoirs in Kigali was updated.

Table 2.17 Survey Items in the Functional Survey of Reservoirs

Survey item	Description
Basic information	Positional data (latitude, longitude, and elevation) and address
Facility structures	Dimensions, material, and shape
Functional state of facilities	Confirmation of overflow and water leaks
Operational state	Interviews with operators (operating hours and method, etc.)
Installation of ancillary facilities	Installation and state of inflow and discharge piping, valves, flowmeters, and float valves
Pipe layout	Composition of piping, valves, meter, etc.
Evaluation of functional state	Comments on the functional state of the existing reservoirs
List of materials and equipment required for repair	BoQ of the materials and equipment required for repair and replacement to be used as a reference for financial planning

The surveys revealed that 75 % of the surveyed reservoirs were being operated and 25 % were not used. Also it was found that many reservoirs were not functioning properly: FVs were lacking or deficient in 84% of the reservoirs, inflow valves were lacking or deficient in 33% of them, 22% were not used because water was distributed through pipelines that bypassed the reservoirs, 6% suffered from overflows, and 18% were leaking water from the wall.

Table 2.18 Result of Functional Surveys on Reservoirs

Number of reservoirs surveyed		Total	%
Operational state	Operated	80	75
	Not operated	6	6
	Disused	20	19
Installation of FV	Yes	17	16
	Not in functional	16	15
	No	73	69
Inflow valve	Yes	67	67
	Yes (but broken down)	14	14
	No	19	19
Water distribution through bypass pipeline	Yes	22	22
	No	79	78
Overflow	Yes	6	6
	No	41	40
	Unknown	55	54
Water leakage	Yes	19	18
	No	84	82

1.5 Based on the results of Activity 1.3 and 1.4, the management team prepares a draft of the 5YSP.

The final draft report of 5YSP was completed at the end of September 2017 and the report was discussed in the workshop attended by the branch managers and key staff of six branches in Kigali on October 4. Then, at the second SC meeting held on October 12, 2017 in which MININFRA and the WASAC Management Team and Action Team participated, common knowledge and consensus building with regard to the prepared 5YSP (Final Draft) were promoted among all related departments. Afterwards, further discussions were carried out on the draft mainly by the NRW unit aimed at practical implementation, and a monitoring plan was added to it.

1.6 The management team identifies organizational and institutional changes necessary to conduct methods and procedures proposed by Activity 1.3 and prepares a report.

Although WASAC planned to reform its organizational structure with MININFRA's approval, the reform plan (WASAC Revised Structure, March 2017) has not been implemented.

In order to promote the implementation of 5YSP, related staff are aware of the necessity of organizational structure reform, but it cannot be carried out at this stage, and for the time being, and it was decided to clarify the responsibilities of the department in charge within the current organization and strengthen cooperation between each department.

However, the 5YSP update report of September 2021 proposed to have a team in charge of NRW in each branch and requested the following personnel increases:

- ✓ 1 engineer and 2 technicians at each of the 10 largest branches for quick and quality repairs of water pipes;
- ✓ 2 engineers and 3 operators at the NRW unit to enhance the inspection of water theft and the enforcement of corrective measures;
- ✓ 2 engineers and 3 operators at the NRW unit to enhance water leakage survey.

1.7 The management team prioritizes and schedules the conducts of specific actions of 5YSP.

An outline yearly implementation schedule for each specific action was prepared. As a future issue, it is necessary for each branch office to draw up individual detailed action plans, including construction of the facilities and procurement of the equipment (equipment for surveys and operation of water distribution system). Specific actions, which can be performed under 5YSP, were to be incorporated sequentially in the annual action plans of each branch for the time being.

1.8 WASAC secures budget in accordance with the priorities of Activity 1.7 for the next fiscal year.

Although the regular budget of WASAC needs to be allocated to the NRW reduction activities conducted by individual branches, it is not actually executed as requested by the branches. Annual budget execution is inadequate, failing to cover most of the costs required for the NRW reduction activities. Furthermore, CAPEX required for initial investment in NRW reduction is huge as compared with the current WASAC budget.

WASAC should consider another funding source to support CAPEX. As for OPEX, budget allocation and execution for NRW reduction activities need to be made clearer going forward. Practical budget allocation will be needed in response to the NRW reduction activities conducted by individual branches.

1.9 The Management Team prepares the 5YSP that summarizes the achievements from Activities 1.1 to 1.7.

A management meeting attended by all DUWSS managers and all section heads was held on November 14, 2017, and explanations were made on the latest edition of the report. The result was reported to the CEO and the Branch Managers on the following day. On December 15, the report was submitted by the Project Director to the Senior Management Team. The report was approved in the Senior Management Meeting held on February 12, 2018. Following response to the feedback provided at the meeting, 5YSP was formally approved by the WASAC Board of Directors on April 27, 2018. Implementation of the plan was delayed by 1-year relative to the schedule, and was commenced in the fiscal year 2018/2019.

1.10 The Management Team holds seminars and presents 5YSP for WASAC and other concerned parties.

5YSP was shared with the relevant persons in MININFRA and WASAC at the second session of the SC in October 2017. The Project Manager and JICA expert visited all WASAC branches between April and the end of July 2018 and explained 5YSP to the staff members of the branches to make all of them understand it. The recording format for the monthly 5YSP activity report required for the explanation was finalized. An in-house workshop was held in WASAC on July 19, 2018, to identify activities required for achieving the goal of the first year of the NRW Reduction 5YSP from the progress of and the problems found in the implementation of the plan.

1.11 The Management Team facilitates implementation and the monitoring of the 5YSP.

A 5YSP monitoring team consisting of five members was officially appointed by the CEO on September 3, 2018.

1) 5YSP Activity Monitoring and Activities for Updating

Regarding the implementation status of the 5YSP, monitoring is carried out every quarter based on the reports (monthly reports) from the branches. Monitoring started in July 2018. The contents of the reports are evaluated and a workshop on the reports is held every quarter.

On July 24, 2019, a workshop was held on the selection of quick impact activities under 5YSP. On June 28 and September 20, Water Distribution Officers (WDOs) were convened to discuss implementation issues. On July 12, the heads of branches were convened to agree on the NRW rate objectives and action targets for FY2019/2020.

2) High-Pressure Management, Reservoir Surveys and Test Meter Procurement as Quick Impact Activities

On July 19, 2019, the 4th year project explanatory meeting was held, and in particular, to confirm the contents of the additional “quick impact” activities approved at the 4th SC held on May 22, 2019

Regarding the high-pressure management surveys and the reservoir function surveys, it was decided to deal with the urgent work to install the PRVs and the float valves (FVs), and the surveys of the functions of all the reservoirs in Kigali City separately. On July 23, a meeting was held with all the Water Distribution Officers (WDOs) of six branches in Kigali, and the reservoirs and distribution pipes that required urgent action in each branch were listed. Subsequently, it was conducted on-site surveys on the 17 high-pressure areas and 29 reservoirs that required urgent action.

For the high-pressure control, the areas with frequent leaks due to the differences of elevation within the water distribution areas that range from 150 m to 250 m, were identified based on the opinions of the branch WDOs, and it was decided to install PRVs in 9 of these areas where there was a particular urgency to reduce the high pressure.

With regard to the functioning of reservoirs, field survey was conducted on 22 sites. Overflow had been indicated as one of the issues requiring urgent action. Although the installation of FVs was essential as a measure to prevent overflow, many of the auxiliary valves were not functioning, either. It was decided to install FVs in only 10 reservoirs requiring particularly urgent action.

Having understood the actual conditions and problems of the reservoirs by conducting visits accompanied by branch staff and interviewing the operators, the NRW Section led the effort to find

solutions to the problems. The procurement of PRV and FV equipment commenced in late September, and the installation was completed in April 2020.

With regard to portable test meters, WASAC had decided to distribute two meters for each branch, or 40 meters in total to promote 5YSP. Since 14 meters (manufactured in China) had been procured at the expense of WASAC, the remaining 26 meters were procured as part of this Project.

1.12 The Management Team drafts the revised New Connection Policy and a Standard Enforcement Policy. In addition, the management team will facilitate training and monitoring of standard compliancy of pipes with the existing pipe standards.

Initially, it was planned to prepare a revised version of the New Connection Policy and the Standard Enforcement Policy as part of this Project. In compliance with an emergency instruction by the Rwanda Utilities Regulatory Authority (RURA), however, the Directorate Commercial Services of WASAC led the preparation of the documents, which were completed in January 2019.

It was subsequently checked 5YSP monthly reports to see whether the new connections had been established in accordance with the Policy. It was confirmed that many of the leaks were caused by the poor quality of service pipes. Thus it was founded necessary to re-revise and enforce the Policy in order to ensure that customer-procured materials are of good quality.

1.13 The Management Team reviews 5YSP, updates it as necessary, and secures the budget for the next fiscal year.

Key team members, including managers and heads, were convened for a workshop on the review of 5YSP on July 25, 2019. In light of the outcome obtained in the Pilot Areas and the result of monitoring of 5YSP implementation for one year, it was set the activities and monitoring indicators for the Implementation and Monitoring Plan as follows:

Table 2.19 5YSP Activities, Actual Results, and Targets

Activity item	Index	Actual value 2018/2019	Target for 2019/2020
On site meter test	Test implementation percentage	0.2%	2%
Customer meter replacement	Replacement percentage	2%	8%
Customer surveys	Survey percentage	1%	5%
Reservoir management	Float valve replacement percentage/percentage installed (Ratio of the number of defective valves)	ND	50%
Pressure management	Number of surveys and PRVs installed	ND	50

Going forward, 5YSP will be revised once the hydrological isolation of the four branches has been completed, based on the insights obtained from the result of water balance monitoring.

1.14 Seminars are organized to present all the achievements of the project for WASAC and other concerned parties.

On November 17, 2021, a seminar was held at the Thematic Working Group hosted by MININFRA, and it was an opportunity to deepen understanding of water-related stakeholders. Participants came from relevant MINIFRA departments, WASAC and AfDB. The seminar had been slated for March 2020, but was delayed due to the COVID-19 pandemic.

WASAC gave a presentation on the current state of NRW in the water supply, introduction of projects under implementation including this project, contents of future medium-term plans and long-term plans (master plans), and the necessity of financing in implementing them, among others.

(2) Activities Relating to Output 2

[Acquisition of basic knowledge, skills and techniques on NRW control by WASAC staff.]

The training on all subjects had been completed by April 2018. A cumulative total of 596 WASAC staff members have been trained. Since then, activities to upgrade the expertise acquired through the training have continued within the framework of two pilot projects. A list of the training materials is shown in the table below. A list of training sessions can be found in Attachment 3.

2.1 Training materials on NRW control are prepared.

The training on the general theory of NRW, NRW reduction planning, updating of GIS data, hydraulic analysis, water leakage detection, pipe repair, commercial services and facility design were conducted.

Table 2.20 List of Training Materials

No.	Sector	Text & Manual	Contents	Source	Form	No
1	NRW Overview	NRW Reduction Concept Manual Attachment: -The Manager's NRW Handbook (A Guide to Understanding Water Losses) -The Manager's NRW Handbook for Africa (A Guide to Understanding Water Losses)	NRW Overview	Experts USAID, 2008 USAID, 2010	DOC DOC DOC	N1 N1-2 N1-1
2	Reduction plan	Topic-1_WASAC strategy (“To enhance further by adopting people-oriented approach”)	Insufficiency of census data, and the necessity for long-term planning	Experts	PP	N2
3		Topic-2_needs of quality data (Customer Data and Drawings)	Importance of GIS data, customer data, and drawing development	Experts	PP	N3
4		Topic-3_public taps (What’s the existing conditions?)	Issues regarding public water taps, and the necessity for surveys	Experts	PP	N4
5		Topic-4_large customers (Customer behavior largely affects WASAC)	The importance of management of large customers	Experts	PP	N5
6		Topic-5_asset management (What’s the criteria for replacement)	The status of aged pipes and materials, and the necessity for construction of DMAs and renewal in accordance with elevation	Experts	PP	N6
7		Topic-6_illegal water users (Legal or not?)	Analysis of the status of illegal connections using existing data, and why there are illegal connections	Experts	PP	N7
8		Topic-7_summary (What’s your priority measure?)	Proposal of NRW reduction methods and confirmation of order of priority	Experts	PP	N8
9		Topic-8_Five Year NRW Reduction Plan (“Approach and Procedures”)	Framework for NRW reduction proposed by the specialists	Experts	PP	N9
10		Topic-9_Develoment of WASAC	Necessity of change of awareness and organizational improvements	Experts	PP	N10
11		Topic-10_Rehabilitation or Extension	Necessity for countermeasures against water leakage and renewal	Experts	PP	N11
12	NRW Overview	Topic-11_NRW in City_M_Indonesia	Examples of NRW reduction in Indonesia	Experts	PP	N12
13		Topic-12_Meter and Specification	Types, specifications, and accuracy of water meters	Experts	PP	N13
14	Pressure management	High Pressure Area by Branching from Transmission Pipeline and Pump	Methods of survey and analysis of the status in high water pressure areas	Experts	PP	N14
15	NRW Reduction plan	Framework of NRW Reduction Action Plan	Flow of NRW reduction activities plan	Experts	PP	N15
16		5YSP for NRW Reduction	5YSP for NRW Reduction	WASAC	PP	N16

No.	Sector	Text & Manual	Contents	Source	Form	No
				- Experts		
17		Approach and Methodology	Method of preparation of the NRW reduction plan	Experts	PP	N17
18		WASAC-NRW Reduction 5YSP Presentation	5YSP explanatory document	Experts	PP	N18
19		Pilot Project Work Plan	Pilot project work plan document	Experts	DOC	N19
20	GIS	GIS Procedure Guide	Data updating procedures	Experts	DOC	G1
21		GIS Operational Manual	Data updating methods	Experts	DOC	G2
22		Folder Structure and how to open QGIS	Methods of information sharing using QGIS	Experts	PP	G3
23		Utilization of Geographic Information System	Overview of GIS (for users)	Experts	PP	G4
24	Hydraulic analysis	Introduction to Hydraulic Analysis 1	Basics of hydraulic analysis and methods of use	Experts	PP	H1
25		Introduction to Hydraulic Analysis 2	Methods of use of EPANET	Experts	PP	H2
26		Introduction to Hydraulic Analysis 3	Methods of use of Mike Urban	Experts	PP	H3
27		Introduction to Hydraulic Analysis 4	Explanation of use of EPANET	Experts	PP	H4
28		Introduction to Hydraulic Analysis5	Hydraulic analysis practice	Experts	PP	H5
29		Pressure Calculation by Hydraulic Analysis	Pressure calculation using hydraulic analysis	Experts	PP	H6
30		Calculation Sheet	Hydraulic Calculation Sheet	Experts	Excel	H7
31		EPANET Manual	EPANET Manual	Experts	DOC	H8
32	Water leakage detection	Composition of NRW	NRW Overview	Experts	DOC	L1
33		Handling and attention to use Ultrasonic and Electromagnetic Flowmeter	Theory and method of use of electromagnetic and ultrasonic flowmeters	Experts	DOC	L2
34		Method and Classification of Leakage Detection	General overview of water leak detection	Experts	DOC	L3
35		Occurrence and transmission of leakage sound	Principles of occurrence of water leakage sound and survey methods	Experts	DOC	L4
36		Analysis of acoustic (sound) investigating	Methods of analysis of acoustic surveys	Experts	DOC	L5
37		Manual for Leakage Detection	Manual of procedures for using water leak detectors	Experts	DOC	L6
38		Principle of correlation	Theory of leak noise correlators and survey methods	Experts	DOC	L7
39		Leakage survey in Japan	Examples of water leak detection in Japan	Experts	PP	L8
40		Equipment to be provided and utilization method （Donating Equipment from JAPAN)	Theory and method of use of the water leak detectors to be provided	Experts	PP	L9
41	Pipe repair	In-Room training & OJT of “Piping Works”	Appropriate construction management, earthworks, and recording methods	Experts	PP	P1
42		Pipe connection	Appropriate pipe connections, and issues and points of improvement	Experts	PP	P2
43		Pipe connection -Practice-	Methods of cutting and connecting distribution pipes, and points to note	Experts	PP	P3
44	Commercial services	Water Meter	Water meter structure and installation	Experts	PP	M1
45		Definition & Use, Working Principle	Use or non-use of meters	WASAC	PP	M3
46		Different Types of Meters	Meter types	WASAC	PP	M4
47		Meter Reading General	Water charge billing	WASAC	PP	M2
48		Standard Service Connection & Main pipes Installation	Installation of water service pipes	WASAC	PP	M5
49		Customer Focus Programme	Customer service	WASAC	PP	M6
50	Facility design	Calculation method of Thrust block	Method of designing thrust blocks	Experts	PP	O1

(Experts: JICA Team, DOC: Document, PP: PowerPoint)

Table 2.21 Register list

No.	Sector	Record	Contents	Source	Form
1	GIS	Check sheet for Customer Data Update	Check sheet for GIS customer data updating	Experts	Excel
2	GIS	Check sheet for Water Network Update	Check sheet for GIS pipeline and connection data updating	Experts	Excel
3	Pipe repair	Template Daily Report (pipe works)	Register of the history of distribution pipe repairs	Experts	Excel

2.2 Training on NRW control is conducted for the management team and WASAC management as necessary.

Awareness of NRW control became deepened through the implementation of the trainings during Phase 1 of the Project and the series of workshops held in the process of formulating the 5YSP. A NRW Reduction Manual in light of the lessons learned in project implementation was developed. The results of the training were as shown in the table below.

Table 2.22 Output of Training in NRW control

Required Capacity	Training Item	Achievements and Challenges
Understanding of definition of NRW and components of NRW	General items	Degree of achievement: B Sufficient understanding of the components of NRW, in accordance with the definitions of the IWA.
Preparation of NRW reduction action plan	5YSP	Degree of achievement: B Understanding of the details of countermeasures and activities through the process of study of the preparation of the 5YSP.
Implementation, management and monitoring of NRW reduction action plan	5YSP	Degree of achievement: B Preparation of activity monitoring report format.
Evaluation of NRW reduction activities	Pilot Project capacity (Cost-benefit analysis)	Degree of achievement: C Implementation of training in accordance with the progress of the Pilot Project.
Analysis of NRW components	Pilot Project capacity (Water distribution analysis)	Degree of achievement: C Implementation of training in accordance with the progress of the Pilot Project.
Preparation of NRW reduction measures manual	Pilot Project capacity (Implementation manual)	Degree of achievement: C Implementation of training in accordance with the progress of the Pilot Project.

Notes A: The training target has been sufficiently achieved, and activities can be carried out systematically without problem.
B: The training target has been virtually achieved, and if there is a wish to implement the plan at management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.
D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

Table 2.23 List of C/P that received Training in NRW control

Department	Name
Methode Rutagungira	Director of UWSS
Felix Gatanazi	Manager of Customer Service Management (CSM), CS:
Jean Berchmas Bahige	Manager of NRW, UWSS

2.3 OJT is conducted on the updating of GIS data, using available GIS data base.

The training on the updating of GIS data was provided. The timing of development of WASAC GIS data (pipe network data, customer data) by ESRI and introduction of software (ArcGIS) was unclear, so it was not possible to commence specific activities using ArcGIS in the Project. In addition, the GIS Team had comparatively high individual skills in the use of the ArcGIS software, but the organization itself could not fully utilize the software. As the results of implementing the training as indicated in the following table based on this situation, the WASAC staff involved in the work regarding GIS fully understood the processes setting for updating the GIS data and know-how in connection with these operations.

Table 2.24 Output of Training in GIS

Required Capacity	Training Item	Achievements and Challenges
GIS data updating (customer data, pipe network data)	・Continuous updating of GIS data (customer and pipe network data, new customers) ・Updating data using Manuals (GIS Procedure Guide and GIS Operation Manual)	Degree of achievement: B Training was carried out into reassessment and improved efficiency of the current flow for updating in WASAC, using usable data. The C/P understood the skills and techniques necessary for updating of data. In the future, it will be necessary to change the updating procedures in accordance with circumstances, such as completion of the ESRI work, etc., but they will be capable of dealing with these. The target of the technology transfer was only 5 members of the GIS Team, but the technologies can be spread to other members by utilizing the manuals that have been provided.
Sharing and practical use of GIS data	・Utilization and sharing of GIS data in WASAC ・GIS data sharing by QGIS and Google Earth ・Use of drawings created using GIS	Degree of achievement: B Training in utilization and sharing was carried out for a total of 20 members of staff for whom there is a possibility that they will be involved with GIS in the future. The response of the staff members to the introduction of the QGIS data set was good and significant. There were major advantages in that each member of staff could immediately look up elevations, etc., on their PC, and in addition, there is the awareness effect that they will become familiar with the use of GIS.
Transfer of applied technology related to layout and data analysis by ArcGIS	・Method of preparation of “data-driven pages” ・Method of constructing and analyzing an [ArcGIS	Degree of achievement: B These two applied functions of ArcGIS were introduced to 2 or 3 members of the GIS team, and an extremely good response was obtained. On this

Required Capacity	Training Item	Achievements and Challenges
	Geometric Network], for analyzing pipe networks using ArcGIS	occasion, it was not possible to provide instruction on these functions to the practical use level, but it can be greatly utilized in the work of the C/P in the future.

Notes A: The training target has been sufficiently achieved, and activities can be carried out systematically without problem.
B: The training target has been virtually achieved, and if there is a wish to implement the plan at management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.
D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

The GIS-related techniques for which the response of the counterparts was particularly good in this technology transfer were as shown in the table below.

Table 2.25 List of Techniques Used in GIS

Geocoding	This is the generic term for the method of incorporating data into GIS by specifying positional coordinates using keywords such as addresses, etc. It is applied in updating customer data.
Layout of "data-driven pages"	This is a method in ArcGIS for generating layouts for continuous printing over a wide range divided by boundaries, etc.
Geometric Network	This is a method of constructing and analyzing pipeline networks on ArcGIS. (Normal GIS data has higher accuracy when it has more faithful reproduce positions to reality, but modeling is necessary for network analysis. This is the method of constructing and analyzing these models.)
Topology editing, topology validation	Topology indicates the topographical relationship between figures in GIS. Using this relationship function it is possible to, for example, simultaneously edit the boundary lines of two adjacent figures, or detect overlapping figures as errors.
QGIS	QGIS is free GIS software having a world share. It enables various data sets such as ESRI Shape files, etc., to be read, edited, processed, analyzed, etc.

Table 2.26 List of C/P that received Training in GIS

Department	Name
Head of zoning and mapping services, NRW, UWSS (Main)	Jean Paul KAYITARE (retired)
Officer (Main)	Claudien MAZIMPAKA
Officer (Main)	Désiré UWITONZE
Operator	Damacine (retired)
Branch Manager, Distribution Officer, Technician	20 Persons

The issues and recommendations for the future are as follows.

1) Improvement in data accuracy

When the work of ESRI Rwanda is completed, it will be necessary to promptly carry out a check for consistency with the content of the data updated by the WASAC side. The first priority will be to complete the sorting and corrections, such as double counting of WASAC updated parts and

ESRI delivery parts. It is not practical to aim for 100% complete accuracy, so a mechanism of reporting by branch staff, etc., should be implemented, and it is appropriate that making corrections should be incorporated into daily work.

2) Construction of data sharing system with other departments and other organizations

The customer location data possessed by the Directorate of Commercial Services is extremely valuable for use of GIS by WASAC. Each branch supplies new customer information to the GIS Team and the Directorate of Commercial Services. In addition, it is desirable that data on cadastral parcels used in updating customer data is always the latest data supplied from the Rwandan Natural Resources Authority, Ministry of Natural Resources and Environment. To promote utilization of GIS, it is essential to create a system so that the GIS Team can always browse the data that should be linked to GIS in this way.

3) Use of training materials

The following materials were prepared for training activities. These were given to the counterparts in file formats that can be edited, such as Microsoft Word, etc. It is expected that they will be utilized making amendments as appropriate mainly by the GIS Team.

・Operation Manual (Reference: WASAC_GIS_Operation_Manual_20161109)
・Procedure Guide (Reference: WASAC_GIS_Procedure_Guide_20161109)
・GIS data updating records sheet +TIPS (Reference: GIS sheet for pasting in office_20161109)

2.4 OJT is conducted on hydraulic analysis and pressure management, using available hydraulic models.

A survey was carried out relating to the issues in WASAC regarding hydraulic analysis and water pressure control and training on the issues was conducted. Before this, there were no personnel or departments within WASAC with experience in hydraulic analysis. Since the GIS Section was made responsible for the introduction of hydraulic analysis software (MikeUrban), in-room training to the staff of the section and counterparts in charge of design was provided. However, as a result of the delay in developing GIS data, the introduction of software dedicated to hydraulic analysis (MikeUrban) had also been delayed including licensing. Therefore, training was carried out on the basic theory and using alternative software.

The issues in WASAC regarding hydraulic analysis were as follows.

1) Quality of GIS data and water quantity data: There is a lack of basic data needed for hydraulic calculations, such as data on the pipeline network and the amount of billed water consumption and water leakage.

2) Understanding and practice of hydraulic analysis: There was very limited experience in learning the basics of hydraulic analysis in WASAC, so the understanding of the practice of hydraulic analysis was weak.
3) Vision of hydraulic analysis: Hydraulic analysis is a new technology so far unknown for WASAC, so they have no clear vision as to what they can do or should do with analysis.
4) Fragile LAN: The communication network within WASAC is extremely fragile, so it is difficult to share the analysis results, etc.
5) Capabilities of WASAC hydraulic analysis staff: The number of staff in the WASAC GIS Services Section was three (initially), of whom only one person was responsible for hydraulic analysis, so a variety of capabilities of WASAC staff for hydraulic analysis is extremely small.

The contents and outputs of the training carried out are as shown in the table below.

Table 2.27 Output of Training in Hydraulic Analysis

Required Capacity	Training Item	Achievements and Challenges
Understanding of purpose of use of hydraulic analysis	・ Understanding and purpose of hydraulic analysis (What to do with hydraulic analysis?)	Degree of achievement: C The vision of hydraulic analysis goes beyond each of the individual components of the technology, so it is substantially advanced and difficult. It is difficult to become proficient through lectures, and even if there has been two-way discussion, ultimately each individual must diligently gain insight.
Understanding of general basics of hydraulic analysis	・ Basic knowledge of hydraulic analysis ・ Understanding of Hazen-Williams formula	Degree of achievement: B The general basics of hydraulic analysis have been understood. However, the amount of practice is insufficient, so the ability to apply it to practical work is insufficient.
Handling of existing data (GIS, water consumption) required for hydraulic analysis	・ Flow of data in WASAC and handling of data ・ Quality of data and reliability of hydrological analysis results	Degree of achievement: C Repeated lectures were given on the organized flow of data in WASAC. The analysis practices were carried out using actual data in order to demonstrate to WASAC staff how difficult it is to achieve success. Degree of achievement: B The importance of the quality of data has been understood. However, this is a long-term organizational issue, and is not a problem that can be immediately solved by the GIS Team alone. Whether or not WASAC can construct an effective data collection system remains to be seen.
Understanding of ways of using hydraulic analysis software	・ How to use EPANET ・ How to use simple conversion application to join EPANET and WASAC GIS ・ How to use Mike Urban	Degree of achievement: A Regarding the methods of use of hydraulic analysis apps with EPANET and Mike Urban, they have been using PCs for a long time, so they quickly became proficient in the use of analysis apps. They have become proficient in the basics and manuals have been provided, so in the future they will be able to proceed with practical examples while investigating on their own.

Notes A: The training target has been sufficiently achieved, and activities can be carried out systematically without problem.
B: The training target has been virtually achieved, and if there is a wish to implement the plan at management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.

D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

Table 2.28 List of C/Ps that received Training in "Hydraulic analysis and pressure management"

Department	Name
Head of zoning and mapping services, NRW, UWSS	Jean Paul KAYITARE
Officer	Claudien MAZIMPAKA
Officer	Désiré UWITONZE
Planning, Research and Development (UPS), UWSS, Operator	Jean Damascene Nteziyaremye
Water Maintenance Services (WOS), UWSS, Operator	Jean Damascene Kamanayo
Sewerage Operation Service, UWSS, Operator	Emmanuel Mihigo
Water Distribution Services, UWSS, Officer	Jean Claude Manirakiza (retired)

The installer and user manual for EPANET have been distributed free of charge by the US Environmental Protection Agency (https://www.epa.gov/water-research/epanet).

There was almost no availability of GIS data in WASAC and expert teams by the lack of decompressed data, but they are now able to check data by themselves using free apps. WASAC GIS data can normally only be viewed using special high-cost applications, but if the data is appropriately converted it can be used in free applications such as Google Earth or QGIS. GIS data were converted and distributed to all services or organizations concerned together with applications for viewing.

2.5 In-room training and OJT on leak detection for the pilot project are conducted with provided equipment.

It was necessary to foster human resources taking charge of water leak detection, which was not carried out in WASAC, so intensive training was carried out for the staff of the NRW Section.

In Phase 1, a seminar was organized and in-house and OJT was conducted. Since the water leakage detection equipment procured by JICA was not delivered in time for the training, ultrasonic flowmeters was rented, leak detector headsets and electronic leaking sound detectors.

Phase 2, from December 2017, featured on-the-job and in-room training on Pilot Area 1 (Kadobogo). Equipment procured by JICA was used for the training. In parallel with in-room training on how to use the provided detectors, OJT with leak detectors in the Pilot Area and the main trunk water lines of Kigali, as well as in Musanze District outside the capital was conducted.

Water volume management and water pressure management are important items for water leak management. Regarding water volume management, the amount of water leakage in the water transmission pipes and the main water distribution pipes can be estimated by measuring the flow of specific segments using aqueduct, pipes attached to bridges and other exposed pipes. It is also possible to determine the amount of water leakage by measuring the Quantity of Minimum Night Flow (Qmnf)

of a distribution pipe network at each DMA (District Metered Area), and to narrow down the location of the water leak by carrying out a step test or direct measurement on the pipeline (modified step test). This can also be applied to surveys of water theft. In the case of water pressure management, by detecting abnormal water pressure through continuous measurement of water pressure, it is possible to determine the appropriate water pressure to minimize water leakage. In addition, abnormal water distribution can be detected. The contents of the training carried out were as follows.

Phase 1 (Phase 1 March to May 2017)

- A seminar was held on methods of water leakage detection.
- Training for checking, repair, and handling of water leak survey and detection equipment possessed by WASAC.
- Surveys of water leakage amount by measuring flow rates in the main water transmission pipes.
- Measurement of minimum night flow in Pilot Area 1 (how to use a data logger).

Phase 2 (Phase 2 December 2017 to February 2018)

- Training for checking, repair, and handling of water leak survey and detection equipment procured by JICA.
- OJT was carried out within the pilot area using water leak detectors on the water distribution pipe network.
- OJT was carried out outside the pilot area using water leak detectors on the main water supply and water distribution pipes.
- Survey to determine the quantity of water leakage in the pilot area (minimum night flow, step test).
- Methods of water pressure measurement, data logging, and analysis

Table 2.29 Output of Training in Leak Detection

Required Capacity	Training Item	Achievements and Challenges
Leakage points detection work	・Capable to understand water leak surveys/functions of leak detector, and to operate the equipment. ・Capable to understand the general basics of the method of detection of sound source for water leak detection. ・Capable to understand purposes of water leak surveys, purposes of use of detector, as well as to choose suitable equipment in accordance with the circumstances on site. ・Capable to choose the equipment suitable for sound source detection on metal pipes, non-metal pipes, small-diameter pipes, large diameter pipes, distribution pipes, and service pipes.	Degree of achievement: B There are no problems regarding the use of water leak detector, but further proficiency can be expected by further efforts through practical work. The trained staff can provide training to other members of staff. There are no vehicles only used for surveys, and the survey system has to be put together ad hoc.

Required Capacity	Training Item	Achievements and Challenges
Water volume management	・Capable to carry out continuous measurement (monitoring) over a long period using a data logger. Capable to understand the basic of signal measurement. ・Capable to collect and visualize flow rate data before analysis. ・Capable to conduct surveys of water leak amount by the nighttime minimum flow rate method. ・Capable to determine important zones for water leak detection by sub-zone step tests and direct measurement. Capable to estimate water leak quantities between two locations by measuring the flow rates at some different points.	Degree of achievement: B The theory of measurement and methods of use of ultrasonic flow meters have been understood. The trainees identified the water leak quantities by measuring the nighttime minimum flow rate and carrying out a step test on the WASAC pipeline and confirmed the effectiveness of the method of tracking the area where the water leak exists, as well as understood how to carry out these operations. They are now capable of using these methods in practice on their own judgment.
Water pressure management	・Capable to carry out continuous measurement (monitoring) over a long period using a data logger. Capable to understand the basic of signal measurement. ・Capable to collect and visualize water pressure data before analysis. ・Capable to understand the basics of water pressure data signal measurement. ・Capable to understand the relationship between high water pressure and NRW.	Degree of achievement: C The general basics of measurement and the method of use of water pressure gauges were understood. Monitoring can be carried out using a data logger. In undulating topography, there are many areas with excess pressure, but dynamism and motivation of trainees are insufficient for active risk management.
Formulation of plans for water leak detection operations	・Capable to understand water leak surveys and detection methods and choose effective methods in accordance with the circumstances of the water distribution pipe network. ・Capable to understand the relationship between water pressure and flow rate. ・Capable to evaluate the distribution pipe network, make judgments of what part is functionally impaired, and formulate improvement measures. ・Capable to elaborate plans of water leak surveys with awareness of the 5YSP.	Degree of achievement: D The ability to formulate water leak survey plans for water distribution networks has not been achieved. In order to carry out an effective water leak survey, it is necessary to form DMAs in the distribution network, and as such, a more detailed study should be carried out for appropriate layout of reservoirs, etc., and development of distribution network. It is necessary to select areas available for water leak surveys, and it is needed to carry out work to hydraulically isolate the area.
Maintenance of water leak detector	・Capable to decide on the storage location of the equipment, and to store the equipment in an orderly manner. ・Capable to appoint a person responsible for the storage, in order to prevent loss of equipment, and to maintain records of issuing the equipment. ・Capable to carry out minor maintenance such as replacement for poor connection of dry or other batteries.	Degree of achievement: D One room in WASAC Headquarters is used for storage of the equipment, but the space is narrow, and the arrangement is not tidy. A management record register has been prepared for issuing equipment, but it is not being properly used. A person responsible for maintenance has not been appointed. The point of contact for repairs whenever there is a breakdown of equipment has not been determined.

Notes A: The training target has been sufficiently achieved, and activities can be carried out systematically without problem.
B: The training target has been virtually achieved, and if there is a wish to implement the plan at the management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.

D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

Table 2.30 List of C/Ps that received Training in Leak Detection

Department	Name
Head of Leak Detection and pressure management	Desire Ntamuturano
Operator	Mugabo JMV
Operator	Rutenbesa JMV

WASAC did not possess the practical techniques for systematic measures against real losses, but as a result of this training, members of staff of the NRW section have learned the methods of using water leak survey and detection equipment, and the methods of carrying out surveys and detection using this equipment. In particular, through the activities of the Pilot Project, WASAC has acquired the techniques of detecting underground water leaks, which it could not achieve previously, and this is a major breakthrough. As described later, the underground water leakage as a percentage of the NRW in the WASAC water distribution network is extremely high, and it is expected that these techniques will contribute greatly to the NRW reduction activities of WASAC.

The training enabled WASAC to have the minimum necessary equipment for water leaks survey and detection, and to foster technicians capable of carrying out water leak survey and detection, although the number of them is small, so in the future it will be necessary to extend this practically to specific activities in the WASAC branches. The following are necessary challenges.

Thus far, only the NRW Section has been involved in the water leak survey and detection activities, but this is insufficient, and it will be necessary to make the WASAC system function better. There are capable members of staff among the managers and engineers of the NRW Section, but their number is small and they cannot be exclusively assigned to water leak survey and detection work. It is necessary that the organization be enhanced in accordance with the action plan.

The NRW Section does not systematically plan leak detection work. It is desirable that an overall plan be formulated in accordance with the 5YSP for the activities of WASAC as a whole, while utilizing the experience accumulated in the Pilot Project of this Technical Cooperation Project. To this end, it is necessary to create an implementation mechanism by carrying out reorganization at Headquarters or at the branch level, for carrying out the survey and detection. However, at present, this has not even been discussed.

There are highly skilled technicians that have the basic capabilities, and even though equipment is available to a certain extent, there is no planned water leak detection work carried out. Maintenance of the equipment is sloppy, and even batteries are not replaced, so the equipment is not effectively utilized. From now on, each operation needs to be more practical including maintenance of the

equipment based on the technologies acquired in this technical training.

Internal education and training of staff has been carried out about once per month, but the highly specialized training required for water leak detection has not been carried out. As a result of the training carried out in this project, the training of others by the trained staff of the NRW Section became possible, so it is necessary to proceed with the training planning within WASAC after strengthening the organizational structure.

The trained WASAC staff members have been using what they have learned in the training (water leak survey and detection) in the activities in the pilot areas (Pilot Areas 1 and 2) of Output 3. The C/Ps can implement the survey and report its result without external assistance.

2.6 In-room training and OJT on repairing leaking pipes and installing service connection for the pilot project are conducted.

In Phase 1, seminars on the installation of water pipes and repair of leaking pipes in general were held and the in-room training and OJT on the installation and repair were implemented. In Phase 2, the training in this field was mainly carried out for members of staff in the branches, so the six branches in Kigali were visited sequentially, the status of work was closely examined, and OJT was carried out on connection methods of water service pipes. The practical training for the improvement of the methods for water pipe repair and service pipe connection was held at the six branches (Gikondo, Nyarugenge, Kacyiru, Kanombe, Nyamirambo and Remera Branches) in Kigali in February and March 2018. Engineers and technicians of the six branches participated in the final seminar held in Nzove water treatment plant on March 29.

Table 2.31 Seminars held in the project

Branch	Date	Participants	Venue
Gikondo	February 27	14	Branch office
New Nyarugenge	March 8	15	Branch office
Kacyiru	March 14	10	Branch office
Remera	March 22	8	Branch office
Kanombe	March 22	11	Branch office
Nyamirambo	March 26	8	Branch office
Six branches	March 29	28	Nzove water treatment plant
Engineers of HQ	April 4	8	DUWSS

The majority of locations where water leaks occur are on water service pipes. Therefore, the emphasis in training was put on the following points in the installation, and training was provided in thermal welding of HDPE pipe, proper hole drilling using drills (non-water supply suspension drilling method),

proper cutting of screw threads using dies, methods of wrapping Teflon tape, measurement of water pressure and measurement of residual chlorine after drilling, backfilling of pipes, etc. as shown in the table below.

Table 2.32 Output of Training in the Repair of Leaking Pipes and the Installation of Water Supply Equipment

Problem	Description of training
When a branch is formed from a water distribution pipe using a saddle, a hole is formed in the water distribution pipe using a heated steel rod. High pressure occurs, if the hole is too small, which causes damage to the saddle packing and cracking on the pipe wall.	Degree of achievement: B Drilling work with hand-operated drills
PVC pipe or HDPE coils are joined by forming screw threads. Therefore, the pipe wall pressure is reduced.	Degree of achievement: B Cutting of screw threads with dies using oil
When cutting screw treads (with a die), water is used and not oil.	Degree of achievement: B Cutting of steel pipes with triple-blade saws Cutting of PVC pipes with pipe cutters
Sealing tape (Teflon) is wound too much. The screw threads do not come into close contact because of this excess of winding, which causes division at the screws. Moreover, workers do not peel old sealing tape, but wind over it.	Degree of achievement: D How to apply an appropriate quantity of sealing tape
The chippings of pipe material that occur after pipe repair are not removed, mud that falls into the pipe during operations is not removed, and connections are made while this remains. Pipe cleaning is not carried out. This causes blockage of meters.	Degree of achievement: C Burr removal from PVC pipes after chamfering
The allowable pressure resistance of pipe material is not uniform when a mixture of PN16 and PN10 is used.	Degree of achievement: C Water pressure and residual chlorine measurement
The quality of the pipe material is poor, so longitudinal splitting of PVC and HDPE pipes occurs due to high water pressure.	Degree of achievement: D Verification of offset/earth covering at bifurcation points
After carrying out a repair, water is not applied in order to check whether there is a water leak.	Degree of achievement: D Washing of water service pipes after installation
Vehicles are driven even on small, unpaved roads, which can cause damage to pipes due to insufficient depth or inappropriate backfill. The excavated soil such as clay in which consolidation settlement can easily occur or gravel is used as backfill, and this can cause new pipe cracking and water leakage. Sufficient compaction of the pipe foundation is not carried out, and this causes water leaks.	Degree of achievement: D Removal of stones, etc. from backfilling material and compaction at the time of backfilling
No consistency in admissible pressure for pipe materials: mixture of PN16 and PN10.	Degree of achievement: D Uniform pressure capacity of pipes (PN16 or over)
High water pressure causes longitudinal cracks on PVC and HDPE pipes due to the poor quality of pipe materials.	Degree of achievement: D Non-use of HDPE (use of materials meeting applicable standards)
Procurement of pipe materials and excavation of the pipe route for laying these pipes are carried out by customers, and quality of the materials and excavation work is not ensured.	Degree of achievement: D Performance of earthmoving by WASAC staff
It is not possible to shut off the water when carrying out water leak repairs or connecting a new water service pipe	Degree of achievement: D Installation of stop valves at the bifurcation

Problem	Description of training
because there are no valves nearby, and this causes lost water.	points of water service pipes
Low efficiency in piping works due to inadequate maintenance of tools	Degree of achievement: D Tool maintenance
Branch warehouses are in disorder.	Degree of achievement: C Keeping warehouses in order
Drawings are not used in branch operation	Degree of achievement: D Introduction of a system to leverage drawings

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B: The training target has been virtually achieved, and if there is a wish to implement the plan at the management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.
D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

Table 2.33 C/P List of the Training for Leaking Repair and Installation of Pipes

Department	Name
Head of Leak Detection and pressure management	Desire Ntamuturano
Branches	
Water Distribution Officer, Kacyiru	RWABUNEZA Claudien
Operator	KAMANA Jean Claude
Water Distribution Officer, Gikondo	IYAKARE Egide
Operator	UYISABYE Egide
Water Distribution Officer, New Nyarugenge	NSENGIMANA Damascene
Operator	MUGANZA Jean Michele
Water Distribution Officer, Nyamirambo	MUKIMBIRI Pierre Claver
Operator	GAKURU Yassin
Water Distribution Officer, Remera	RUTAGENGWA Etienne
Operator	UWAYEZU Ananias
Water Distribution Officer, Kanombe	MUHAWENIMANA Antoine
Operator	BICAMUMPAKA Alex

2.7 In-room training and OJT on meter reading, billing, and customer services for the pilot project are conducted.

In Phase 1, members of staff from the 6 branches in Kigali (heads of the branches, meter readers, customer service personnel, water distribution technicians, plumbers) attended in-room training over 3 days from May 9 to 11, 2017, regarding meter reading, billing, and customer service. In Phase 2, OJT was continued through the Pilot Project activities.

In the Pilot Project, emphasis was placed on the accuracy of the customer meters used as the main cause of the apparent loss of NRW, and in-situ calibration of the meters and replacement of the meters in accordance with the result is proceeding. At WASAC previously meters were only replaced in the

event of a breakdown, and assessment of accuracy on the WASAC test bench was only carried out when the meter had been procured and when there was a complaint from a customer.

As the following issues became apparent through the pilot project activities, the customer management department of HQ and branch personnel was repeatedly consulted on the measures to be taken, and instructed to immediately implement them. In addition, the training on software usage such as Excel, etc. for the persons in charge and applicants was conducted as appropriate from February to March 2019.

Table 2.34 Output of Training in Meter Reading, Billing and Customer Services

Problem	Description of training
1) Appropriate processing of data on water consumption amount (occurrence of NRW in the process of water metering and consumption) ・ When a meter was replaced, the amount of water used between when the meter was read and when it was replaced or the estimated amount of water was lost in terms of accounting. Correction of the programming of the CMS system for customer data management is required. ・ The criteria of the method of estimating the volume of water consumption when it was not possible to read the meter are unclear.	Degree of achievement: D Response varies among the 20 branches, making unification all the more difficult. Coordination with relevant sections is required, but the initiative of the Directorate of Commercial Services has remained weak.
2) Establishment of methods of analyzing customer data ・ The purpose of monitoring and analyzing the quantity of water consumption for each customer is not recognized (detection of abnormal data, water consumption volume processing errors, meter faults, detection of suspected theft of water, etc.) ・ A database for analysis of customer data has not been prepared. Even though there is GIS customer data and Commercial Services Department customer data, they have not been linked, so their uses are limited. Therefore, it is an urgent task to prepare a unified database for all branches. ・ There is no manual for the methods of analysis of customer data. Almost all of those responsible in each of the branches are beginners in the use of Excel and Access software, and at present are occupied with basic operations such as data input, calculation, etc. In addition to improvement in basic capabilities, it is necessary to provide training to improve the capabilities of the members of staff to deal with data modification, cross tabulation, methods of detecting abnormal data, preparation of graphs, determining customer properties, and other simple analysis methods. ・ The operability for processing a large amount of data with the Excel software is limited, and the potential for making a mistake is large, so it is desirable that this is dealt with by programming such as a Customer Management System (CMS), etc., as the method for processing and analyzing complex customer data, under the initiative of the GIS department.	Degree of achievement: D As with the above problem, response varies among the 20 branches, making unification difficult. The initiative of Commercial Service has remained weak.
3) Meter calibration method, and establishing criteria for replacement of meters ・ Customer meters with problems in measurement accuracy (about 20% of all customer meters) are used over the long term, and are left as they are. ・ From the lessons learned in Pilot Project 1, the criteria for the calibration operations on site using a simple test meter were reviewed,	Degree of achievement: A WASAC staff utilized the water meter efficiently on-site in the activities in Pilot Areas (Areas 1 and 2) to achieve Output 3

Problem	Description of training
and it was planned to implement them in Project 2. At the same time, the criteria for meter replacement were justified based on the calibration results.	
4) Allocating POC numbers to customer addresses ・ A POC label (seal/metal plate) is applied to the customer residence. ・ Preparation of POC map (plotting on GPS map, conversion to GIS data). ・ In order to automatically add the POC of the new customers that are increasing every month to the pilot area (DMA) customer list, a DMA code for the pilot area is allocated to the POC data of the CMS. ・ In order to link to the GIS customer data, it is necessary to collect the required customer data at the same time as the new customer contract. It is necessary to create a system to be implemented responsibly by a branch WDO or a technician.	Degree of achievement: D The POC label has not been applied widely.
5) Dealing with disconnection, and abandoned public water taps ・ In the case of customers for whom measures have been taken to stop their water supply, the risk of illegal use of the water supply increases, so it is necessary to carry out tracking surveys after taking measures to stop their water supply. As the survey method, interview surveys for each household are proposed in order to confirm the local situation and the items required for each customer, etc. ・ Since water supply to a public water tap is suddenly interrupted because of non-payment of charges (2 weeks or more), many customers act repulsively, and there is a strong possibility that it can cause illegal use and illegal connections, etc. Even if there is a need to stop the water supply, sufficient care should be taken with respect to the users.	Degree of achievement: D It is difficult for branch staff members to undertake additional tasks because they are busy with their current tasks.

Notes) A: The training target has been sufficiently achieved, and activities can be carried out systematically without a problem.
B: The training target has been virtually achieved, and if there is a wish to implement the plan at the management level then there is the potential for systematic development.
C: There is a moderate level of achievement, and with the accumulation of work experience in the future, there is a prospect of development at the individual level.
D: The degree of achievement is insufficient, and further training is necessary.
E: There is no potential for growth.

Table 2.35 C/P List of the Training in "Meter Reading and Customer Service"

Department	Name
Manager of Customer Service Management (CSM), CS	Felix Gatanazi
Manager of Revenue Management Services (RMS)	Désiré Kayiru
Head of meter management services, CSM, CS	Felecien Niringiyimana
Branch Manager, 6 Kigali Branches	6 Persons
Water Distribution Officer of each Branch	6 Persons
Customer Service Officer of each Branch	6 Persons
Billing Officer of each Branch	6 Persons
Commercial Field Officer	77 Persons

2.8 Training materials on NRW are reviewed and updated.

As part of Activity 3.18 for Output 3, a team was established for the preparation of a manual of the pilot project and the team began the preparation at the end of January 2019. Based on the various training materials used in the Output 2 activities, the manual was developed by adding the methods

practiced in pilot project activities for Output 3. The revision of the training materials is part of the manual preparation.

2.9 Based on feedback of Activities from 2.5 to 2.8, training programs are developed and training courses are planned.

The DSS is responsible for the planning of training in WASAC. The training programs to be prepared in this project should be incorporated in the scheme of the training plan of the entire WASAC.

Training on activities based on the above-mentioned manual was to be incorporated in the training program of WASAC to disseminate the NRW control technology to all staff members of WASAC. The cooperation between the departments responsible for NRW control and DSS was to be strengthened for the dissemination of the technology. A practical discussion on the manual was to be commenced when its specific contents began to take shape.

The eleven subjects listed in the table below were selected to be included in the training program, having been recognized as important issues through the Pilot Project. The core person for the dissemination of the manual on NRW reduction activities has been trained in this Project. The training can be conducted mainly by NRW Section staff of DUWSS, independently from the WASAC training course implemented by DSS.

Table 2.36 Training Courses on NRW Reduction Activities

Item	Subject
1	Introduction to NRW Reduction Activities
2	High-Pressure Management
3	Water Distribution Management
4	Leakage Surveys and Repair
5	Replacement of Water Supply and Distribution Pipes
6	Management of Reservoirs
7	Management of Volume of Water Distribution
8	Maintenance of Charge Collection Data and Customer Meters
9	Monitoring of NRW Rates
10	Preparation for NRW Reduction Activities
11	Handling of Survey Equipment

(3) Activities Relating to Output 3

[Enhancement of WASAC's capacity to conduct NRW reduction measures through implementation of the Pilot Project]

Two pilot projects (Area1: Kadobogo, Area2: Ruyenzi) were implemented in order to identify the best NRW reduction method by clarifying the effectiveness of relevant activities in Kigali and to prepare a manual on this best method. To achieve the target values of NRW reduction (20 % in Area 1 and 25 % in Area 2), the high-pressure control and the replacement of water distribution and service pipes which was not included in the project activities in the original R/D was added in the project activities.

The NRW rate in Pilot Area 1 from January to March 2019 achieved the target value, but the NRW rate has risen to 25% due to PRV failure. It was proven that there was an NRW reduction effect by the cost-benefit analysis. A report on the completion of Pilot Project 1 was prepared in October 2019.

In area 2 with a high achievement target, the water supply from the Nzove pumping station is distributed by the bypass pipe of the water reservoir, resulting in high water distribution pressure, which is a major factor of leakage. Although the pressure management at night and pressure adjustment for the area with a large existing leakage quantity were carried out, the expected result on the reduction of NRW was not obtained. However, although it was a limited reduction amount, it was proven that it had an NRW reduction effect by examining cost-benefit analysis. A report on the completion of Pilot Project 2 was prepared in January 2020.

The monthly monitoring of the NRW rate, which had been performed after the completion of the activities, was discontinued in March 2020 due to the COVID-19 pandemic. The following sections describe the pilot project activities in detail.

3.1 An action team is organized to conduct NRW reduction measures at Pilot Area 1 and Area 2

The counterparts were formally appointed by the CEO, and the formation of the Action Team was completed in August 2016. However, as stated previously, there were relocations of personnel in September 2017, including some of the counterparts.

3.2 The action team grasps the current situations of Pilot Area 1 and Area 2 through reviewing available maps, customer ledgers, surveys, and other necessary means

Two pilot areas (Area 1: Kadobogo, and Area 2: Ruyenzi) were selected in September 2016. Thereafter distribution network drawings and customer information were obtained, field surveys were carried out and the boundaries of the areas were determined, and, the points of inflow into the area were determined.

Table 2.37 Major indicators of pilot areas (at the time of baseline setting)

Indicator	Pilot Area1: Kadobogo	Pilot Area 2: Ruyenzi
Baseline Setting Date	June and July 2017	March and April 2018
WASAC Branch	Kacyiru	New Nyarugenge
Area (ha)	100	648
Baseline of NRW rate (%)	37	68
POC number	1,242	1,574
Monthly Water Consumption (m3/month)	12,379	18,513
Average Consumption per POC (m3/month/POC)	10.0	11.8
Average Consumption per Capita (lit/day/capita)	48	56

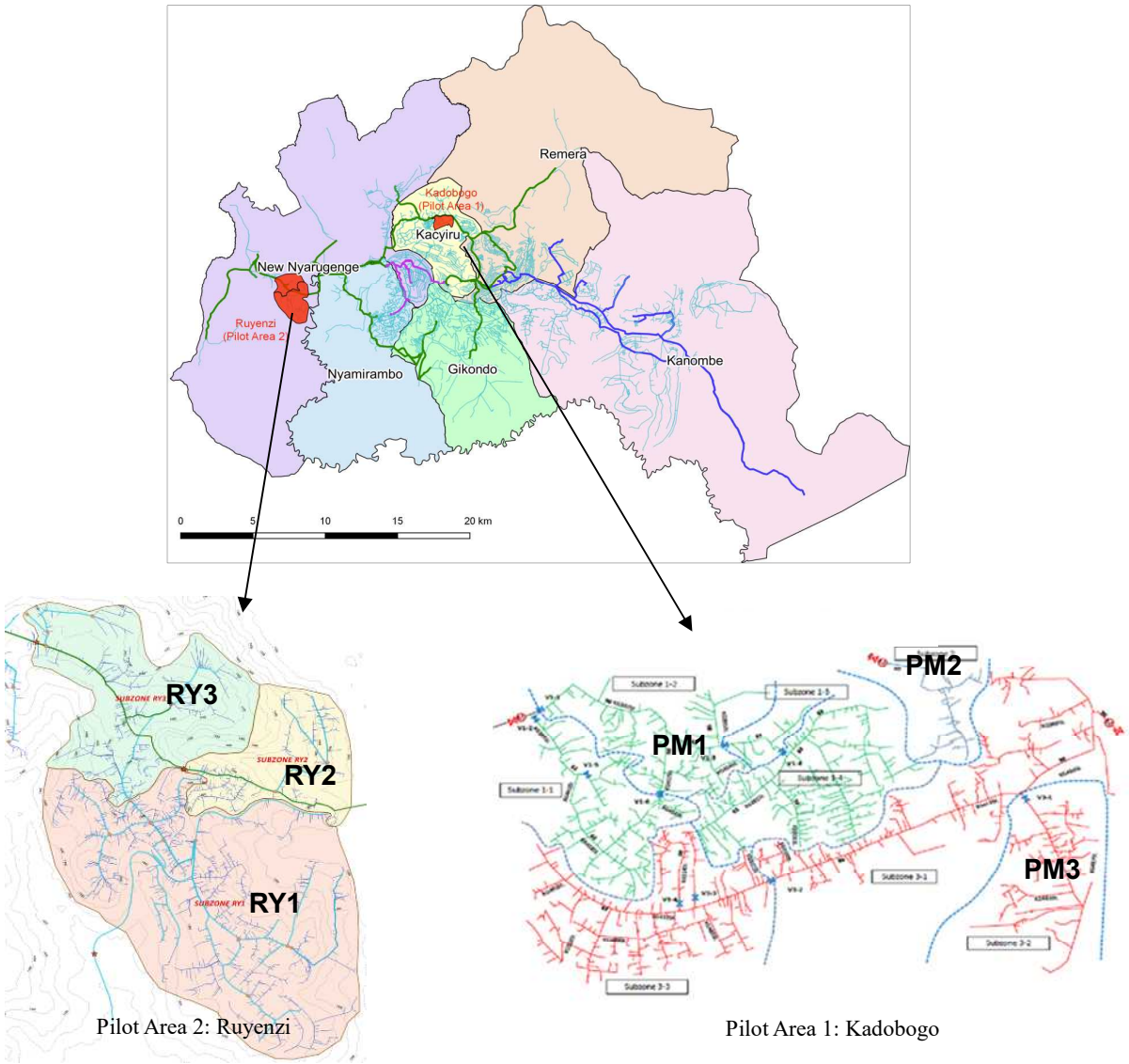


Fig. 2.1 Geographical Locations of Pilot Areas

Pilot Area 1 was divided into three subzones (PM1, PM2 and PM3) in accordance with the design of the existing distribution network. Pilot Area 2 was also divided into three subzones (RY 1, RY2, and RY3) in the same manner.

A point of connection (POC) position map required for the meter accuracy survey was prepared and the boundaries of subzones required for hydraulic isolation were defined.

In the survey for preparation of the customer list in the Pilot Area, it was necessary to check the POC numbers. However, the POC numbers were not necessarily displayed in the positions that were prescribed in advance, but were displayed on various locations such as on gates, gateposts, window frames, doors, electricity meters, water meters, etc. Moreover, in some cases they were handwritten using a marker, and the numbers were lost due to the effects of rain, etc. Therefore, the on-site operation of checking locations of customers and their POC numbers were extremely difficult, and took a lot of time. The POC list and POC location maps are important basic information and are essential for the day-to-day work carried out by WASAC, such as meter reading, meter surveys, leakage surveys, etc., and accurate information was necessary.

3.3 The action team plans and schedules the implementation of the pilot project for Pilot Area 1 and Area 2.

The implementation plans and implementation schedules were formulated for Pilot Areas 1 and 2. The heavy rainfall in May 2018 caused flooding of the Nyabugogo River, which damaged the water transmission pipeline from Nzove treatment plant to Pilot Area 2. WASAC began the repair of the pipeline and completed it finally on June 23, 2018. Because the water supply from the alternative water source during the repair period was not stable, water rationing was frequently put in place. This incident delayed the progress of the project activities and the schedule for the implementation of the pilot activities was revised.

The implementation schedule was also revised in accordance with the outcome of the third, fourth and fifth SC meetings (on August 28, 2018, May 22, 2019, and February 4, 2020, respectively).

3.4 The action team hydraulically isolates Pilot Area 1 and Area 2, and installs flowmeters and pressure gauges at the inlets of the Pilot Area 1 and Area 2.

Three inlet points were created for Pilot Area 1 (PM1, PM2 and PM3) and Pilot Area 2 (RY1, RY2 and RY3), respectively. Equipment procurement and construction of manholes were outsourced locally for the installation of flowmeters and pressure meters at the inlets. Installation of the measuring equipment (flowmeters and pressure meters) was completed on May 31, 2017.

The positional coordinate data of customer POCs were collected with mobile GPSs receiver in the on-site customer POC number survey. POC positional maps were created by superimposing the collected coordinate data on Google Maps-based GIS distribution pipe maps. The hydraulic isolation in each

area and each subzone of the area was confirmed on the POC positional maps to finalize the boundaries of the areas and their subzones. The POC lists and POC positional maps were revised during this confirmation work.

3.5 The action team establishes the baseline NRW rate of Pilot Area 1.

The measurement of flow rates into Pilot Area 1 commenced in June 2017 to determine the baseline as shown in the table below. The monthly NRW rate in each subzone is continuously calculated on a monthly basis by dividing the billed water consumption in each subzone by the volume of water distributed to the subzone. The SC meeting in August set the NRW reduction target at 20%.

Table 2.38 Base line of Pilot Project 1

Items	Unit	June, 2017	July, 2017	Average
Connection	Number	1,240	1,244	1,242
Input Discharge	m3	19,054	20,389	19,722
Billed water	m3	11,345	13,412	12,379
NRW volume	m3	7,709	6,977	5,035
NRW Rate	%	40.5%	34.2%	37.3%

3.6 The action team conducts measures for reducing "Apparent Losses" indicated by the water balance of International Water Association (IWA) for Pilot Area 1.

Apparent losses include illegal water consumption through unlawful connections, small water flow that cannot be detected by water meters, instrumental errors of the meters, errors in meter reading and errors in the estimation of water consumption. To estimate the proportion of each of these components in the apparent losses, the customer water meters were inspected for their operating conditions and reading accuracy on-site and a questionnaire survey of disconnected customers and non-customers were conducted.

In the PDM of the project, activities to reduce real loss were to be implemented after those to reduce apparent loss have been completed. However, as a water leak must be repaired immediately when it has been detected, the meter replacement and repair of leaks were carried out in parallel.

(1) Meter error measurement and meter replacement

The Customer List (POC List) was created in September 2017. There were 1,242 POCs in the area. An on-site meter accuracy measurement survey was planned to be carried out at these 1,242 points in three months, between September and December 2017. The survey could not be carried out at 35 points because the meter was not accessible or residents were not at home. Therefore, the number of points where the meter survey was implemented was 1,207 (or 97 % of POCs).

The errors of water meters were measured on-site with portable test meters when the meters were inspected visually. The water supply was disconnected due to non-payment of bills at 35 points (3% of the survey points) and defective meters were found at 88 points (7% of the survey points). Therefore, the error measurement was carried out at 1,084 points. The meters with errors out of ±5 % (allowable range) were found at 239 points (above the upper limit at 90 points and below the lower limit at 149 points) and the errors of the meters were within the allowable range at 845 points.

Table 2.39 Result of meter accuracy measurement

Subzone	Meter Accuracy				Defective	Total
	-5 % or below	Between ±5%	+5% or above	Total		
PM1	82	467	52	601	49	650
PM2	5	39	5	49	1	50
PM3	62	339	33	434	38	472
Total	149	845	90	1,084	88	1,172
Accuracy	14%	78%	8%	100%	-	-
Usable	12%	72%	8%	-	8%	100%

The total number of points where meter replacement was necessary was 327 (28 % of the number of the measured meters, 1172), 239 due to error out of allowable range and 88 due to defects. Twelve percent of the measured meters had errors below the lower limit and 8 % of them had errors above the upper limit, or the number of the former was 50 % more than that of the latter. The inaccurate meters were replaced with new ones between October 2017 and December 2018.

(2) Water losses derived from illegal consumption and estimation errors

The major causes of the apparent water losses in the water supply service in Kigali City include 1) illegal consumption, 2) water losses derived from the errors in the water consumption estimation and 3) errors in meter reading associated with the meter replacement, in addition to the above-mentioned instrumental errors. The existence of many customers with zero water consumption in the pilot areas suggests that the meter reading has not been conducted in accordance with the rules and this poor meter reading has led to the large water losses derived from the estimation errors.

1) Illegal consumption

No clear evidence of illegal use of piped water through illegal connections cached out in the Pilot Areas. However, five cases of illegal consumption with unauthorized opening of disconnected water taps and intentional removal of meters were uncovered. As the number was very small compared with the total number of customers, the losses caused by the illegal consumption were estimated at less than 0.5 % of the total amounts of water distribution.

2) Estimation errors where it is impossible to read meters

WASAC is supposed to read the meters of all customers every month. However, there are cases where

meters cannot be read because of the inaccessibility due to such reasons as the absence of customers, steep topography and heavy rainfall. In such cases, billed water consumption is estimated. Possible reasons for the zero billed consumption include:

- Water is not used during the month due to the absence of the customer, for example. The customer does use water in other months ("not in use").
- Water service has been discontinued for the customer ("disconnection").
- Water is used but consumption cannot be measured due to the defective meter, etc. ("block").
- Water is used illicitly ("stolen, vandalism").
- The customer is not billed as the meter is not read ("close").
- The meter is read but the customer is not billed ("negligence").
- The customer has terminated the contract, or the meter is placed outside the area or has been relocated ("cancel, not main, shifted").

Inaccurate meter reading was suspected when a customer had been billed for the exactly same amount of water consumption continuously. The table below shows number of the customers billed for the exactly same amount of water consumption for three consecutive months in each subzone (June to August 2017). The number of such customers accounted for 11% of customers (142 out of 1,242 customers) in the area. The staff members in charge of billing at the branch informed that they estimated the water consumption of approx. 10 % of customers.

The customers with zero billed water consumption among the customers billed for the exactly same amount of water consumption were interviewed. The interviews revealed that the meter reading was not conducted appropriately at 50 % of the zero-consumption customers. The error in the estimation of water consumption was estimated from this percentage and average water consumption per customer. The amounts of NRW derived from the estimation errors were estimated at approx. 4.3 % of the water distribution volume as of August 2017.

Table 2.40 Number of customers billed for the same amount of water consumption for three consecutive months (June to August 2017)

Kadobogo	PM1	PM2	PM3	Total
Non-zero billed water consumption	15	0	18	33
Zero billed water consumption	51	5	53	109
Total	66	5	71	142(11%)

Note) The amount of NRW was estimated at 735.8 m3/m (= 109 customers x 50 % (an estimate based on the result of the interview survey) x 13.5 m3/m (average monthly water consumption per customer)), which corresponded to 4.3 % of the total amount of water distributed of 17,277 m3/m.

The table below shows the result of another survey conducted 18 months later (January-March 2019) after encouraging the branch to conduct robust meter readings. The number of customers billed for the

same amount for three months was reduced from 142 in the previous count to 121. Although these figures suggest the improvement in the meter reading, they also show that the meter reading was not conducted as it should be and water consumption of approx. 9 % of the customers was still estimated. It was estimated that the error in the estimation of water consumption, which is related to the meter reading, still accounted for 4 to 5 % of NRW.

Table 2.41 Number of customers billed for the same amount of water consumption for three consecutive months (January to March 2019) in Kadobogo

Kadobogo	PM1	PM2	PM3	Total
Non-zero billed water consumption	17	0	10	27
Zero billed water consumption	45	5	43	93
Total	62	6	53	121 (9.0%)

Attempts were also made to produce estimates from water billing data. Focusing on the data indicating no billed water consumption, the highest possible NRW rate estimated to result from zero water billing was calculated using the monthly-billed water consumption volume in the pilot area in the 12-month period, from May 2018 to April 2019. Specifically, the customers who were zero-billed for water consumption in a given month were identified, and compared with the volume of their billed water consumption in another month, assuming that the latter represented the actual volume of water consumption that should have been billed for. The result of calculation shown in the table below indicates that zero-billed water consumption accounts for 5.3% of the total volume of NRW. It should be noted however that this is the highest possible percentage as it includes the customers who actually did not use any water during the month due to disconnection, for example.

Table 2.42 Estimated NRW rate due to zero-billing

Item	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	Average
Zero Consumption POC	217	196	218	170	208	184	195	185	209	226	214	195	201
Consumption of other month in comparison of Zero Consumption (m3)	943	1,102	1,042	1,285	1,459	1,199	1,011	1,065	961	899	694	0	1,060
	893	1,024	1,171	1,638	1,438	1,350	1,147	1,227	1,096	947	0	1,446	1,216
	891	957	1,066	1,282	1,761	1,103	985	1,041	1,031	0	1,558	908	1,144
	753	953	880	1,035	992	927	718	668	0	1,392	878	799	909
	747	864	819	969	979	773	583	0	982	836	686	633	806
	787	853	780	968	1,199	1,030	0	1,267	960	934	853	746	943
	626	793	681	765	671	0	867	1,074	788	775	658	697	763
	948	947	1,019	1,027	0	1,736	948	1,039	1,067	1,149	1,023	1,165	1,097
	587	677	570	0	1,297	1,137	594	725	890	800	797	697	797
	775	872	0	1,713	1,160	1,195	955	1,177	1,211	1,141	972	1,125	1,118
	567	0	1,289	1,185	1,025	1,263	876	1,237	1,139	1,079	1,029	1,131	1,075
	0	1,247	1,122	1,360	1,298	1,336	1,064	1,319	1,296	1,406	1,226	1,284	1,269
NRW Volume caused by Zero Consumption (m3)	1,269	1,075	1,118	797	1,097	763	943	806	909	1,144	1,216	1,060	1,016
Input Distribution (m3)	21,373	22,445	22,862	23,138	20,913	21,358	18,991	18,000	18,800	16,408	16,120	16,077	19,707
NRW Rate caused by Zero Consumption(%)	5.9%	4.8%	4.9%	3.4%	5.2%	3.6%	5.0%	4.5%	4.8%	7.0%	7.5%	6.6%	5.3%
Volume/Number (m3/POC)	5.8	5.5	5.1	4.7	5.3	4.1	4.8	4.4	4.3	5.1	5.7	5.4	5.0

3) Water losses associated with meter reading at meter replacement

It was revealed during the meter replacement that the meter replacement had not been recorded accurately and the readings of replaced meters had not been recorded. Therefore, the water consumption measured by the replaced meter was disregarded in the billing for the months of the meter replacement. As the average number of meters replaced in a month was 46, the NRW rate due to meter replacement was estimated at 1.2 % (= 63% x 46 meters/1,242 meters x 0.5 month).

3.7 The action team measures NRW after conducting Activity 3.6 and examines its effectiveness.

In order to measure improvement in the volume of NRW attributable to meter replacement, the totals of meter errors and billed water consumption before the replacement of meters were compared with the post-replacement totals. The result indicates a negligible effect of the meter replacement on the reduction of NRW, as meter errors can work in both ways: overestimation and underestimation. Meter coverage was 100% in the pilot area. The meter replacement exercise was evaluated as follows.

(1) Changes in NRW rates

The meter replacement was carried out at 293 points (91 %) by April 2018. However, the NRW rates in April and May were 39.5 % and 40.0 %, respectively, which were larger than the baseline value of 37.3 %. A slight reduction in the NRW rate was observed later, as the rates in June and July were 31.7 % and 33.6 %, respectively. The WASAC branch office repairs water leaks at an average of 10 points per month in the area. As both the replacement and the repair contribute to the reduction of NRW, it is impossible to tell the effectiveness of the meter replacement on NRW reduction. Therefore, it was not reasonable to evaluate the effectiveness of the replacement of customer meters with monthly NRW rates.

(2) Estimation of NRW reduction with the replacement of meters exceeding the allowable margin of error

The effectiveness of the meter replacement was evaluated by comparing the estimated average errors per meter before and after the assumed replacement of 239 meters that were required to be replaced.

The total errors of the 1,084 meters on which the on-site meter test was carried out was -1,508.21 % and the average error per meter was -1.39 %. Of those, assuming that 239 meters with errors out of ±5 % were replaced, and that the errors of all the replacement meters were ideally zero, the total error would be -749.54 %, or -0.69% per meter. The improvement realized by the actual meter replacement is thus estimated at 0.7 %, the difference between the two errors per meter. This improvement is extremely small. (Note that water consumption of each customer was assumed to be the same before

and after the replacement.)

Table 2.43 Evaluation of effectiveness of meter replacement

Item	Result of survey	Estimation after replacement	
		Errors of meters: 0 %	Errors of meters: ±5 %
Number of points used in the estimation	1,084	1,084	1,084
among which the number of points where pumps were replaced	-	239	239
Total meter error (%)	-1,508.21	-749.54	-1,044.54
Average error (%)	-1.39	-0.69	-0.96

If the calculation of NRW based on the actual data of May 2018, when the replacement of the meters was in progress in Kadobogo, showed a 0.7 % increase of billed water consumption due to the meter replacement, improvement in the NRW rate would be limited to only 0.4 %, as shown in the table below. In this case, it would take 12 years to recover the cost of the meter replacement with the increment in the sale of water realized by the replacement. This calculation result shows that the meter replacement will not produce a financial benefit to WASAC. If a large number of meters have positive errors, the replacement may bring adverse financial effects to WASAC.

Table 2.44 Evaluation of effectiveness of meter replacement based on data of May 2018

Item	Result of survey	Estimation after replacement	Effectiveness
Rate of meter accuracy improvement		0.7%	0.7%
Billed water consumption (m3)	12,822	12,912	90
Distributed water (m3)	21,373	21,373	-
RW rate (%)	60.0%	60.4%	0.4%
NRW rate (%)	40.0%	39.6%	-0.4%

Table 2.45 Effectiveness of investment in meter replacement

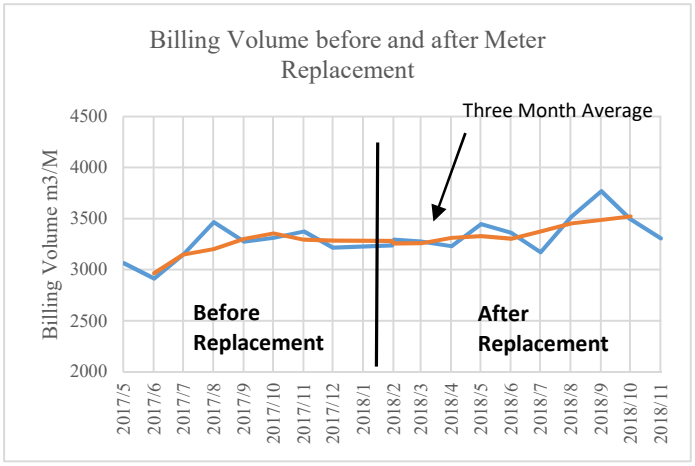
Item	Unit price (Frw)	Quantity	Cost (Frw)
Average water bill	565	90 m3	50,850
Price of meter	30,000	239 units	7,170,000
Repayment period (months)	-	-	141
Repayment period (years)	-	-	12

1) Comparison of water consumption before and after meter replacement

The effectiveness of the meter replacement was evaluated with the comparison of total billed water consumption before and after the replacement. The data of billed water consumption in eight months before and after a reference month, the month in which water meters were replaced, were available at 305 points among the points where the meters were replaced. The comparison of the data revealed a

0.6 % increase after the replacement. It is difficult to conclude that this slight increase was caused by the meter replacement because the data of only six months before and after the replacement were used in the comparison and monthly water consumption changes from month to month. In conclusion, the direct effect of the meter replacement on the entire area is considered quite small.

201706	201707	201708	201709	201710	201711	201712	201801	201802	201803	201804	201805	201806	201807	201808	201809	201810
39	23	24	36	0	0	23	17	14	14	13	10	13	14	13	13	19
7	9	7	7	5	5	5	5	5	4	4	7	0	0	27	9	7
10	10	0	10	12	8	10	5	10	12	14	7	10	12	9	26	10
10	10	0	10	10	11	11	5	10	11	10	7	11	8	10	9	9
0	30	7	6	0	0	0	10	9	0	0	0	0	0	20	0	25
5	8	8	8	10	8	10	10	5	0	11	6	11	10	9	10	8
64	44	36	36	36	29	30	38	47	36	31	38	54	39	42	23	22
9	10	18	12	8	7	16	10	11	8	10	9	12	8	8	10	13
11	14	10	0	19	12	0	0	20	10	9	13	13	11	15	12	13
11	19	29	35	11	18	21	20	21	45	38	31	57	34	37	126	53
8	8	7	0	18	0	13	11	7	8	14	8	9	7	8	10	8
13	0	6	18	20	20	20	20	13	16	0	39	15	16	20	20	16
0	0	0	0	0	0	0	0	35	50	33	201	35	27	24	22	54
0	0	6	18	0	30	13	0	0	0	0	0	0	0	0	0	0
6	0	0	54	18	0	28	0	36	25	22	15	18	22	22	20	15
14	9	9	9	16	15	15	9	17	9	11	5	10	10	10	10	10
15	16	11	11	9	10	10	10	11	16	13	16	18	20	23	23	20
19	20	20	23	21	19	15	22	16	18	12	15	12	14	14	13	18
0	23	10	10	11	0	15	15	0	17	0	20	10	10	21	15	14
9	10	16	10	11	11	13	10	7	6	9	13	12	8	10	11	9
94	101	184	165	156	25	177	92	118	67	145	80	182	113	108	200	142
23	19	23	25	20	17	17	21	26	18	15	19	20	17	20	23	22
49	35	31	40	35	33	28	39	41	33	32	41	35	31	40	44	43
0	14	5	0	0	8	4	7	6	6	6	6	5	2	5	4	6
7	5	5	6	4	5	2	3	5	5	5	5	6	7	7	6	0
0	31	15	0	32	11	5	20	0	27	8	0	0	37	13	11	13
17	25	16	17	24	20	12	19	22	22	18	16	16	18	21	16	15
8	8	8	6	8	7	8	8	0	20	0	0	0	0	0	0	0



Note) Data at some of the 305 points are shown.

Item	Before replacement	After replacement	Ratio
Average monthly billed water consumption: m3	3,314	3,334	1.006

Fig. 2.2 Comparison of billed water consumption before and after meter replacement

A policy for meter replacement was developed in light of the result of meter error measurement. The above-mentioned findings suggest the appropriateness of the following meter management strategies.

- WASAC has installed water meters at a large proportion (nearly 100 %) of POCs.
- While it takes time and labor to calibrate and replace water meters, the benefit of the meter replacement is small in terms of NRW reduction.
- The replacement may have a negative effect because some meters have positive errors.
- The purpose of meter replacement is usually to guarantee the fairness and reliability of billing to customers.
- The following meters should be replaced or repaired immediately:

  Defective meters (to be identified during the meter reading)

  Blocked meters (to be identified during the meter reading)
- The meter accuracy test should be carried out in the cases mentioned below. If a meter has an error below -5 % or above +5%, it should be replaced:

  When the analysis of billed water consumption has revealed abnormally large or small billed water consumption;

  When an abnormality in the movement of the point of a meter or an abnormal change in billed

water consumption from that of the previous reading is found during the meter reading; or
When a customer makes a complaint about the billing.

- Meters shall be replaced at regular intervals of approx. 10 years to maintain their accuracy.
- The possibility of installing a smart meter at a place where it is difficult to carry out meter reading will be studied.

3.8 The action team conducts measures for reducing surface leakage (visible leakage).

3.10 The action team conducts measures for reducing underground leakage (invisible leakage).

(1) Water leakage survey

For the survey purpose, the physical water leakage cannot be clearly distinguished between surface leakage and underground leakage.

Surface leakage is discovered daily during various site surveys (including the customer meter accuracy surveys, customer questionnaire surveys and flow measurements in the water distribution network, etc.) and WASAC's on-site operations. The repair of surface leaks is part of the regular maintenance of each branch and water leaks in the pilot areas are repaired by the branch responsible for the areas immediately after leaks have been discovered.

The survey of underground leakage commenced in January 2018. The measurement of minimum night flow (Qmnf) was carried out to quantify water leakage and the leakage step test was carried out to identify areas with large water leakage. The purposes of the Qmnf measurement are:

- ✓ To know the quantity of existing leakage by area to identify the target location for reducing leakage (step test).
- ✓ To compare the existing leakage quantity before and after for the effect measurement of the leakage reduction activities.
- ✓ To conduct periodic monitoring of the existing leakage quantity.

The step test is a survey method to measure the existing leakage quantity in each section of the survey area by the portable ultrasonic flowmeter (UFM) installed in the inflow pipe while opening and closing the existing stop valve installed in each branch pipe at the section.

In one month, between March and April, the survey found water leakage at 10 points (of which three were underground leakage), which was subsequently fixed. The volume of underground leakage at the three points totaled 7.8m3/h. Since underground leakage continued without being

Water leakage from a HDPE pipe

detected visually, it accounted for some 70% of the 11.59m^3/h NRW in the subzone over the same period. Water leakage was also found at 11 points (of which one was underground leakage) in August, which was fixed subsequently.

Apart from the repair works mentioned above, the Kacyiru branch continues to repair surface leaks every day, and even if one leak is repaired in one place, new leaks seem to occur one after another. The frequent occurrence of water leakage was attributable to the high water pressure and the poor quality of pipe materials.

The table below shows the result of the Qmnf measurement.

Table 2.46 Qmnf Measurement History (Pilot Area 1)

Kadobogo

Date	Time		PM1		PM2		PM 3	
			Qmnf (m3/h)	P (bar)	Qmnf (m3/h)	P2 (bar)	Qmnf (m3/h)	P2 (bar)
May 25-26, 2017			**5.71**	-			**6.49**	-
Jun. 7-8, 2017					**0.21**	-		
Nov. 9-10, 2017					**1.40**	-	**6.00**	-
Nov. 22-23, 2017				**6.5-10.5**				
Nov.30-Dec7, 2017						**0.0-8.0**		**0.5-9.0**
Dec. 20-21, 2017			**7.80**	-	**3.30**	**2.0**	**10.80**	**9.6**
Jan. 11, 2018			**5.50**	**10.5**			**12.50**	
Jan. 24- Feb. 8, 2018				**6.0 - 10.5**		**0.0- 8.3**		**4.0 - 9.3**
Jan. 24-25, 2018					**3.27**			
Feb.22-23, 2018							**13.50**	**7.8**
May 23-24, 2018					**2.90**		Leakage Repair3/22	
May.31, 2018					PRV Re-setting 5/31	**4.0**		Leakage Repair 4/13, 24
Jun. 12-14, 2018					**2.31**	**4.0**		
Jun. 21, 2018					**2.81**			
Jun 25-27, 2018					**0.09**	Leakage Repair 6/24		
Jul. 19-20, 2018			**9.23**		**0.20**	Pipe Replacement 6/28	**9.30**	
Sept. 18, 2018							PRV Setting 9/18	**3.5**
Oct. 5, 2018	PRVBaseline, Stage Test				**0.74**	**7.0**	**9.44**	**7.5**
Oct. 23-24, 2018	PRVEffect Measurement		**7.70**	**10.0**	**0.31**	Pressure Adjustment **2.5**	**5.80**	Pressure Adjustment **5.5**
Nov. 26-27, 2018	PRVEffect Measurement		**10.22**	**10.0**	**0.31**	**2.5**	**3.32**	**2.5**
Dec. 20, 2018							**2.91**	**(12/31) 2.5**
Jan. 22-23, 2019							-	
Jan. 28-29, 2019							**4.71**	
Feb. 5-6, 2019			**(5.38)**	**(PM1-3, 4)**			**3.53**	
Feb.4-28, 2019	PM1Pipe Replacement							
Mar.26-27, 2019			**5.80 (3.1)**	**(PM1-3, 4) 6.5**				**(3/22) 7.22**
								(4/5) 3.5

(2) Replacement of water pipes

The poor quality of water supply and distribution pipes had been considered a major cause of water leakage. In Subzone PM2, frequently leaking distribution pipes (HDPE, PN50, 200m) were replaced with PVC pipes in June 2018, effectively reducing the volume of water leakage by 2.22m^3/h. At the third SC meeting in August 2018, WASAC proposed the replacement of existing distribution and

service pipes in the pilot areas to demonstrate the effectiveness of the replacement. It was decided to perform the replacement in an area within PM1 where substantial amounts of water leakage were identified by a series of Qmnf measurements. The procurement of pipes and other necessary materials and equipment was completed in December 2018. In February 2019, 800m of water pipes were replaced in total.

With reference to the history of repair from August 2017 to December 2018, the leaking points were plotted on Google Earth Map, as shown in the figure below. Ledger data for this period indicated that leakage repair had been performed at as many as 10 points per month on average. Many of the leaking points were found among the existing distribution pipes (HDPE) in PM2 as well as those existing pipes in PM1 which were subsequently replaced in February 2019. Plotting data showing the record of leakage repair on a map in this way helps visualize the area prone to water leakage and the location of problematic water distribution pipes. This approach provides a crucial tool for planning water leakage survey.

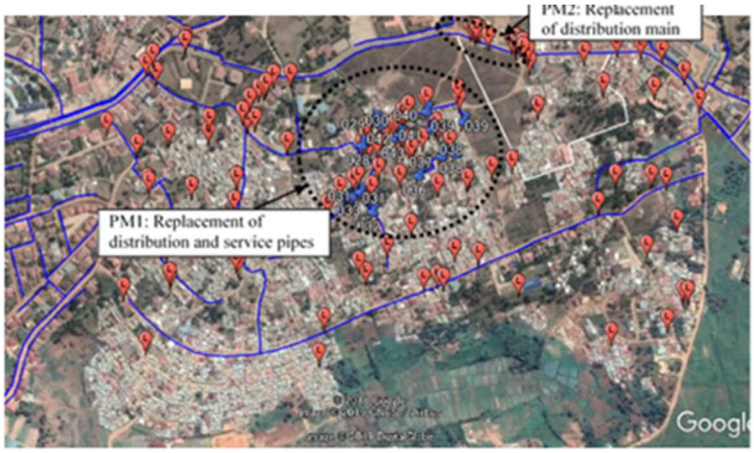


Fig. 2.3 Leakage repair points in Pilot Area 1 (Kadobogo) plotted on a map (before replacement)

As shown below, the replacement of water pipes in Subzones PM1 and PM2 had an effect reduced water leakage quantity more than 40%.

Table 2.47 Effect of water pipe replacement on water leakage reduction

Item	PM1	PM2
Pre-replacement Qmnf (m^3/h)	5.38	2.31
Post-replacement Qmnf (m3/h)	3.10	0.09
Reduction (m^3/h)	2.28	2.22
Reduction rate (%)	42	96

As shown below, the number of leaking repair points dropped sharply in the area of PM1 that benefited from distribution and service pipe replacement.

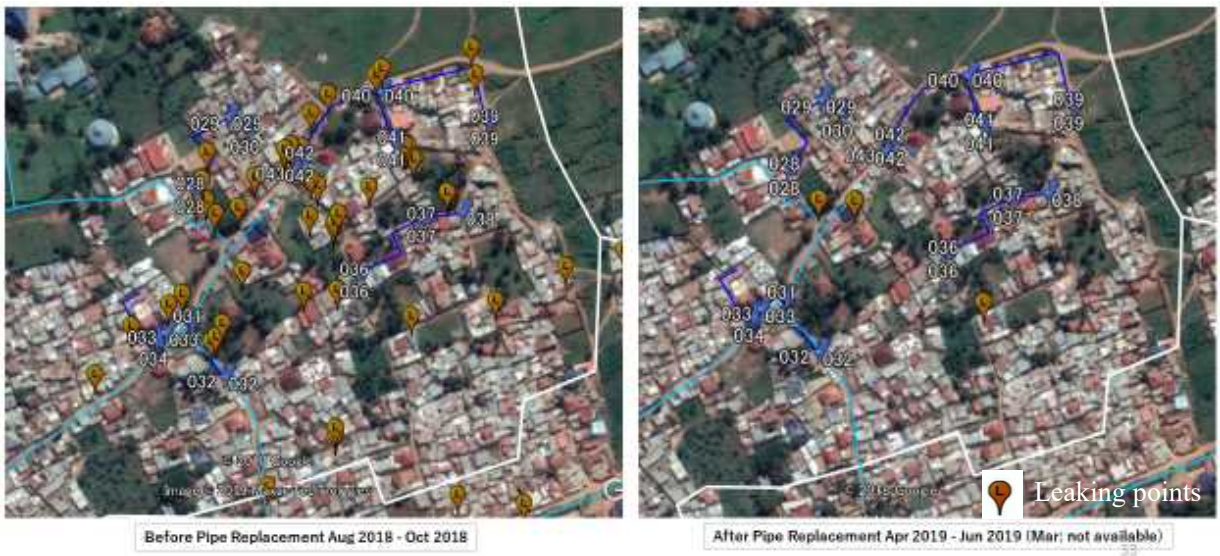


Fig. 2.4 Effect of water pipe replacement on the reduction of leakage repairs

The replacement of existing pipes was carried out in accordance with the management standards of WASAC (Requirements for Water Distribution and House Connection). The technicians were instructed strictly to follow the dimensions of the cross-section of excavation and the required earth covering over pipes in the standards and to use quality earth without stones, gravel or consolidated coarse earth clods for the backfilling. Three 1 cm-mesh sieves were manufactured and used for the preparation of the backfilling material on and around pipe foundation. In addition, as-built drawings (including the plan views, extension, pipe information and x-y coordinates) were prepared and the quantities of the used materials were tallied after the completion of the replacement.

3.12 The Action team conducts measures for reducing high water pressure.

Water leakage detection in Pilot Area 1 was suspended at August 2018 and the monthly monitoring of NRW rate was continued. Since it became clear that water leakage would recur even after repairing if high water pressure measures were not taken, the necessity of pressure management was discussed at the third SC in August 2018, and activities for high water pressure countermeasures were incorporated into R/D's activities.

Since pilot area 1 has a high water distribution pressure exceeding 10 bar at the inflow point of the high level in the area, the decision was made to install pressure reducing valves (PRVs) for the purpose of reducing pressure in the water distribution area. PRVs were installed in August 2018 at the inflow point of each subzone PM2 and PM3 and at PM1 in September 2019.

The operation of PRV launched water distribution with the regulated pressure that is the secondary pressure (P2) 2.0-3.5 bar (minimum feed-water pressure to customers in the area) which was reduced from the high primary pressure (P1). PRVs and pipes that WASAC had in stock were used to install the PRVs. The Japanese side undertook the procurement of the pipes required for the PRV installation that WASAC did not have in stock and the construction of manholes.

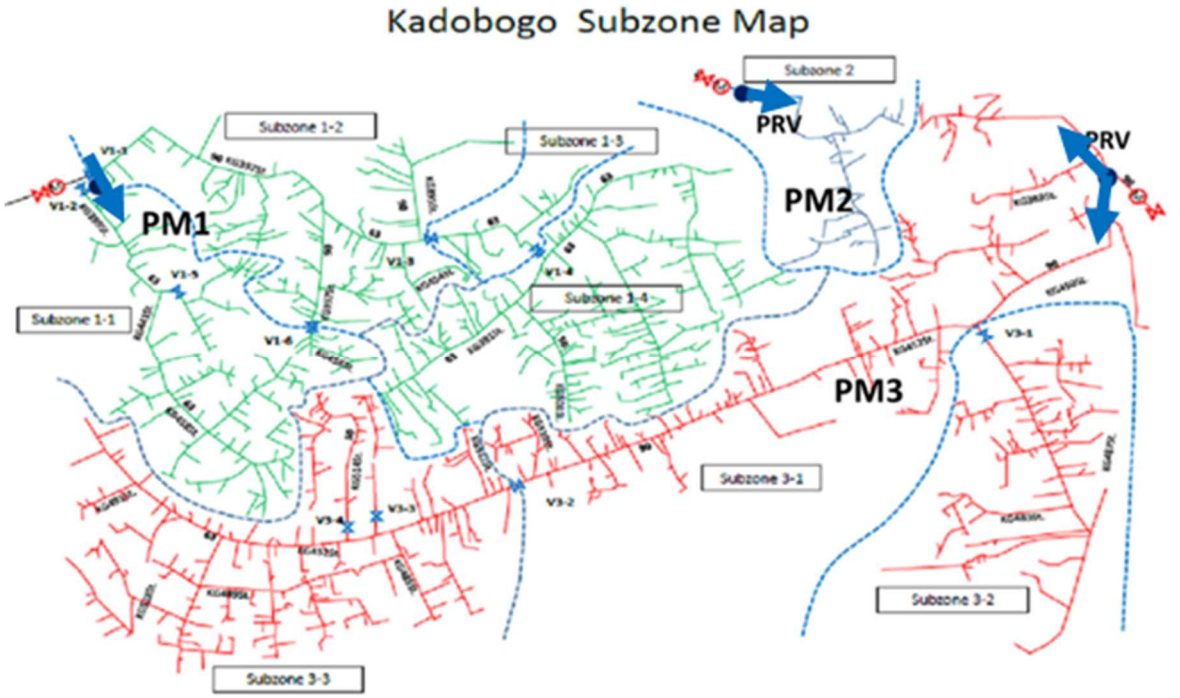


Fig.2.5 PRV Location Map for Pilot Area 1 (Kadobogo)

To verify the effect of PRVs, a staged measurement of the water pressure and Qmnf was conducted in October 2018 in PM2 and PM3. Qmnf was measured while the P2 was reduced by steps of 1.0 bar from the condition that the PRV is fully open. As shown in the figure below, correlation was found between P2 and Qmnf: As P2 is lowered by a PRV, Qmnf decreases.

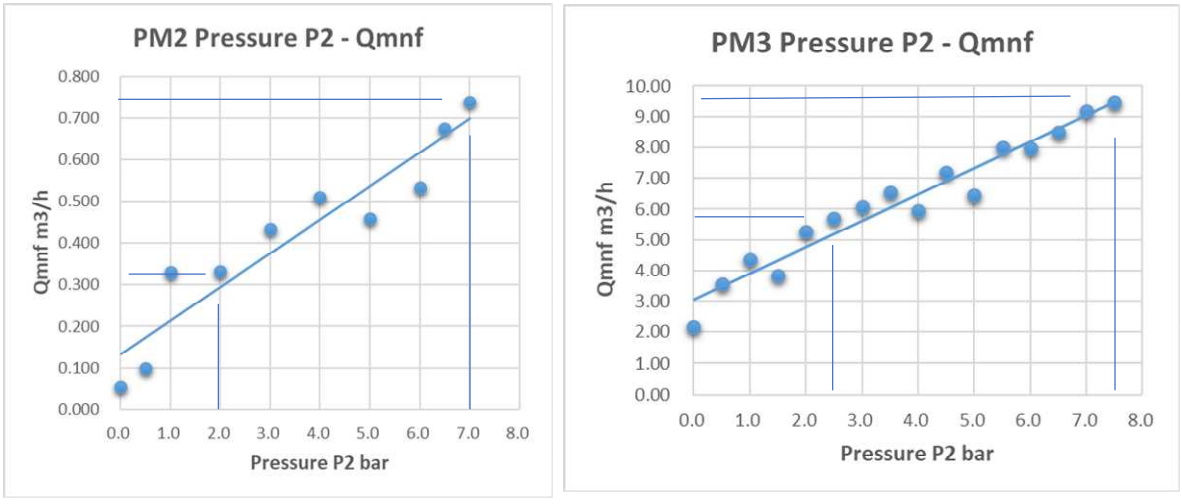


Fig. 2.6 Effectiveness of PRVs (staged P2-Qmnf measurement)

As shown in the table below, the installation PRV effectively reduced the volume of water leakage by 40-60%.

Table 2.48 Effectiveness of PRVs (Pilot Area 1)

Item	PM2	PM3
Pre-installation Qmnf (m^3/h)	0.74 (7.0bar)	9.44 (7.5bar)
Post-installation Qmnf (m^3/h)	0.31（2.5bar）	5.80 (2.0bar)
Effective reduction (m^3/h)	0.43(58%)	3.64(39%)

Water leakage from the PRV in PM3 was detected in October 2018 and the valve was replaced on February 14, 2019. However, in June and July, it was investigating the cause of the rapid increase of leakage in PM3, but it was found that there was a factor in the PRV pressure setting could not being set on scheduled.

Having achieved the 20% target in January 2019, the NRW rate declined to 10%, only to rise gradually to over 20% in June.

The biggest cause was the recurrence of the leak because the function of the pressure management was reduced by the failure of PRV. It was indicated how important the maintenance was after the leak reduction work was carried out.

In pilot area 1 (Kadobogo), the target NRW rate was achieved in January 2019, and trial work as a pilot project was completed, so no water leakage survey has been conducted since February 2019.

3.9 The action team measures NRW after conducting Activity 3.8 and examines their effectiveness.

3.11 The action team measures NRW after conducting Activity 3.10 and examines their effectiveness.

3.13 The action team measures NRW after conducting Activity 3.12 and examines their effectiveness.

In the analysis of the project effect, the effect of all the activities in the pilot projects and that of individual activities on the NRW reduction were evaluated. The effect was evaluated with the following four indicators: i) NRW rate, ii) Number of the repair, iii) Qmnf, iv)Cost-benefit

(1) Change in NRW Rate

The transition of the amount of NRW water and the NRW rate of Kadobogo are shown in the following figure.

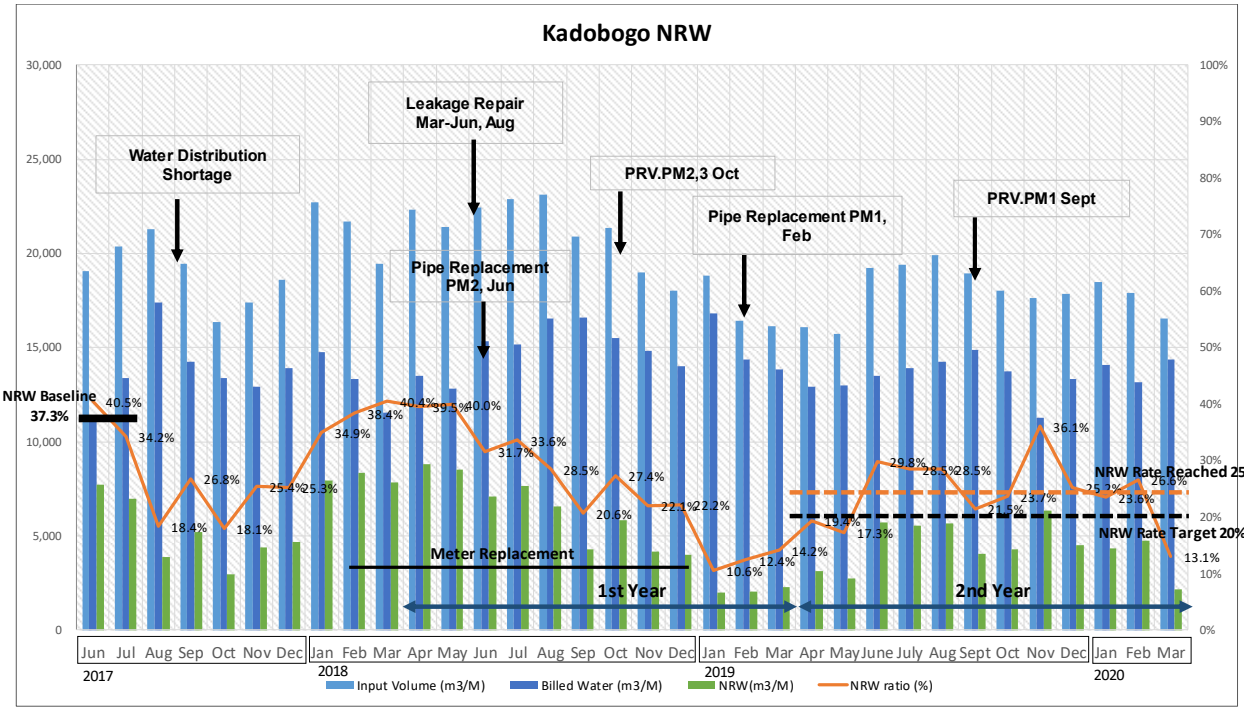


Fig. 2.7 Changes in the NRW volume and rate in Kadobogo

Table 2.49 Changes in NRW indicators in Kadobogo

Kadobogo NRW Rate

Item	2017							2018												2019												2020		
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Input Volume (m3/M)	19,054	20,389	21,279	19,466	16,350	17,366	18,609	22,694	21,677	19,439	22,328	21,373	22,445	22,862	23,138	20,913	21,358	18,991	18,000	18,800	16,408	16,120	16,059	15,712	19,227	19,404	19,885	18,956	18,012	17,633	17,843	18,456	17,911	16,561
Billed Water (m3/M)	11,345	13,412	17,374	14,246	13,397	12,959	13,908	14,765	13,351	11,579	13,499	12,822	15,340	15,175	16,541	16,595	15,496	14,792	14,000	16,816	14,367	13,834	12,939	12,986	13,492	13,880	14,221	14,877	13,736	11,265	13,342	14,100	13,143	14,388
NRW(m3/M)	7,709	6,977	3,905	5,220	2,953	4,407	4,701	7,929	8,326	7,860	8,829	8,551	7,105	7,687	6,597	4,318	5,862	4,199	4,000	1,984	2,041	2,286	3,120	2,726	5,735	5,524	5,664	4,079	4,276	6,368	4,501	4,356	4,768	2,173
NRW ratio (%)	40.5%	34.2%	18.4%	26.8%	18.1%	25.4%	25.3%	34.9%	38.4%	40.4%	39.5%	40.0%	31.7%	33.6%	28.5%	20.6%	27.4%	22.1%	22.2%	10.6%	12.4%	14.2%	19.4%	17.3%	29.8%	28.5%	28.5%	21.5%	23.7%	36.1%	25.2%	23.6%	26.6%	13.1%
POC	1,308	1,312	1,330	1,335	1,335	1,338	1,343	1,351	1,358	1,302	1,306	1,306	1,307	1,307	1,322	1,325	1,326	1,326	1,326	1,353	1,355	1,358	1,359	1,360	1,363	1,363	1,366	1,422	1,422	1,422	1,422	1,429	1,429	1,429

The calculation of NRW rate began in June 2017. The billed water consumption by customers obtained from the meter readings and the flow rates at the inflow points in PM1, PM2 and PM3 measured with the flowmeters installed in manholes were used for the calculation.

Because of the abnormally small precipitation, strict water rationing was introduced in the distribution area in September and October 2017. While the water rationing reduced the water inflow in the pilot area, the billed water consumption in the area did not change much. Consequently, the NRW rate was greatly reduced in these months. As the customers in this area usually used a small amount of water, the water demand in this area was satisfied to a certain level even when water supply was restricted. On the contrary, if the potential inflow increases, the water leakage increases because of the high water pressure in the distribution pipes. Visible leakage has been routinely found and repaired repeatedly.

The NRW rate has been clearly and continuously decreasing since around April 2018. This finding suggests that the full-scale implementation of the leakage survey and repair and the installation of PRVs for reducing the high water pressure in October exerted the effect on the NRW reduction. The

effect of the customer meter replacement implemented up to around April on the NRW reduction was not clearly seen in the change in the NRW rate presumably because the correction of positive error and that of negative error by the replacement offset each other.

In January 2019, the NRW rate was reduced to 10.6 %, which was below the reduction target of 20%. It subsequently followed an uptrend, exceeding 20% in June presumably because of water leakage caused by the malfunctioning of PRV 3. Following the recalibration of PRV 3 and the installation of a PRV in PM1 in September 2019, the NRW rate was stabilized at around 25%. In the final analysis, the whole pilot project succeeded in reducing the NRW rate by 12 points, or 32%.

Table 2.50 NRW rates for the pilot project

Pilot area	Target	Baseline	Achieved	Reduction	Rate of reduction
NRW rate (%)	20	37	25	12	32

Note: The baseline and achieved values represent the averages of June-July 2017 and April 2019-March 2020, respectively.

(2) Changes in the number of leakage repairs (preparation of a map showing the locations of leakage repairs with Google Earth Map)

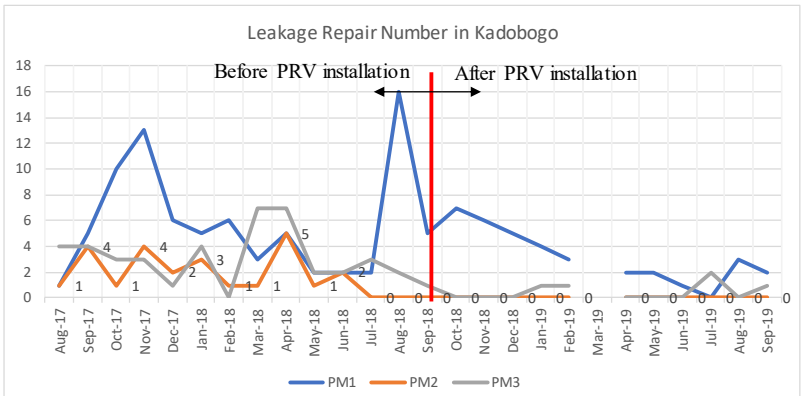
The figure below compares the number of leakage repairs before and after the installation of PRVs in PM2 and PM3. In the whole Pilot Area 1, the total number of leaks declined 65%, from 94 in the 10 months before the installation of PRVs to 33 in the 10 months after the installation. The monthly number of leaks declined year after year thanks to the synergy of leakage repair, PRV installation and water pipe replacement: 12 in 2017, 9 in 2018 and 3 in 2019.

Kadobogo Pilot Area

Leakage Repair Number

Month	PM1	PM2	PM3	Total
Aug-17	1	1	4	6
Sep-17	5	4	4	13
Oct-17	10	1	3	14
Nov-17	13	4	3	20
Dec-17	6	2	1	9
Jan-18	5	3	4	12
Feb-18	6	1	0	7
Mar-18	3	1	7	11
Apr-18	5	5	7	17
May-18	2	1	2	5
Jun-18	2	2	2	6
Jul-18	2	0	3	5
Aug-18	16	0	2	18
Sep-18	5	0	1	6
Oct-18	7	0	0	7
Nov-18	6	0	0	6
Dec-18	5	0	0	5
Jan-19	4	0	1	5
Feb-19	3	0	1	4
Mar-19	No data	No data	No data	0
Apr-19	2	0	0	2
May-19	2	0	0	2
Jun-19	1	0	0	1
Jul-19	0	0	2	2
Aug-19	3	0	0	3
Sep-19	2	0	1	3
Total	116	25	48	189
Average	4.5	1.0	1.8	7.3

PRV installation (PM2,PM3)



Leakage Repair Number (10 months)

Term	PM1	PM2	PM3	
Jan-18～Oct-18	53	13	28	94 Before PRV installation 9/month
Nov-18～Sep-19	28	0	5	33 After PRV installation 3/month

Leakage Repair Number per Month

Year	PM1	PM2	PM3	Total
2017	7.0	2.4	3.0	12.4
2018	5.3	1.1	2.3	8.8
2019	2.1	0.0	0.6	2.8

Fig. 2.8 History of leakage repair in Kadobogo

Maps plotting leakage points clearly indicates the drastic decline in the number of leaks.

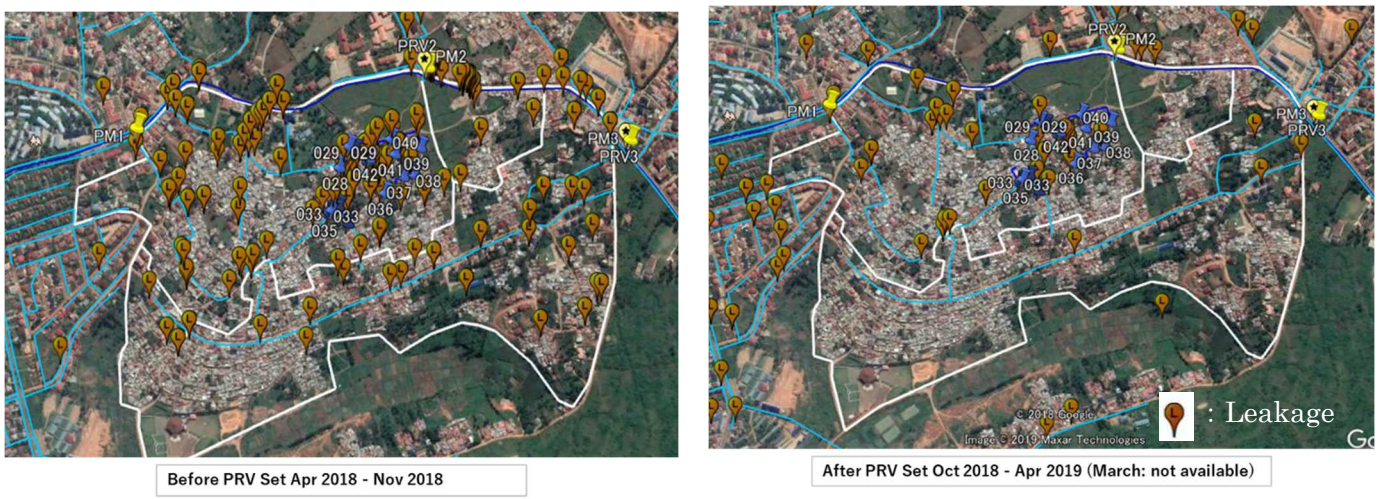


Fig. 2.9 Location of leakage repair points in Kadobogo (before and after the installation of PRVs)

(3) Changes in Qmnf

The history of Qmnf measurement is shown in Table 2.46 above. The figure below, showing the change of Qmnf based on the measurement clearly indicates a decline in the value following the installation of PRV, leakage repair and water pipe replacement.

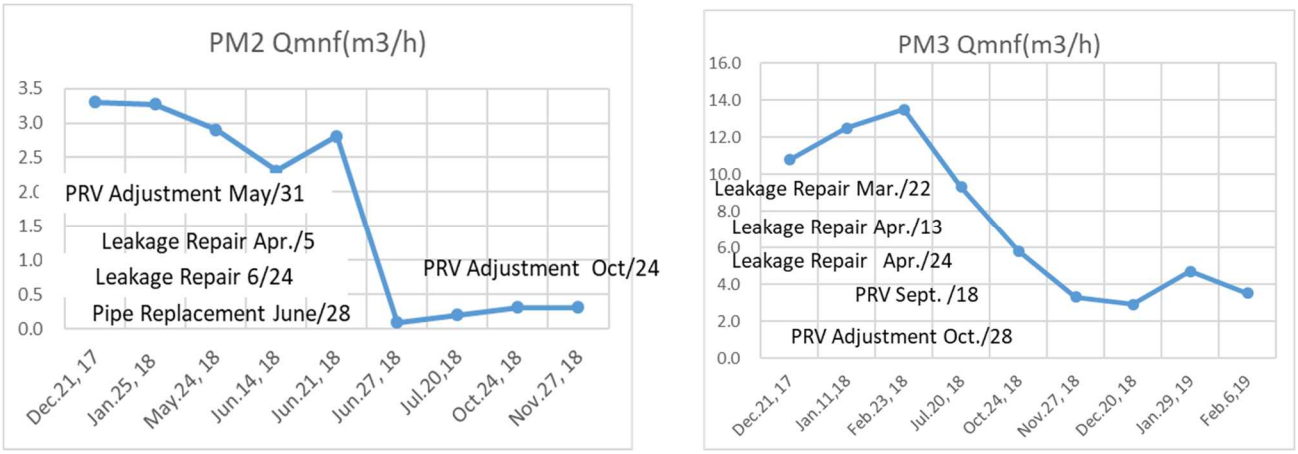


Fig. 2.10 Changes of Qmnf in Kadobogo (before and after the installation of PRVs)

3.17 Action team conducts activities from Activities 3.5 to 3.16 at Pilot Area 2.

3.5 The action team establishes the baseline NRW rate of Pilot Area 1.

As the existence of a pipeline discharging water from Pilot Area 2 to Kigese, outside the pilot area, was revealed in February 2018, a new flowmeter was installed at the exit point from the area to measure the outflow. The measurement of inflow to the pilot area was started in March 2018, and the baseline values were determined as shown in the table below. The monthly NRW rate was calculated for each subzone of the pilot area, based on billed water consumption and the volume of water

distributed to the subzone. The SC meeting held in August 2018 adopted an NRW rate of 25 % as the target value for the NRW reduction.

Table 2.51 Baseline values for Pilot Area 2

Items	Unit	March2018	April 2018	Average
Connection	Number	1,572	1,575	1,574
Input Discharge	m3	54,812	63,327	59,070
Billed water	m3	19,486	17,540	18,513
NRW	m3	35,326	45,787	40,557
NRW Rate	%	64.4	72.3	68.4%

3.6 The action team conducts measures for reducing "Apparent Losses" indicated by the water balance of International Water Association (IWA) for Pilot Area 1.

All 1,705 customer water meters in Pilot Area 2 were inspected visually for their operating conditions first to improve the efficiency of the survey. Then, the time-consuming examination of meter accuracy was conducted only at the places of large consumers with a monthly consumption of at least 20 m^3 in one of the past three months (413 customers). In the questionnaire survey, disconnected customers that were likely to be using water illegally (145 customers) and the customers that had not been billed for water consumption in the past three consecutive months (56 customers) were interviewed on the water sources they depended on, family structures, water consumption, water charges and requests to WASAC. The results of these surveys and the data of monthly billed water consumption were used for the estimation of illegal water consumption and water losses derived from the errors of estimation in the apparent water losses. Measures were taken such as the replacement of defective meters detected in the survey, installation of water meters at illegal connections after their official registration and the training of meter readers on the meter reading.

(1) Result of the meter survey

The customer survey carried out at 1,705 POCs between July and November 2018 revealed the meter installation at 1,702 POCs. The meter installation rate of 99.8% is very high. Among the surveyed meters, 47 were defective and 1,655 were operating. The operation rate of 97 % is good. The meter defects included damaged body, non-operating (blocked) indicator and unreadable index. Water supply was suspended at 6 % of the points and 20 % of the meters were encased.

Table 2.52 Result of the meter survey

Place of installation	Within premises: 47%	Outside premises: 54%
Consumer	Owner: 90%	Tenant: 10%
Operating status	Operating: 97%	Defective: 3%
Meter box	Yes: 20%	No: 80%
Water supply	Normal: 94%	Suspended: 6%

The on-site meter error measurement was implemented at only 413 points of large consumers (consumers who consumed 20 m^3/month or more of water in at least one month between May and July 2018) with the efficiency of the measurement taken into consideration. (Measurement period: August 27 to November 23, 2018).

The meter survey identified 139 points where meter replacement was required: 92 points of large consumers (22 % of the survey points) with inaccurate (measurement error below -5 % or above +5 %) and defective meters and 47 points of small consumers with defective meters. In Kadobogo, where all the meters in the area were surveyed, 28 % of the meters required replacement. The figures obtained in the two areas (Kadobogo and Ruyenzi) indicate that 20 to 30 % of water meters are either inaccurate or defective.

Table 2.53 Result of the meter accuracy test

Meter error	Result of meter accurasy test				Defective	Total
	-5 % or below	Between -5 % and +5 %	+5 % or above	Total		
Large consumer	46	321	40	407	6	413
Accuracy	11%	79%	10%	100%		
Availability	11%	78%	10%	-	1%	100%

Table 2.54 The number of meters required to be replaced

Meter error	-5 % or below	Between -5 % and +5 %	+5 % or above	Defective	Total
Large consumer	46	321	40	6	92
Small consumers	-	-	-	47	47
Total	46		40	53	139

The meter replacement at the 139 points was carried out between December 13, 2018, and January 7, 2019. Meters were replaced at a total of 137 points, 57 in December 2018 and 80 in January 2019.

(2) Water losses derived from illegal consumption and estimation errors

The major causes of the apparent water losses include 1) illegal consumption, 2) water losses derived from the errors in the water consumption estimation and 3) errors in meter reading associated with the meter replacement, in addition to the above-mentioned instrumental errors. The existence of many customers with zero consumption in the pilot areas suggests that the meter reading has not been conducted in accordance with the rules and this poor meter reading has led to the large water losses derived from the estimation errors.

1) Illegal consumption

No clear evidence of illegal use of piped water through illegal connections was discovered in the area. However, three cases of illegal consumption with unauthorized opening of disconnected water taps and intentional removal of meters were uncovered. As the number of these cases was very small

compared with the total number of customers, the losses caused by the illegal consumption were estimated at less than 0.5 % of the total amount of water distributed.

2) Estimation errors where it is impossible to read meters

WASAC is supposed to read the meters of all customers every month. However, there are cases where meters cannot be read because of the inaccessibility due to such reasons as the absence of customers, steep topography and heavy rainfall. In such cases, billed water consumption is often estimated.

Inaccurate meter reading is suspected because of the existence of customers that have been billed for the exactly same amount of water consumption continuously. The table below shows the number of the customers billed for the exactly same amount of water consumption for three consecutive months (May-July 2018) by subzone. The numbers of such customers accounted for 12.9 % of customers (214 out of 1,655 customers). The staff members in charge of billing at the branch informed that they estimated the water consumption of approx. 10 % of customers.

The customers with zero billed water consumption among the customers billed for the exactly same amount of water consumption were interviewed. The interviews revealed that the meter reading has not been conducted appropriately at 50 % of the zero-consumption customers. The error in the estimation of water consumption was estimated from this percentage and average water consumption per customer. The amounts of NRW derived from the estimation errors were estimated at approx. 6.4 % of the water distribution volume in Ruyenzi, where steep topography was found, as of July 2018.

Table 2.55 Number of customers billed for the same amount of water consumption for three consecutive months (May to July 2018) in Ruyenzi

Ruyenzi	RY1	RY2	RY3	Total
Non-zero billed water consumption	30	11	6	47
Zero billed water consumption	103	23	41	167
Total	133	34	47	214 (13%)

Note) The amount of NRW was estimated at 800 m^3 (= 167 customers x 50 % (an estimate based on the result of the interview survey) x 12.6 m^3/m (average monthly water consumption per customer)), which corresponded to 6.4 % of the total amount of water distributed of 16,410 m^3.

The table below shows the result of another survey conducted 18 months later (January-March 2019) after encouraging the branch to conduct robust meter readings. The number of such customers was reduced from 214 to 165. Although these figures suggest the improvement in the meter reading, they also show that the meter reading was not conducted as it should be and water consumption of approx. 9 % of the customers was still estimated. It is estimated that the error in the estimation of water consumption, which is related to the meter reading, still accounted for 4 to 5 % of NRW.

Table 2.56 Number of customers billed for the same amount of water consumption for three consecutive months (January to March 2019) in Ruyenzi

Ruyenzi	RY1	RY2	RY3	Total
Non-zero billed water consumption	20	6	4	30
Zero billed water consumption	84	15	36	135
Total	104	21	40	165 (9.5%)

Attempts were also made to produce estimates from water billing data. Focusing on the data indicating no billed water consumption, the highest possible NRW rate estimated to result from zero water billing was calculated using the monthly billed water consumption volume in the pilot area in the 12-month period, from May 2018 to April 2019. Specifically, the customers who were zero-billed for water consumption in a given month were identified, and compared with the volume of their billed water consumption in another month, assuming that the latter represented the actual volume of water consumption that should have been billed for. The result of calculation shown in the table below indicates that zero-billed water consumption accounts for 3.6% of the total volume of NRW. It should be noted however that this is the highest possible percentage as it includes the customers who actually did not use any water during the month due to disconnection, for example.

Table 2.57 Estimated NRW rate due to zero-billing

Item	May-18	Jun-18	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19	Feb-19	Mar-19	Apr-19	Average
Zero Consumption POC	368	317	294	254	326	272	330	271	257	265	311	287	296
Consumption of other month in comparison of Zero Consumption (m3)	1,258	1,752	1,803	2,073	1,548	1,700	903	1,222	1,970	1,504	1,115	0	1,532
	1,290	1,810	1,770	2,285	1,640	1,757	1,138	1,528	1,947	1,540	0	1,986	1,699
	1,228	930	1,366	1,655	1,491	1,285	886	1,032	1,246	0	1,605	1,236	1,269
	1,378	1,459	1,572	1,760	1,140	1,488	764	893	0	1,782	1,152	1,116	1,319
	1,062	1,495	1,638	1,861	1,234	1,476	785	0	1,817	1,374	1,202	1,263	1,382
	1,488	1,928	1,889	2,204	1,580	1,632	0	2,061	2,542	1,922	1,706	1,915	1,897
	1,258	1,743	1,465	1,757	1,159	0	1,247	1,353	1,998	1,617	1,598	1,803	1,545
	1,881	1,894	1,675	1,694	0	2,358	1,306	1,692	2,397	1,918	1,593	1,890	1,845
	1,307	1,377	935	0	1,694	1,535	1,101	1,497	1,781	1,570	1,461	1,617	1,443
	1,459	1,052	0	1,928	1,912	1,909	1,490	1,798	2,174	1,958	1,621	1,975	1,752
	1,031	0	1,583	2,209	1,850	2,101	1,547	1,777	2,298	1,937	1,731	1,809	1,807
	0	1,623	2,007	2,576	2,189	2,145	1,718	2,008	2,740	2,127	2,041	2,446	2,147
NRW Volume caused by Zero Consumption (m3)	2,147	1,807	1,752	1,443	1,845	1,545	1,897	1,382	1,319	1,269	1,699	1,532	1,636
Input Distribution (m3)	50,826	37,437	40,226	47,153	47,161	51,242	48,539	47,923	49,026	47,189	38,875	45,967	45,964
NRW Rate caused by Zero Consumption(%)	4.2%	4.8%	4.4%	3.1%	3.9%	3.0%	3.9%	2.9%	2.7%	2.7%	4.4%	3.3%	3.6%
Volume/Number (m3/POC)	5.8	5.7	6.0	5.7	5.7	5.7	5.7	5.1	5.1	4.8	5.5	5.3	5.5

3.7 The action team measures NRW after conducting Activity 3.6 and examines its effectiveness.

The table below shows the result of the measurement of meter error carried out at 332 points among the 413 planned points, excluding the points where the measurement cannot be carried out because of water outage or defective stop valves of the meters.

Table 2.58 Evaluation of effectiveness of meter replacement

Items	Result of meter survey	Estimate after replacement
Number of measured meters	332	332
Number of replaced meters	-	86
Total meter error (%)	-79.46	-143.77
Average error per meter (%)	-0.24	-0.43

The total of the error measurements taken at the 332 points was -79.46 %, which corresponded to an average error per meter of -0.24 %. If the 86 inaccurate meters with error out of ±5 % are replaced with new ones and the errors of the new meters are ideally assumed at 0, the total meter error will be -143.77%, or an average error per meter will be -0.43 %. The improvement realized by the meter replacement is estimated as the difference between the average errors per meter before and after the replacement. In this case, the improvement is estimated at -0.19 %, which means the replacement will increase negative error. This estimation shows that, if the correction of positive error is larger than that of negative error, the meter replacement may reduce the total billed water consumption.

3.8 The action team conducts measures for reducing surface leakage (visible leakage).

3.10 The action team conducts measures for reducing underground leakage (invisible leakage).

(1) Overview of the pilot area

As shown in the figure below, Pilot Area 2 consists of Subzones RY1 and RY2, a vast hilly area fed by the Ruyenzi reservoir located at the center, as well as Subzone RY3, where water flows from the Gihara reservoir (400m3) by gravity, after having been lifted approximately 230m.

The distribution of water from the Gihara Reservoir was limited to three days a week, as not enough volume of water was available. Water is constantly pumped up from the Nzove treatment plant to the Ruyenzi Reservoir, but the same water is also delivered to a higher-lying zone (Kigese) through a bypass pipeline of the reservoir.

RY1 is fed by this pipeline. With an elevation difference of 120m in the area and the surplus water pressure of 6.5 bar due to pumping from the Nzove treatment plant, RY1 was characterized by high water pressure (16 bar or more) in low-lying parts, making it difficult to prevent water leakage with ordinary control methods. To RY2 is distributed by gravity from the Ruyenzi reservoir.

The flow rate was measured at the inlet point to each subzone for one week in July 2018 to identify its change and Qmnf. Special attention was warranted in selecting the method for step testing, given that water supply was rationed daily in RY3 and that some of the waters delivered to RY1 was flowing out of the area.

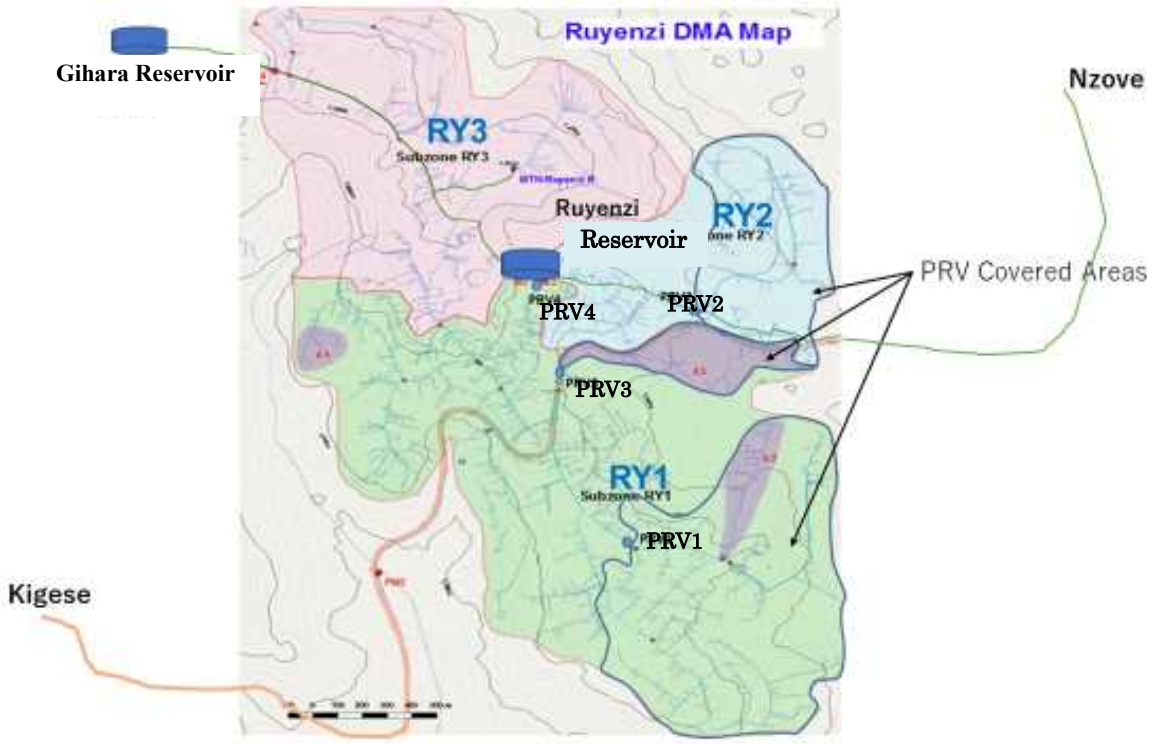


Fig. 2.11　Overview of Pilot Area 2 (Ruyenzi)

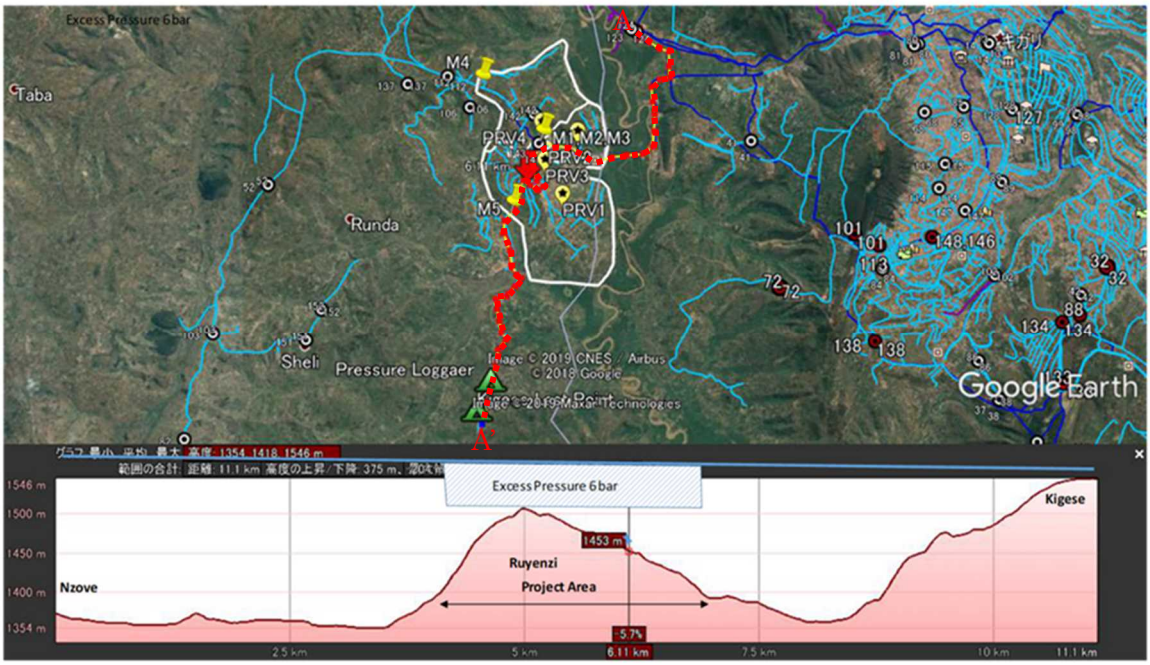


Fig. 2.12　Longitudinal section of Nzove-Pilot Area-Kigese (dotted line A-A')

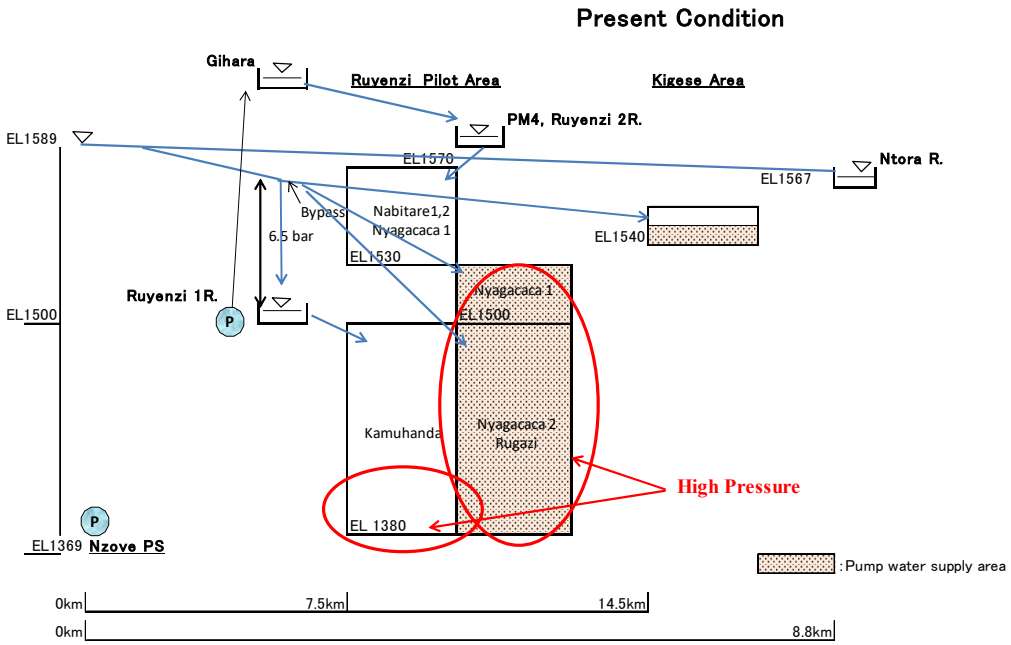


Fig. 2.13 Present water distribution condition

In this area, high water pressure countermeasures (PRV installation) were prioritized based on lessons learned in Pilot Area 1, and next, work was carried out in the order of customer meter test and meter replacement based on test results, and then water leakage survey and repair.

(2) Subzone R1 (distribution area of the bypass) and Subzone R2 (gravity distribution area)

The water leakage survey was started in December 2018 The measurement of the minimum nighttime flow (Qmnf) to know the amount of water leakage was carried out, and a step test was carried out to narrow down the areas where the existing leakage quantity was large. The Qmnf measurement revealed that there was a large amount of leakage of about 28 m^3/h in RY1. In RY2, leakage of about 7m^3/h was found. The large number of water leaks in RY1 could be clearly read from the plot diagram of the leak repair history (right figure). An intensive water leakage survey was carried out in RY1 and RY2 with large amounts of water leakage.

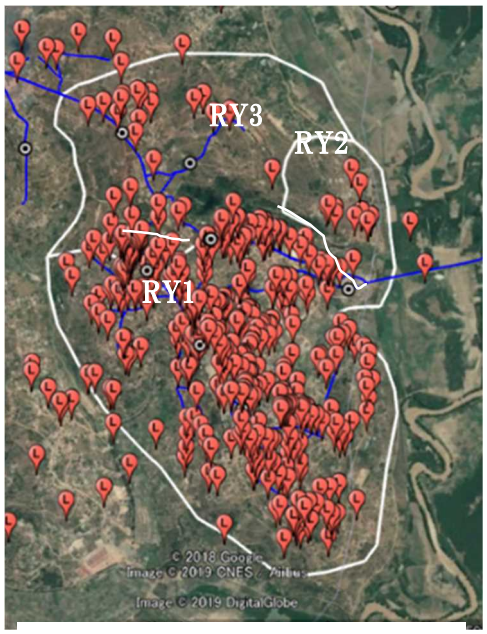


Fig. 2.14 Map plotting leakage repair points

The step test was carried out by making full use of portable ultrasonic flowmeters because the water distribution pipe network was complicated and only a small number of stop valves were installed in the subzone, but since the soil on the road was hard and solid, including some were rocky parts, a great deal of effort was spent on the excavation work for the flow

meter installation. In March 2019, 16 leak repairs were carried out according to the survey results, and then a night time step test was conducted to confirm the effect of the repairs in April, but no noticeable reduction in water leakage could be seen.

In the survey from July 2019, the target area of the survey was narrowed down to RY1 with obviously large water leakage, and within the subzone, the priority survey points of leaks were narrowed down by step test on the piping line of PVC 63 mm pipe. As a result, 14 leaking sites were found and repaired in the month from the second half of July.

When the water pressure was low, the low-quality pipes of the old distribution pipes did not cause serious problems. However, after the high-pressure distribution through the bypass pipeline began, many small-scale leaks have been observed everywhere in the distribution network, particularly on the service pipes of long-time customers.

Two PRVs, PRV1 and PRV3, were installed in RY1 in October 2018, but the coverage of the PRVs was limited to 45% of the whole area due to restrictions related to the existing water distribution facilities and topographical conditions.

(3) Subzone R3（Gravity distribution area）

In RY3, the distribution of water from the Gihara reservoir (400 m3) was limited to three days a week due to insufficient water supply, the water supply was frequently cut off in the daytime due to the water distribution to another area, and, consequently, water consumption at night increased. For this reason, it was impossible to measure the minimum night flow in RY 3. In addition, the Gihara reservoir also distributes water through the bypass pipe, and the storage and adjustment functions that the reservoir should have are not utilized.

As the FVs of the pressure reduction tank (30 m^3) and the reservoir (50 m^3) in RY3 were removed due to being out of order, overflow occurred regularly. In response, an FV (80 mm) was installed in the pressure reduction tank on January 24, 2019. The leakage from the wall surface of the reservoir due to aging forced the use of the bypass pipe for water distribution.

(4) Measurement of minimum night flow (Qmnf)

The purposes of the Qmnf measurement were:

- ✓ To know the quantity of existing leakage by area to identify the target location for reducing leakage (step test).
- ✓ To compare the existing leakage quantity before and after for the effect measurement of the leakage reduction activities.

✓ To conduct periodic monitoring of the existing leakage quantity.

The table below shows the result of the Qmnf measurement.

Table 2.59 History of Qmnf measurement (Ruyenzi)

Flow Measurement (m3/h)

RY1 (Bypass)				RY2 (Gravity)		RY3 (PM4)	
Measurement Day	Bypass (Inflow)	Kigese (Outflow)	RY1 Balance	Measurement Day	Flow	Measurement Day	Flow
Jan. 31-Feb.2, 2018	40～26	-	-				
Jul. 11-18, 2018	30	-	-	Jul. 11-18, 2018	4.8	Jul. 11-18, 2018	6.0
Dec. 3-4, 2018	30.46	2.51	27.95	Dec. 3-4, 2018	7.5	Dec. 3-4, 2018	13.0
Feb. 13, 2019	46.57	14.19	32.38	Feb. 19, 2019	4.7		
April 25-26, 2019	29.8	-	-	April. 10, 2019	2.9		
April 29-30, 2019	22.2	-	-				
May 21, 2019	34.87	-	-				
Jun 27-28, 2019	28	-	-	Jun 27-29, 2019	4.5	Jun 26-28, 2019	16.0
July 22-29, 2019	32－40	-	-				
Aug 07-08, 2019	38.7	3.1	35.6				
Aug 27-28, 2019	38.3	4.7	33.6	Aug 27-28, 2019	5.1		
Sept 19-20, 2019	30.1	1.3	28.8			Sept 2-3, 2019	14.0

PRV1,3 : Started from 28 Sept. 2018, Adjustment on 8 Nov. PRV2: from 16 Nov. 2018 PRV5: from 23 Sept. 2019

(5) Comparative survey of NRW in the three selected service areas

In order to pay attention to the fact that most of the leaks are generated from distribution pipes with small diameter and service pipes, and to understand the extent of the effect, NRW survey was conducted in the three selected service areas (A1, A2, A3) with different water pressures. The outline of the survey method is listed below.

① Select three representative areas with the water pressure distribution, topography, number of POCs, etc. taken into consideration,
② Confirm the locations of POCs and create a POC list,
③ Hydraulically isolate distribution pipes and re-confirm POCs,
④ Install an ultrasonic flowmeter on the inflow pipe and begin data logging with a data logger,
⑤ Perform comprehensive pre-survey customer meter reading at the beginning of the data logging,
⑥ Perform comprehensive customer meter reading after 24 hours,
⑦ Collect the data of in-flow rate and customer water consumption,
⑧ Calculate the NRW rates

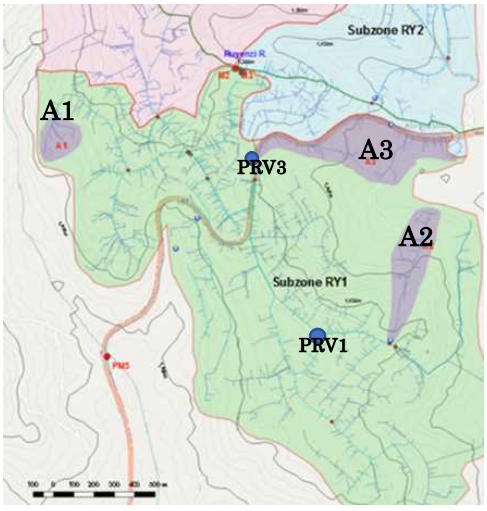


Figure 2.15 Three representative areas (A1, A2, A3)

The survey results are shown in the following table. The NRW rate is as low as 12% for A1, which is relatively low in pressure, but the NRW rate is very high at 76 to 81% for A2 and A3, where the pressure is as high as 10 bar or more. The higher the pressure, the higher the NRW rate.

Table 2.60 Comparative survey of NRW in the three selected service areas

Area		A1	A2	A3
Subzone		RY1	RY1	RY1
Customer		23	20	33
Pipe Diameter	mm	90	63	40
Pressure	bar	4.0-5.5	6.0-11.5	4.0-13.0
Inflow	m3	12.00	35.39	98.02
Consumption	m3	10.58	8.409	18.262
NRW	%	88.2	23.8	18.6
NRW rate	%	11.8	76.2	81.4
Survey Date		29-30,May	20-21,Jul	17-18,Jul

3.12 The Action team conducts measures for reducing high water pressure.

(1) Survey for reduction measures of high water pressure

Since the water distribution area by the bypass water pipe has a high surplus pressure at the Ruyenzi reservoir point (about 65 m), and the altitude difference between the Ruyenzi1 reservoir and the lowest point in the area is as high as 120 m, high pressure acted on the water distribution pipe. When simply calculated from the static water pressure at the reservoir point and the elevation difference, there was a pressure of up to 185m (65m + 120m) in the area.

The four plans mentioned below could be used for the water pressure reduction in the pilot area. The best plan is to terminate the water distribution through the bypass (Plan 1). However, this plan would require the establishment of a self-contained water distribution system in the Kigese Area. Plan 2, a plan to use the bypass exclusively for water delivery would require disconnection of the bypass and distribution pipes and rearrangement of the water distribution network in the pilot area. As a long period and a large amount of money would be required for the implementation of either of the two plans, neither of them could be adopted in the Pilot Project. Because the purpose of this pilot project was to experiment with a water leakage reduction measure, Plan 3, namely the installation of PRVs was adopted for the relative ease of its implementation.

Table 2.61 Candidate plans for the reduction of high water pressure

Plan	Description	Requirement	Implementation period and cost
Plan 1	Complete termination of the use of the bypass	Development of an independent water source and water supply facilities is required for water distribution in the Kigese Area	A long time and a large amount of money were required

Plan	Description	Requirement	Implementation period and cost
Plan 2	Use of the bypass exclusively for water delivery to Kigese (separation from the water distribution network)	Separation of existing water pipes from the main line water pipe to Kigese, rearrangement of water pipes from Ruyenzi reservoir	A long time and a large amount of money were required
Plan 3	Installation of PRVs	Installation of PRVs at multiple locations	Relatively short time and a small amount of money were required
Plan 4	Stop using bypass pipes during periods when water usage is low	Limiting water supply time for customers at night	Short period and no cost

(2) PRV Installation (at 3 locations)

The construction of PRV manholes and installation of equipment in them began on August 27, 2018. The installation of PRVs at two locations in RY1 (PRV1 and PRV3) was completed by the end of September, while the installation of PRV2 at a location in RY2 was completed on November 7. The effect of the PRV installation at these locations was measured in October and November. (See Fig. 2.11: Overview of Pilot Area 2 for their locations.)

1) Subzone RY1

The difference between the water pressure measured at the Ruyenzi reservoir and that at the lowest part of the PRV1 (P2:3.5 bar) pressure reduction area in the night used to be 18.5 bars before the installation of PRV1. However, the installation PRV1 reduced the difference by approx. 6 bars to 12.3 bars. Similarly, at the PRV3 (secondary pressure 2.0 bar) point, what was 21 bar at night was 10 bar, which was reduced by about 10 bar.

2) Subzone RY2

Since some areas in Subzone RY2 are above the elevation at which PRV is installed (EL 1,410 m) and the highest point in the zone is at EL 1,460 m, the secondary pressure of PRV2 could not be reduced below 6.0 bars and this limitation on the pressure reduction interfered with the realization of the effect of PRV2. Therefore, a survey was conducted regarding the rearrangement of the water distribution areas, and the study on the rearrangement was made by WASAC. In order to ensure stable water distribution to the rearranged area, it is a precondition that stable water distribution can be obtained from subzone RY3, but the float valves on the pressure reducing water tank and reservoir within RY3 had been removed because of breakdown, so it was not possible to distribute water in accordance with the demand. On January 24, 2019, a float valve was installed on the pressure reducing water tank. The extension of the (PVC, DN50) pipe from RY3 (for approx. 1 km) was suspended because of the extreme hardness of the ground on the planned pipe installation route and financial problems.

3) Subzone RY3

In Subzone RY3, although there was a central reservoir (Ruyenzi 2) with an effective capacity of 50 m^3, the pipes flowing out from the reservoir are only two 25mm PVC pipes (of which one was for the public tap near the reservoir), the number of customers that were directly supplied was limited to several houses near the reservoir.

Because of the shortage of water, delivery of water from the Gihara reservoir (400 m^3 effective capacity) was restricted to 3 days per week, on Sundays, Mondays, and Thursdays. In addition, the water supply was often suspended in the daytime because the water in the Gihara reservoir was distributed to another area. Because of the suspension in the daytime, the water consumption in RY3 was high at the night, unlike other subzones. Therefore, it was impossible to measure Qmnf in RY3.

Due to water supply restrictions, most of the water delivered from this reservoir was either distributed directly to residents living along the delivery pipe or was distributed directly to customers within the area through a 75 mm PVC bypass pipe branching off from the inflow pipe to the reservoir. Therefore, the storage, adjustment, and pressure reduction functions that the reservoir should have was not being utilized.

When water delivery to RY3 resumed after suspension for the water rationing and water storage tanks of customers was filled, the volume of water delivery decreased. Because of the large flow rate of the water delivery from the Gihara reservoir (72 m^3/h), the Ruyenzi 2 reservoir, which was a small effective capacity (50 m^3), was filled in a short time. As the float valve in this reservoir was removed after it had broken down, the reservoir overflows. The overflow was observed during the field survey. The interviews with the people living near the reservoir also confirmed that the overflow occurred regularly. The reservoir was a masonry structure. It had deteriorated over time and water leaks from its side wall. Therefore, it was decided to terminate the use of this reservoir and distribute water directly downstream through the bypass branching off from the inflow pipe to the reservoir.

There is a 30 m^3 pressure reducing tank in RY3. This tank also overflowed regularly because of the lack of a float valve. To stop the overflow, a float valve (80 mm) was installed in the tank on January 24, 2019.

(3) Verification of the effect of NRW reduction by PRV

1) Verification 1

In order to confirm the effect of PRVs, Qmnf was measured by reducing the secondary pressure (P2) of the three PRVs by steps of 1.0 bar in October and November 2018. As shown in the figure below, there was a correlation between P2 and Qmnf, and it was confirmed that Qmnf decreased reliably as

P2 was lowered by PRV.

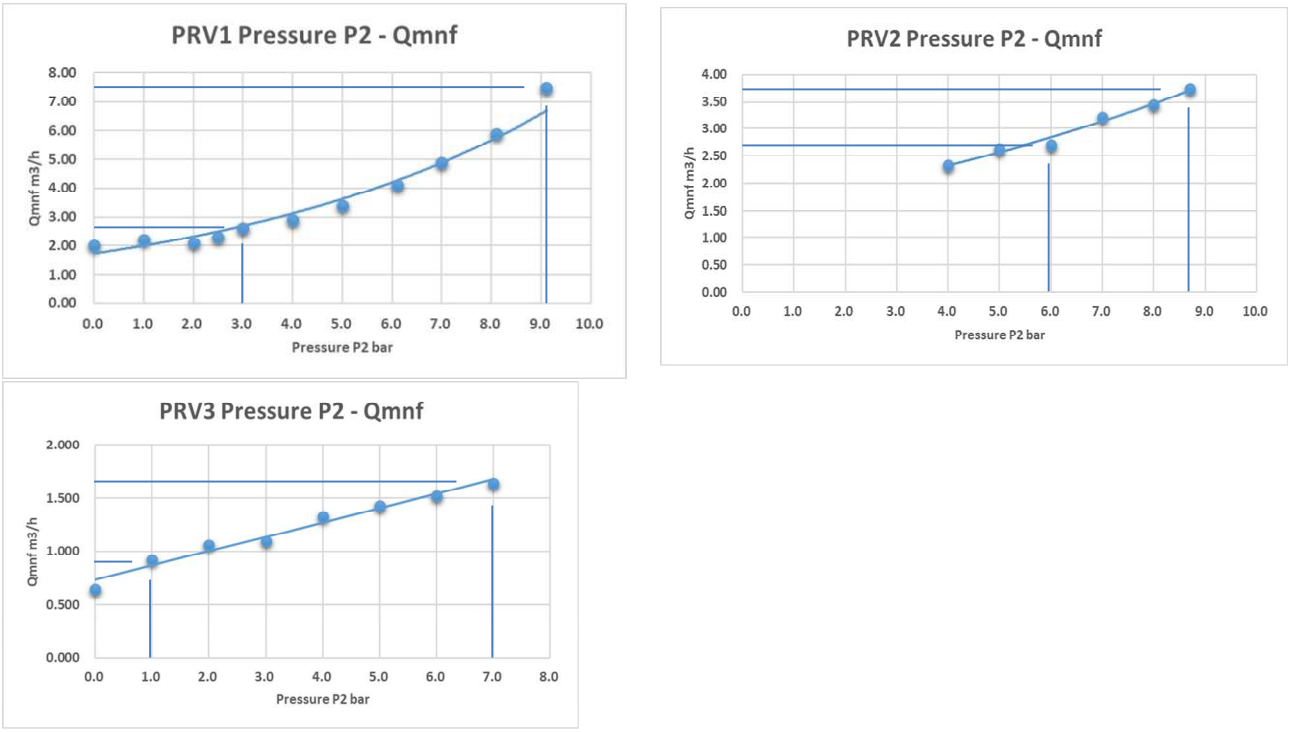


Fig. 2.16 Effectiveness of PRVs (staged P2-Qmnf measurement)

The setting of the PRVs has effects of 30% to 80% water leakage reduction as shown in the table below.

Table 2.62 Effectiveness of PRVs (Pilot Area 2)

Item	PRV1	PRV2	PRV3
Pre-installation Qmnf (m^3/h)	7.48 (9.1bar)	3.74 (8.7bar)	1.84 (7.0bar)
Post-installation Qmnf (m^3/h)	1.50 (2.5bar)	2.60 (6.0bar)	0.78 (1.0bar)
Effective reduction (m^3/h)	5.98(80%)	1.14(30%)	1.06 (58%)

2) Verification 2 (A2 Area)

PRV1, a pressure reduction valve already installed in RY1, was used to verify the effectiveness of PRVs. Specifically focusing on A2, the above-mentioned area located within RY1 for the purpose of pressure control, the NRW rate was compared under two different settings of PRV1: pressure reduction and open.

At the inlet to the area, the volume of inflow was measured with a portable ultrasonic flowmeter. The volume and rate of NRW were calculated by measuring water consumption from the readings of the water meters of all the customers in the area. The measurement for four days, between January 28 and February 1, 2019 - two days each under the pressure-reduced and open conditions - proved that the pressure reduction by the PRV had greatly reduced the water leakage.

As shown in the figure below, the NRW rate increased rapidly from 58.9% to 76.8% when the pressure

setting of PRV1 was not performed, and the reduction effect of 17.9% by adjusting the hydraulic pressure of PRV was verified.

In addition, since the minimum night flow rate at the time of water pressure adjustment was 0.33 m3/ h, the amount of water leakage for two days was 15.84 m3 (0.33 ×24 hours × 2 days), which was 58.2% of the water distribution volume of 27.22 m3, accounting for 99% of the total amount of NRW rate 58.9%. The commercial loss was 1%.

Table 2.63 Verification of the effect of PRV by comparing NRW rates (customer meter readings)

No	POC	Customer Meter Index										Term1	Term2	Total
		1/28	Index	1/29	Index	1/30	Index	1/31	Index	2/1	Index	1/28-1/30	1/30-2/1	1/28-2/1
1	240216057	10:15	173.4650	10:19	173.6301	10:15	173.8429	10:19	173.9304	10:15	174.1213	0.3779	0.2784	0.6563
2	240219060	10:18	69.5110	10:22	69.6738	10:16	69.7955	10:22	69.9240	10:17	70.0684	0.2845	0.2729	0.5574
3	240215957	10:22	548.5635	10:26	548.7984	10:18	549.0543	10:26	549.4645	10:18	549.6815	0.4908	0.6272	1.1180
4	240215943	10:54	389.1254	10:57	389.5320	10:49	389.9639	10:57	390.3298	10:47	390.6981	0.8385	0.7342	1.5727
5	240215956	10:30	546.8480	10:34	547.0218	10:24	547.1580	10:34	547.3200	10:24	547.6149	0.3100	0.4569	0.7669
6	240216079	10:26	347.8170	10:30	348.1116	10:22	348.4000	10:30	348.7868	10:20	349.2018	0.5830	0.8018	1.3848
7	240216980	10:47	146.2615	10:54	146.3068	10:45	146.3613	10:54	146.3613	10:45	146.3613	0.0998	0.0000	0.0998
8	240215999	10:35	329.0225	10:37	329.0225	10:30	329.0225	10:37	329.0225	10:30	329.0225	0.0000	0.0000	0.0000
9	240215997	10:40	331.9978	10:44	332.4374	10:36	332.8468	10:44	333.8402	10:35	334.9868	0.8490	2.1400	2.9890
10	240216931	10:37	189.7955	10:40	189.7955	10:33	189.7955	10:40	189.7955	10:32	189.7955	0.0000	0.0000	0.0000
11	240216000	10:47	186.3451	10:50	186.4766	10:36	186.6048	10:50	186.7342	10:42	186.9236	0.2597	0.3188	0.5785
12	240219327	10:45	47.1357	10:47	47.4076	10:40	47.6236	10:47	47.8723	10:55	48.2193	0.4879	0.5957	1.0836
13	240215963	10:49	447.7114	10:49	448.3951	10:49	448.6958	10:49	449.0844	1:49	449.2113	0.9844	0.5155	1.4999
14	240215941	10:17	115.7802	10:17	115.8602	10:15	115.9002	10:15	115.9802	10:17	116.0602	0.1200	0.1600	0.2800
15	240215940	10:40	426.1317	10:40	426.2995	10:40	426.8453	10:40	426.8652	10:40	427.4164	0.7136	0.5711	1.2847
16	240215939	10:43	1.1169	10:43	1.3450	10:44	1.8774	10:44	1.9243	10:44	2.3485	0.7605	0.4711	1.2316
17	240215973	10:31	136.4575		136.4575		136.4575		136.4575		136.4575		0.0000	0.0000
18	240216233	10:20	606.8958	10:20	607.5193	10:20	608.0367	10:21	608.5171	10:20	608.9875	1.1409	0.9508	2.0917
19	240215938	10:34	219.1010	10:34	219.4544	10:34	219.9235	10:34	220.5942	10:33	220.9744	0.8225	1.0509	1.8734
20	240215964	10:22	37.5482	10:22	37.8942	10:22	38.2043	10:23	38.4309	10:22	38.7634	0.6561	0.5591	1.2152
21	240215965	10:27	246.8660	10:27	247.4695	10:28	247.9081	10:28	248.5196	10:27	249.2205	1.0421	1.3124	2.3545
22	240219638	10:50	12.2012	10:54	12.3125	10:51	12.5721	10:52	12.6624	10:52	12.9512	0.3709	0.3791	0.7500
											Consumption (m3)	11.192	12.196	23.3880
											Inflow (m3)	27.216	52.673	79.8890
											NRW (m3)	16.024	40.477	56.5010
											NRW Rate (%)	58.9%	76.8%	70.7%

Qmnf(m3/h)	0.330
Qmnf 2days(m3)	15.840
Meter Error (m3)	0.184
Commercial Loss(%)	0.7%
Physical Loss(%)	58.2%

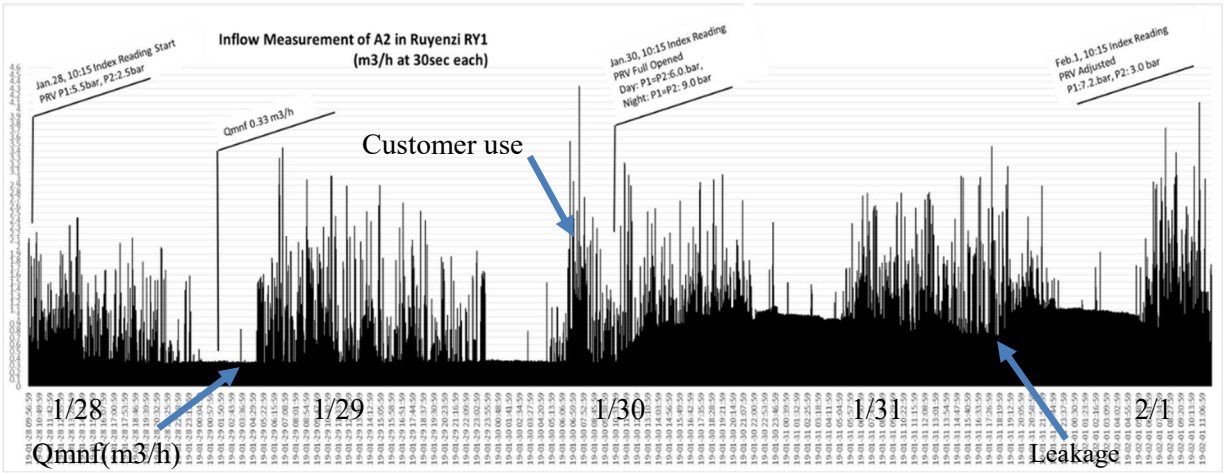


Fig. 2.17 Verification of the effect of PRV by comparing NRW rates (flow measurement)

(4) Installation of PRV4 in RY1 as additional

In this project PRVs were installed on the water distribution network at 3 locations as described above, but it has been concluded from the results of the monthly monitoring of the NRW rate that this measure had limited effect, as no significant effect was observed in terms of reduction in the NRW rate in the pilot area a whole.

It is not possible to maintain the pressure at a low level all the time, because water must be distributed to the Kigese Area, outside the pilot area. Therefore, reducing water pressure in the bypass to the Ruyenzi reservoir in the night was proposed as a compromise between Plans 3 and 4 mentioned in Table 2.61. In discussions with the C/P, it was decided that the additional PRV4 should be installed on the distribution pipe directly below the reservoir. Construction commenced on May 14, 2019, and was completed on June 30.

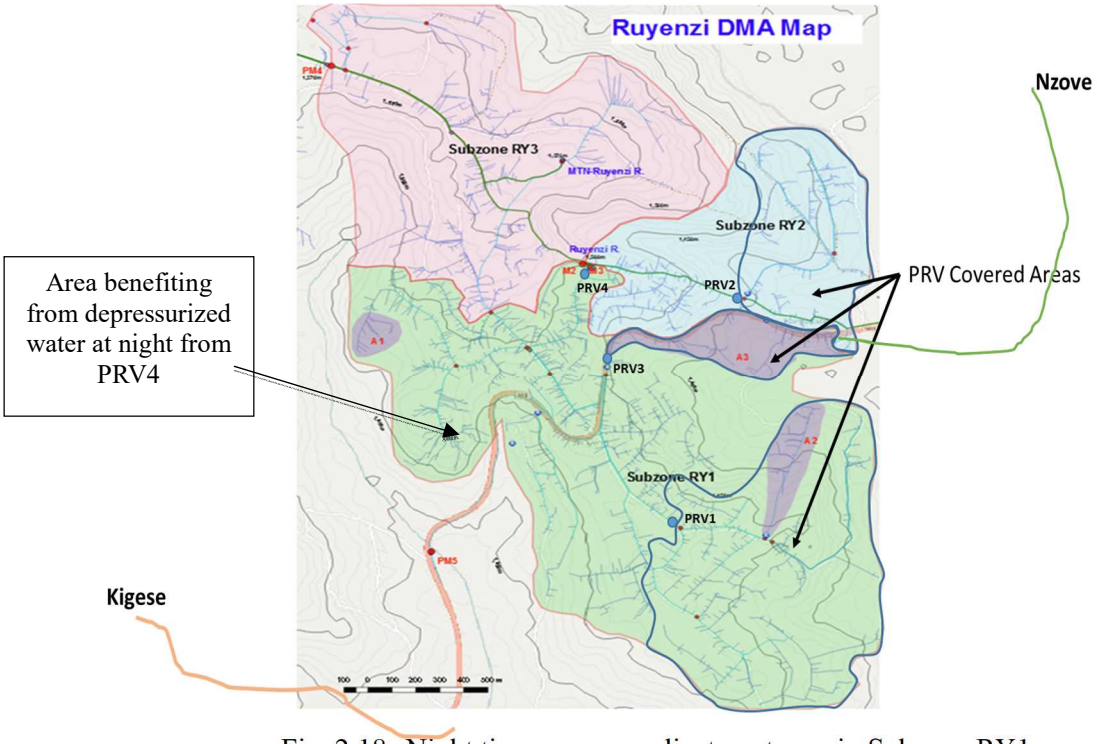


Fig. 2.18 Night time pressure adjustment area in Subzone RY1

The pumped water delivered to the Ruyenzi reservoir by the Nzove treatment plant passes through the bypass of the reservoir, and the water which lot of it become to leakage is distributed to the subzone RY1 in the pilot area, and finally about 10% of the volume of inflow water is delivered towards Kigese. Kigese is located at an elevation about 40 m higher than the Ruyenzi reservoir, and therefore the excess pressure of about 65 m available at the Ruyenzi reservoir was leveraged to deliver water to the area.

In the flow rate measurements of PRV4 on the bypass at the Ruyenzi reservoir, the minimum flow rate at night time was about 40 m^3/h in both July and August as shown in the figures below.

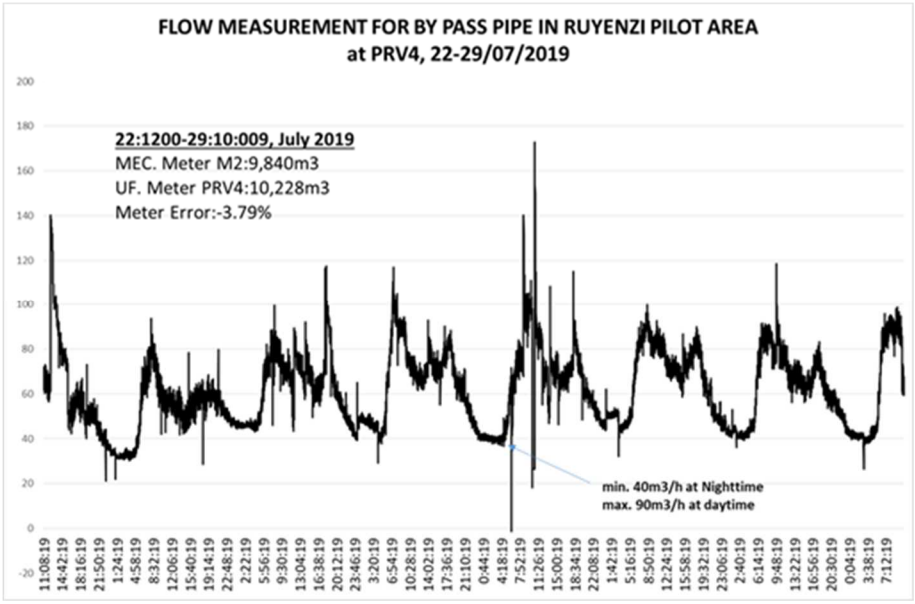


Fig. 2.19 Measurement of the flow rate for 7 days directly below the Ruyenzi reservoir (flow rate into the RY1 area)

In order to reduce the amount of water leakage, since it becomes impossible to supply water to Kigese when reduced pressure for 24 hours by PRV4, it was decided to use PRV4 only at night (PRV is installed in the bypass pipe and switching from the main pipe), and nighttime operation was started on August 29.

The pressure of secondary side of PRV4 was set to 3.5 bar (reduced amount: about 3.0 bar) considering the minimum water distribution pressure in RY1. The table below indicates how PRV4 was operated to regulate water pressure at night.

Table 2.64 PRV4 operation method

PRV4 operation	Usage time	Pilot area RY1	Kigese
Use of main pipe	4:00 to 21:00 (17 hours)	Same status as previously.	Water can be supplied. Pressure of 0.5 to 1.5 bar is envisaged. However, water supply will be difficult in the time periods when the quantity used in the pilot area is high, so the time period in which water can be supplied is envisaged to be 13:00 to 18:00 hours.
Use of PRV on secondary pipe	21:00 to 4:00 （7 hours）	Pressure reduction of about 3.0 bar to reduce water leakage in RY1 at night. Pressure within RY1 is envisaged to be 1.0 to 6.0 bar.	The pressure is insufficient, so water will not be supplied to Kigese. Water leakage out of the area from RY1 to Kigese will also be reduced.

The result of the effect measurement is shown in the figure below. The operation of PRV4 reduced the amount of NRW by 4.7 m3/h (33.6-28.9) at night, but the amount of NRW was still as high as 29 m3/h.

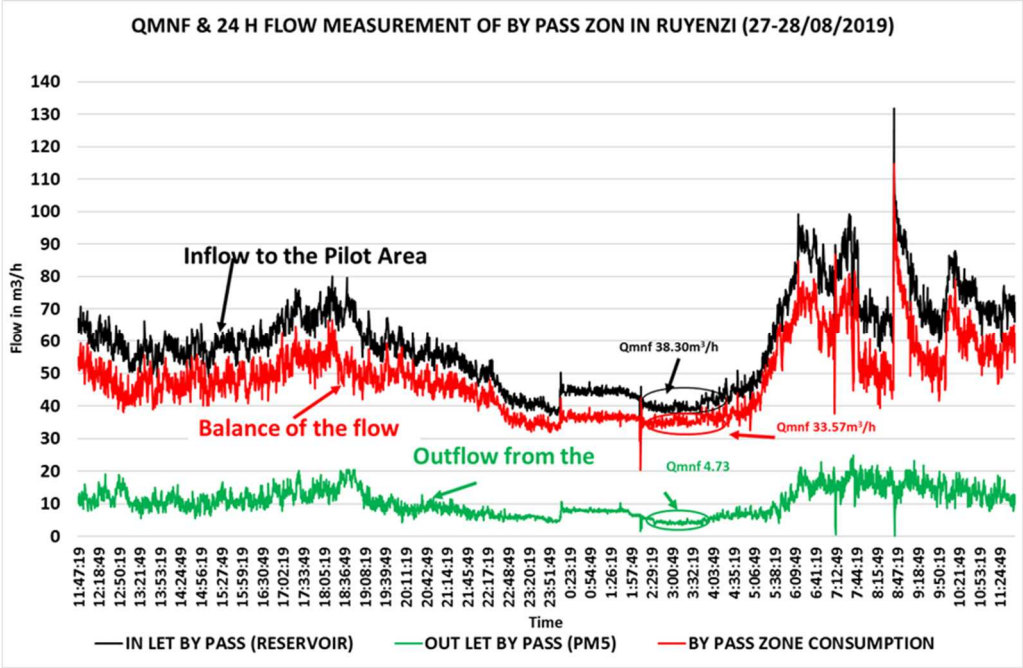
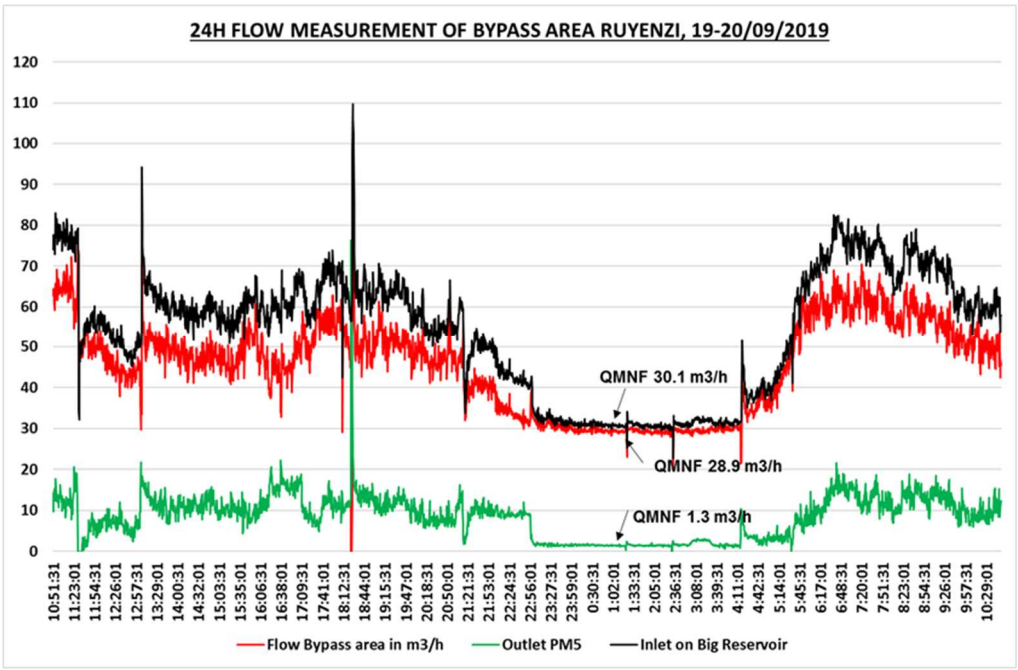


Fig. 2.20 Measurement of Flow Rate in RY1 (before the installation of PRV4)



Fig, 2.21 Measurement of Flow Rate in RY1 (after the installation of PRV4)

In order to further reduce the water leakage, it was necessary to further lower the secondary side setting pressure of PRV4, but it was determined that it was impossible to take additional measures because part of subzone RY1 would be not able to supply water in that case.

3.9 Action Team to measure the NRW rate in Pilot Area 2 after conducting Activity 3.8 and examine its effectiveness

3.11 Action Team to measure the NRW rate in Pilot Area 2 after conducting Activity 3.10 and examine its effectiveness

3.13 Action Team to measure the NRW rate after conducting Activity 3.12 and examine its effectiveness

The project effect was evaluated in the activity of the pilot project as a whole, and it was evaluated in the individual activity. The effect was evaluated by four items: NRW reduction rate, number of water leakage repairs, Qmnf, and cost-benefit.

(1) Changes in NRW

The transition of NRW volume and NRW rate of Ruyenzi is shown below.

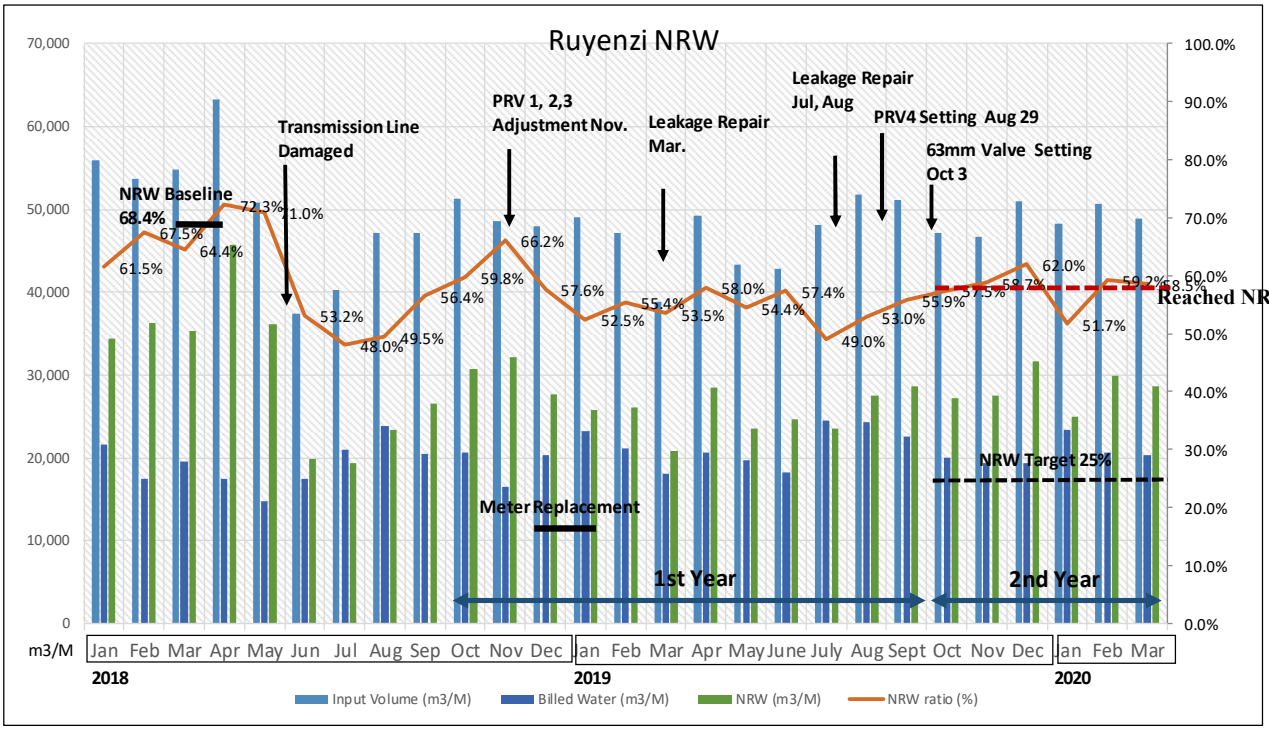


Fig. 2.22 Changes in the volume and rate of NRW in Pilot Area 2

Table 2.65 NRW indicators for Pilot Area 2

Ruyenzi NRW

Item	2018												2019												2020		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Input Volume (m3/M)	55,992	53,704	54,812	63,327	50,826	37,437	40,226	47,153	47,161	51,242	48,539	47,923	49,026	47,189	38,875	49,156	43,285	42,917	48,084	51,863	51,135	47,168	46,755	50,999	48,312	50,589	48,916
Billed Water (m3/M)	21,574	17,441	19,486	17,540	14,753	17,520	20,910	23,820	20,543	20,588	16,427	20,304	23,271	21,055	18,094	20,662	19,722	18,264	24,518	24,397	22,571	20,030	19,306	19,392	23,326	20,651	20,283
NRW (m3/M)	34,418	36,263	35,326	45,787	36,073	19,917	19,316	23,333	26,618	30,654	32,112	27,619	25,755	26,134	20,781	28,494	23,563	24,653	23,566	27,466	28,564	27,138	27,449	31,607	24,986	29,938	28,633
NRW ratio (%)	61.5%	67.5%	64.4%	72.3%	71.0%	53.2%	48.0%	49.5%	56.4%	59.8%	66.2%	57.6%	52.5%	55.4%	53.5%	58.0%	54.4%	57.4%	49.0%	53.0%	55.9%	57.5%	58.7%	62.0%	51.7%	59.2%	58.5%
POC	1,459	1,514	1,572	1,575	1,581	1,585	1,590	1,598	1,618	1,616	1,623	1,629	1,664	1,674	1,675	1,715	1,739	1,743	1,748	1,799	1,847	1,847	1,892	1,894	1,902	1,902	1,910

The calculation of the NRW rate began in January 2018 based on the customer's billed water volume and the in-flow volume which was metered at the inflow points of subzones RY1, RY2, and RY3.

In the aftermath of the flooding of the Nyabugogo river in May 2018, no water was delivered to Pilot Area 2 until the restoration of the aqueduct over the river from Nzove, which was washed away by the flood. The NRW rate dropped sharply as a result.

The installation of the three PRVs immediately demonstrated their effect, as the NRW rate decreased 13%, from 65% in November 2018 to 52% in January 2019. The improvement stalled, however, despite leak repairs performed in March.

The rate subsequently fell to 49% at one time, thanks to further leak repairs in July and August, but then increased again due to the restoration of the leak, and remained at around 58%, which is far from the target value (25%).

Although the effect of PRV installed in a limited part of the area was effective for each control area, the installation position of the PRV was the lower reaches of the area, and only about 45% of the overall area could be controlled, and the degree of effect was small when viewed throughout the pilot area.

PRV4 was installed for nighttime pressure control in the remaining areas, and its operation was started on August 29, but the visible effect was not shown in NRW calculations. Further, in the area of RY2, since there is a small area with high elevation in the PRV covered area, the pressure could not be lowered to 6 bar or less, and it was an inhibitor of effect expression.

The NRW rate in the pilot area should be monthly monitored even after the completion of the pilot project and follow-up with regular maintenance. The reading of water distribution volume was discontinued in April 2020, however, due to the COVID-19 pandemic.

The high pressure of water supplied from the Nzove pumping station was a major cause of leakage as it was distributed directly through a pipeline bypassing the reservoir of the pilot area.

Table 2.66 NRW rates for the pilot project

Pilot area	Target value	Baseline value	Achieved value	Reduction	Rate of reduction
NRW rate (%)	25	68	58	10	15

Note: The baseline and achieved values represent the three-month average of March-April 2018 and October 2019-March 2020, respectively.

(2) Number of leakage repairs (plotting the location of leakage repair points on Google Earth Map)

The repair history from July, 2017 to September, 2019 is shown in the following table. On average, 25 leaks occur a month, and it can be seen that there are many leaks in Ruyenzi, where the problem of high water pressure is serious. Among them, there are obviously a large number of repairs in the

bypass area RY1 of the Ruyenzi reservoir, which is a direct delivery area of the Nzove pumping station.

The table (numbers of leakage repairs before and after the installation of PRVs) and figure (map plotting leakage points) below compare the numbers of leakage repairs before and after the installation of PRVs. The map plotting the leakage points indicates a clear reduction of repairs in the areas located downstream to the PRVs installed in RY1 and RY2. Nevertheless, the total number of leaks in the subzones was not affected by the installation of PRVs: 56 in the 10 months before the installation and 58 in the 10 months after the installation. This might be attributed to an increase in leaks in areas upstream of the PRVs.

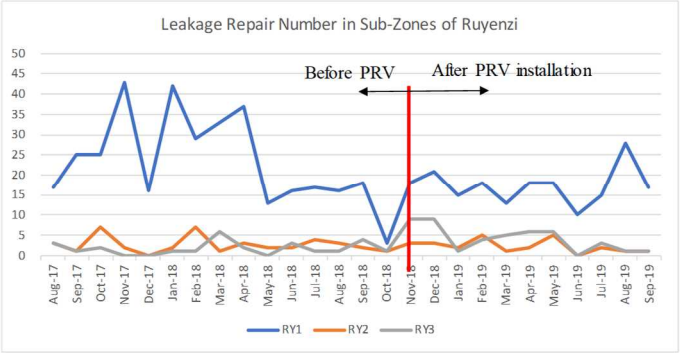
For the whole pilot area, the monthly number of leaks marginally declined year after year thanks to the synergy of leakage repair and PRV installation: 29 in 2017, 28 in 2018 and 22 in 2019.

Ruyenzi Pilot Area

Leakage Repair Number

Month	RY1	RY2	RY3	Total
Jul-17	4	0	1	28
Aug-17	17	3	3	23
Sep-17	25	1	1	27
Oct-17	25	7	2	34
Nov-17	43	2	0	45
Dec-17	16	0	0	16
Jan-18	42	2	1	45
Feb-18	29	7	1	37
Mar-18	33	1	6	40
Apr-18	37	3	2	42
May-18	13	2	0	15
Jun-18	16	2	3	21
Jul-18	17	4	1	22
Aug-18	16	3	1	20
Sep-18	18	2	4	24
Oct-18	3	1	1	5
Nov-18	18	3	9	30
Dec-18	21	3	9	33
Jan-19	15	2	1	18
Feb-19	18	5	4	27
Mar-19	13	1	5	19
Apr-19	18	2	6	26
May-19	18	5	6	29
Jun-19	10	0	0	10
Jul-19	15	2	3	20
Aug-19	28	1	1	30
Sep-19	17	1	1	19
Total	545	65	72	705
Average	20.2	2.4	2.7	26.1

PRV installation (PRV1,2,3)



Leakage Repair Number (10 months)

Tarm	RY1	RY2	RY3	
Feb-18～Nov-18	200	28	28	256 Before PRV installation
Dec-18～Sep-19	173	22	36	231 After PRV installation

26/month

23/month

Leakage Repair Number per Month

Year	RY1	RY2	RY3	Total
2017	21.7	2.2	1.2	28.8
2018	21.9	2.8	3.2	27.8
2019	16.9	2.1	3.0	22.0

Fig. 2.23 History of leakage repair in Ruyenzi

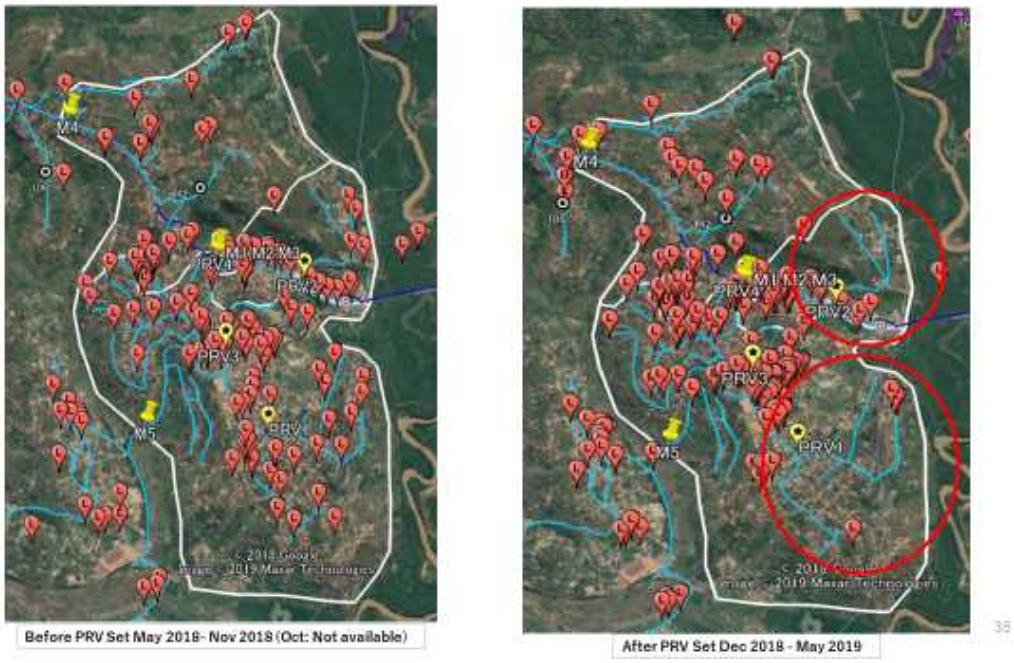


Fig. 2.24 Map plotting the location of leakage repairs in Ruyenzi

(3) Changes of Qmnf

The changes of Qmnf prepared based on the measurement result of table 2.59 is shown in the figure below. Qmnf decreases immediately after leak repair and PRV is installed, but Qmnf can be read that it has been restored afterwards.

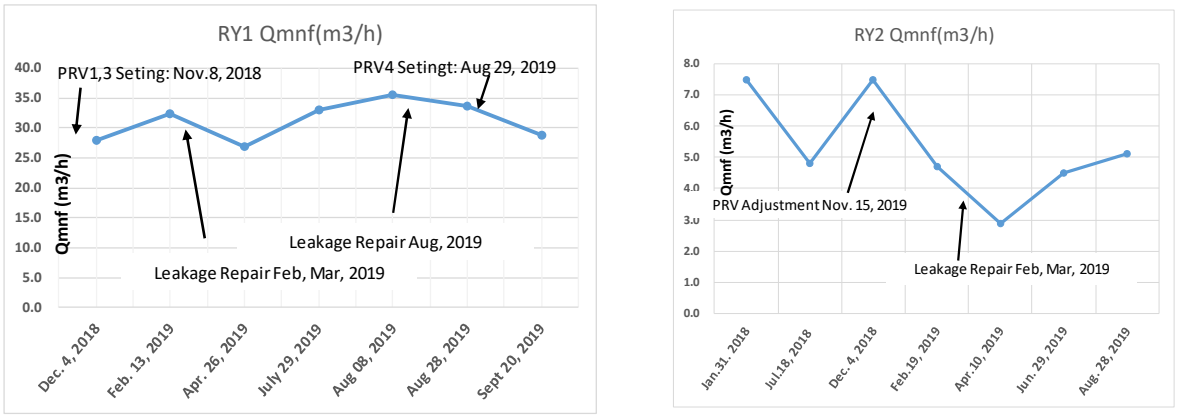


Fig. 2.25 Changes of Qmnf in Ruyenzi

3.14 The action team reviews the results from Activities 3.5 to 3.13, and undertakes cost-benefit analysis of NRW for each Activity of 3.6, 3.8, 3.10 and 3.12.

A cost-benefit analysis was performed to evaluate the outcome of the NRW reduction activities in the pilot projects.

1) Verification of the effect of the pilot projects

1. Used Data

Application periods of the data used for cost-benefit analysis are as the table shown below.

Calculations are based on actual data as of March 2020 pertaining to Pilot Area 1 (Kadobogo) and Pilot Area 2 (Ruyenzi).

Table 2.67 Period of the Cost-benefit Analysis of the Pilot Project

Pilot Area	Baseline	NRW Reduction Activity Implementation Period 1st Year	Effect Evaluation Period of NRW Reduction Activity 2nd Year
Kadobogo	Jun, July 2017	Apr. 2018～Mar. 2019	Apr. 2019～Mar. 2020
Ruyenzi	Mar. Apr. 2018	Oct. 2018～Sept. 201	Oct. 2019～Mar. 2020

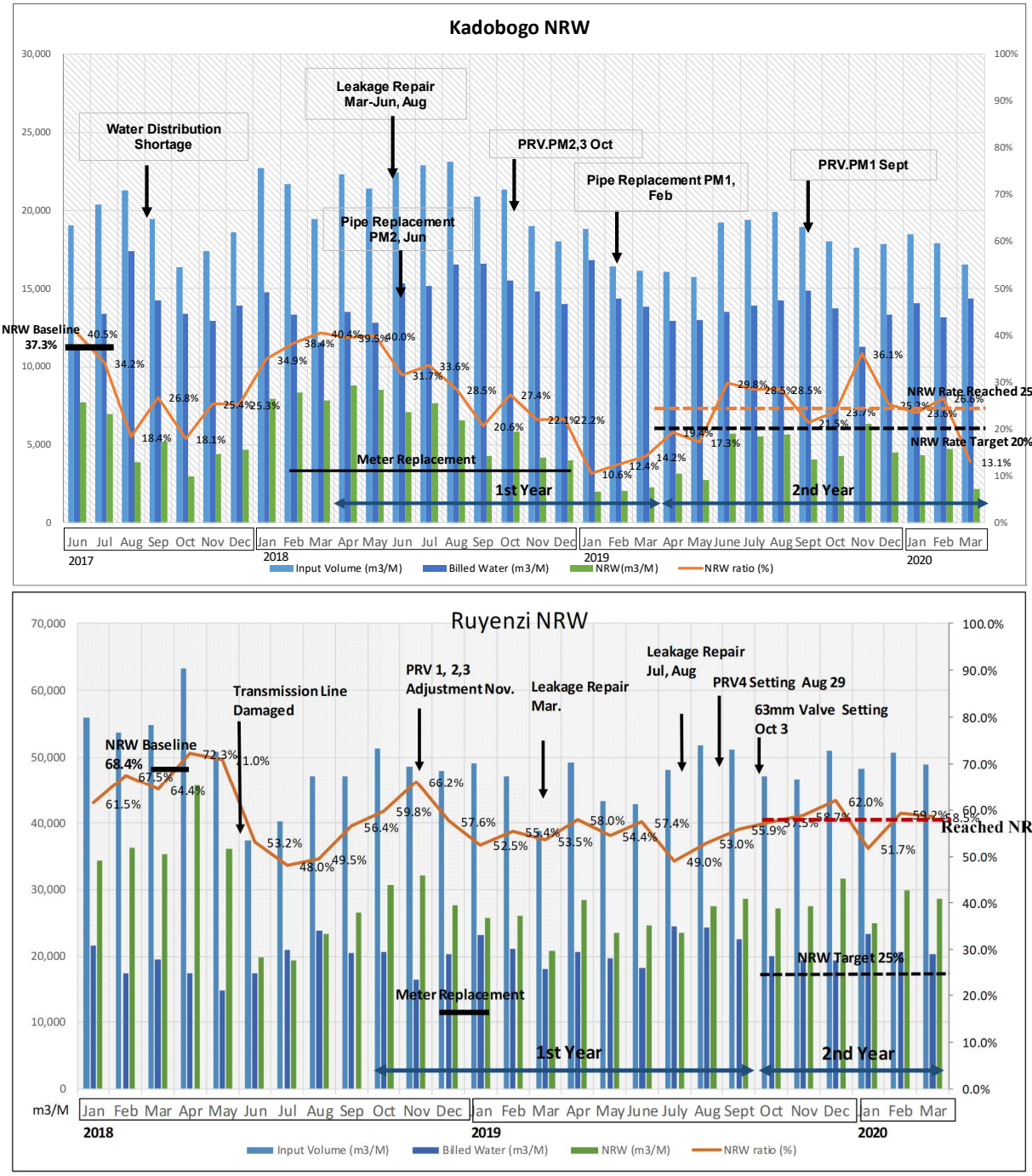


Fig. 2.26 Change of Qmnf in Kadobogo and Ruyenzi

2. Analysis method

i) Benefit generated from the NRW reduction activities

An NRW reduction volume is calculated as the difference between those when the activity was to be implemented (With-project) and when it was not to be implemented (Without-project). The cumulative volume of this difference is an effect volume, and the benefit was calculated by multiplying a water unit price by the effect volume. It was assumed that any surplus water generated by the NRW reduction activities would be used to increase water consumption by the customers, and hence water bills.

ii) Conversion of benefit and cost to "present values"

Benefit is generated and cost is incurred by the activities over the years. For an activity that generates benefit for a long time, a value of benefit at a time different from the present is different from that of the same benefit at present. To compare benefit generated and cost incurred over the years, all benefits and costs need to be converted into "present values," values adjusted to those at a certain fixed point in time, using the following formula:

$$PV = A \times 1/(1+i)^n,$$

where PV : Present value,

A : Benefit generated or cost incurred in the n-th year of the implementation of an activity

i : Discount rate = 6 % (the average of the consumer price index, inflation rate and bank interest rate in Rwanda for the past 10 years)

A net present value (NPV) is calculated by subtracting gross cost from gross benefit. The NPV of this project is obtained by subtracting the NPV in the Without-project case from that in the With-project case. The formula to calculate NPV is as follows:

$$NPV = \Sigma\ (Bt-Ct)/(1+i)^t,$$

where Bt : Benefit in the t-th year

Ct : Cost in the t-th year

T : Numbers of years of an activity

i : Discount rate

iii) Relevance of Project Activities

Investment in project activities is considered relevant if the net benefit from the project is larger than its cost and the return of the investment is large, or if NPV > 0 and B/C > 1, where

- NPV : Net present value and
- B/C : Benefit-cost ratio.

iv) Comparison of Net Benefit and Cost from Project Implementation

The benefit is generated in the following two cases:

Case A: Increase in the water bill revenue resulting from the increase in the volume of revenue water due to the NRW reduction; and

Case B: Reduction in the water treatment and supply cost (O&M cost) at a treatment plant due to the water leakage reduction.

In practice, the benefit was calculated as the revenue from the sales of the surplus water generated by the leakage reduction to supplement the water demand in the service areas of the branches in Case A and as the reduction in the cost of water production at the Nzove Treatment Plant, where the water supplied to the service areas was produced, enabled by the leakage reduction in Case B. The comparison of the calculated net benefits in the two cases conducted in this report revealed that Case A was more practical and had a larger effect than Case B.

v) Cost and Water Prices

- The initial cost (CAPEX for 1st year) included the costs for the activities for NRW reduction (leakage survey and repair, PRV installation, replacement of distribution and service pipes, etc.) and the preparation for the NRW reduction activities (hydraulic isolation of the area for the formation of DMA, installation of flowmeters and manholes, etc.) in the pilot areas (see Table 14 and Table15).
- The maintenance cost (OPEX from 2nd year)

  In the case of With-project：leakage survey, leakage repair

  (repair numbers：Kadobogo 3 places/month、Ruyenzi 23 places/month)

  In the case of Without-project：leakage repair

  (repair numbers: Kadobogo 12places/month、Ruyenzi 26 places/month)
- Period for the calculation: 10 years from the year of activity launch
- Values used in the calculation

  In the case of With-project:

  The actual distribution volumes, billed volumes and NRW rates up to March 2020 from the baseline setting month were used.

  In the case of Without-project:

  The monthly distribution volume was calculated by multiplying the volume of the month when the effect emerged by the rates of monthly changes in the distribution volume in Kigali City (actual value; refer to Table 2). The same volume of billed water as the case of With-project was used. The NRW rate was calculated from distribution volume and billed volume.

- Water price:

  Selling prices: 567 RWF/m^3 in Kacyiru and 592 RWF/m^3 in Nyarugenge (monthly averages in 2018)

  Purified water production cost: 319 RWF/m^3 at the Nzove Treatment plant (monthly averages in 2018)

3. Calculation result and evaluation

The result of the calculation is as shown below. For details of the calculation result, refer to Attachment 5.

Kadobogo

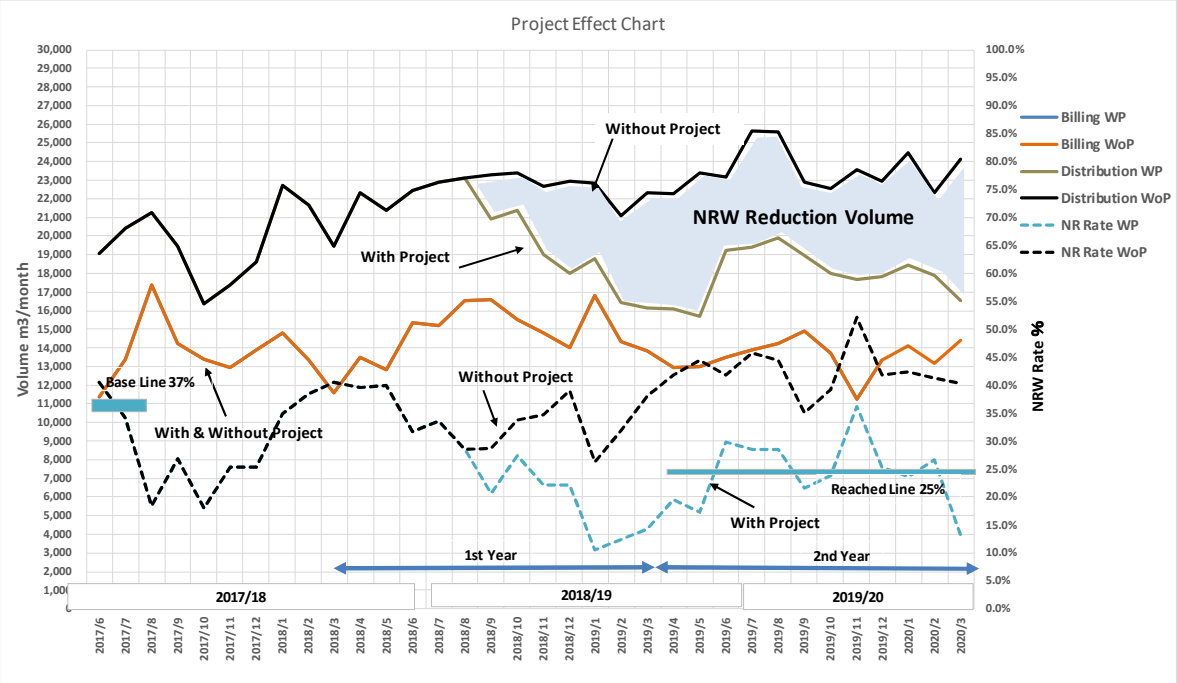


Fig. 2.27 Result of cost-benefit analysis (Kadobogo)

Table 2.68 Cost-benefit calculation for Kadobogo: Case A (increased water billing)

Project Effect of Kadobogo

A: Selling of Surplus Water

Cost (DMA Formation, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

	Year	Benefit			Cost			NPV (Benefit-Cost)	Effect of the Project (Accumulation)				Discount Rate %	6.0
		WP	WoP	Balance	WP	WoP	Balance		Benefit	Cost	NPV Sum	B/C	Conversion Factor	1/(1+i)^n
1	2018/04-19/03	15,826,812	0	15,826,812	50,675,787	3,754,944	-46,920,843	-31,094,031	15,826,812	-46,920,843	-31,094,031	0.3	0	1.000
2	2019/04-20/03	35,967,515	0	35,967,515	1,512,453	3,542,400	2,029,947	37,997,462	51,794,327	-44,890,896	6,903,431	1.2	1	0.943
3	2020/04-21/03	32,010,960	0	32,010,960	1,426,842	3,341,887	1,915,044	33,926,005	83,805,287	-42,975,851	40,829,436	2.0	2	0.890
4	2021/04-22/03	30,199,019	0	30,199,019	1,346,078	3,152,723	1,806,646	32,005,665	114,004,306	-41,169,206	72,835,100	2.8	3	0.840
5	2022/04-23/03	28,489,640	0	28,489,640	1,269,885	2,974,267	1,704,383	30,194,023	142,493,946	-39,464,823	103,029,123	3.6	4	0.792
6	2023/04-24/03	26,877,019	0	26,877,019	1,198,004	2,805,913	1,607,908	28,484,928	169,370,966	-37,856,914	131,514,051	4.5	5	0.747
7	2024/04-25/03	25,355,679	0	25,355,679	1,130,193	2,647,087	1,516,895	26,872,573	194,726,644	-36,340,020	158,386,624	5.4	6	0.705
8	2025/04-26/03	23,920,452	0	23,920,452	1,066,220	2,497,252	1,431,033	25,351,484	218,647,096	-34,908,987	183,738,108	6.3	7	0.665
9	2026/04-27/03	22,566,464	0	22,566,464	1,005,868	2,355,898	1,350,031	23,916,494	241,213,559	-33,558,956	207,654,603	7.2	8	0.627
10	2027/04-28/03	21,289,117	0	21,289,117	948,932	2,222,546	1,273,614	22,562,731	262,502,676	-32,285,342	230,217,334	8.1	9	0.592
11	2028/04-29/03	20,084,072	0	20,084,072	895,219	2,096,741	1,201,523	21,285,595	282,586,748	-31,083,820	251,502,928	9.1	10	0.558

0.28 NPV/Billing

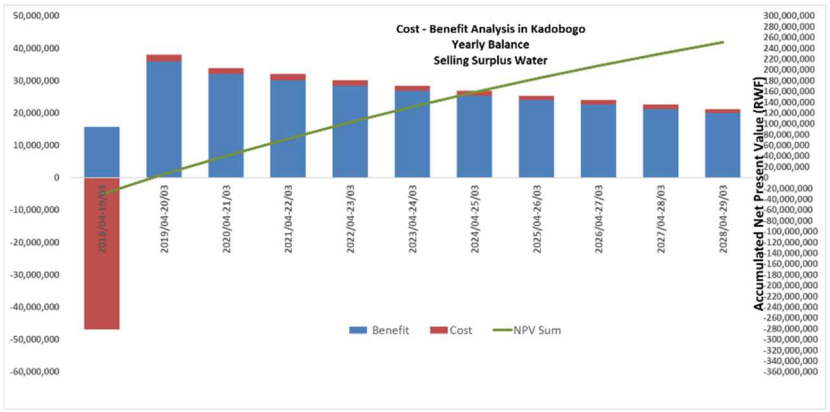


Table 2.69 Cost-benefit calculation for Kadobogo: Case B (reduced water treatment cost)

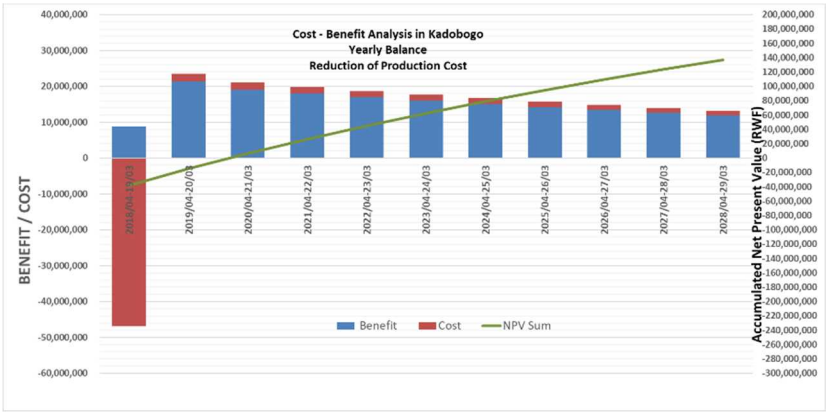
Project Effect of Kadobogo

B: Reduction of Product Cost

Cost (DMA Formation, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

	Year	Benefit			Cost			NPV (Benefit-Cost)	Effect of the Project (Accumulation)				Discount Rate %	6.0
		WP	WoP	WP	WP	WoP	Balance		Benefit	Cost	NPV Sum	B/C	Conversion Factor	1/(1+i)^n
1	2018/04-19/03	8,904,326	0	8,904,326	50,675,787	3,754,944	-46,920,843	-38,016,517	8,904,326	-46,920,843	-38,016,517	0.2	0	1.000
2	2019/04-20/03	21,449,833	0	21,449,833	1,512,453	3,542,400	2,029,947	23,479,780	30,354,160	-44,890,896	-14,536,736	0.7	1	0.943
3	2020/04-21/03	19,090,275	0	19,090,275	1,426,842	3,341,887	1,915,044	21,005,320	49,444,435	-42,975,851	6,468,583	1.2	2	0.890
4	2021/04-22/03	18,009,694	0	18,009,694	1,346,078	3,152,723	1,806,646	19,816,339	67,454,128	-41,169,206	26,284,923	1.6	3	0.840
5	2022/04-23/03	16,990,277	0	16,990,277	1,269,885	2,974,267	1,704,383	18,694,660	84,444,405	-39,464,823	44,979,582	2.1	4	0.792
6	2023/04-24/03	16,028,563	0	16,028,563	1,198,004	2,805,913	1,607,908	17,636,471	100,472,968	-37,856,914	62,616,054	2.7	5	0.747
7	2024/04-25/03	15,121,286	0	15,121,286	1,130,193	2,647,087	1,516,895	16,638,181	115,594,254	-36,340,020	79,254,235	3.2	6	0.705
8	2025/04-26/03	14,265,364	0	14,265,364	1,066,220	2,497,252	1,431,033	15,696,397	129,859,619	-34,908,987	94,950,631	3.7	7	0.665
9	2026/04-27/03	13,457,891	0	13,457,891	1,005,868	2,355,898	1,350,031	14,807,922	143,317,509	-33,558,956	109,758,553	4.3	8	0.627
10	2027/04-28/03	12,696,123	0	12,696,123	948,932	2,222,546	1,273,614	13,969,737	156,013,633	-32,285,342	123,728,290	4.8	9	0.592
11	2028/04-29/03	11,977,475	0	11,977,475	895,219	2,096,741	1,201,523	13,178,997	167,991,107	-31,083,820	136,907,288	5.4	10	0.558

0.17 NPV/Billing



Ruyenzi

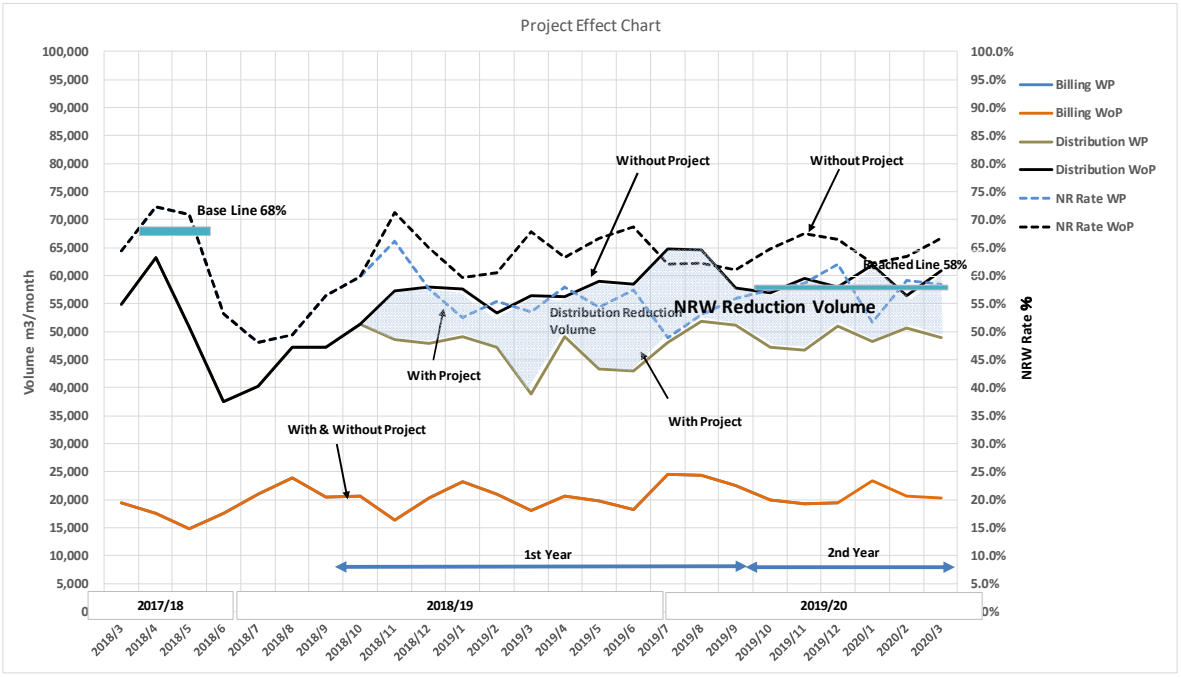


Fig. 2.28 Result of cost-benefit analysis (Ruyenzi)

Table 2.70 Cost-benefit calculation for Ruyenzi: Case A

Project Effect of Ruyenzi

A: Selling of Surplus Water

Cost (DMA Formation, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

	Year	Benefit			Cost			NPV (Benefit-Cost)	Effect of the Project (Accumulation)				Discount Rate %	6.0
		WP	WoP	Balance	WP	WoP	Balance		Benefit	Cost	NPV Sum	B/C	Conversion Factor	1/(1+i)^n
1	2018/10-19/9	74,299,139	0	74,299,139	50,356,400	7,937,280	-42,419,120	31,880,019	74,299,139	-42,419,120	31,880,019	1.8	0	1.000
2	2019/10-20/9	67,984,224	0	67,984,224	7,416,453	7,488,000	71,547	68,055,771	142,283,363	-42,347,573	99,935,790	3.4	1	0.943
3	2020/10-21/9	64,136,060	0	64,136,060	6,996,654	7,064,151	67,497	64,203,558	206,419,424	-42,280,076	164,139,348	4.9	2	0.890
4	2021/10-22/9	60,505,717	0	60,505,717	6,600,617	6,664,293	63,677	60,569,394	266,925,141	-42,216,399	224,708,742	6.3	3	0.840
5	2022/10-23/9	57,080,865	0	57,080,865	6,226,997	6,287,069	60,072	57,140,938	324,006,006	-42,156,326	281,849,680	7.7	4	0.792
6	2023/10-24/9	53,849,873	0	53,849,873	5,874,525	5,931,197	56,672	53,906,545	377,855,879	-42,099,654	335,756,225	9.0	5	0.747
7	2024/10-25/90	50,801,767	0	50,801,767	5,542,005	5,595,469	53,464	50,855,231	428,657,646	-42,046,190	386,611,456	10.2	6	0.705
8	2025/10-26/9	47,926,195	0	47,926,195	5,228,307	5,278,745	50,438	47,976,633	476,583,842	-41,995,752	434,588,089	11.3	7	0.665
9	2026/10-27/9	45,213,392	0	45,213,392	4,932,365	4,979,948	47,583	45,260,975	521,797,233	-41,948,169	479,849,064	12.4	8	0.627
10	2027/10-28/9	42,654,143	0	42,654,143	4,653,174	4,698,064	44,890	42,699,033	564,451,377	-41,903,280	522,548,097	13.5	9	0.592
11	2028/10-29/9	40,239,758	0	40,239,758	4,389,787	4,432,136	42,349	40,282,106	604,691,134	-41,860,931	562,830,203	14.4	10	0.558

0.36 NPV/Billing

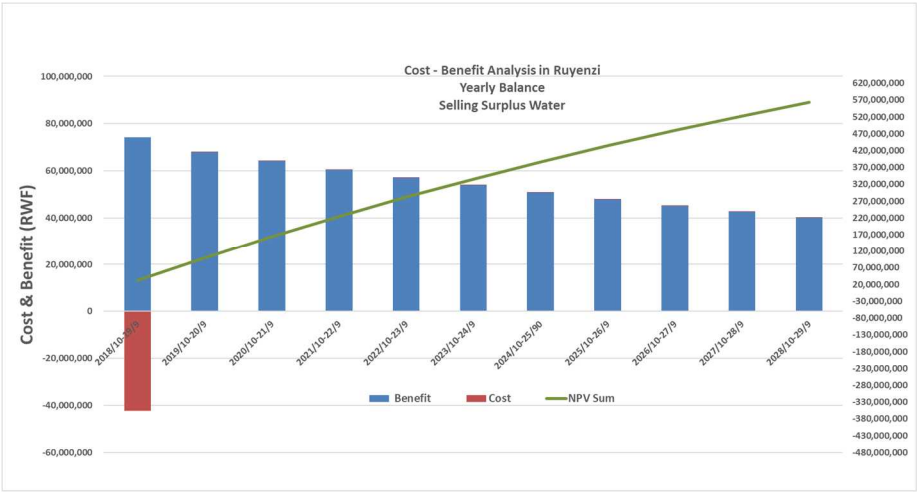
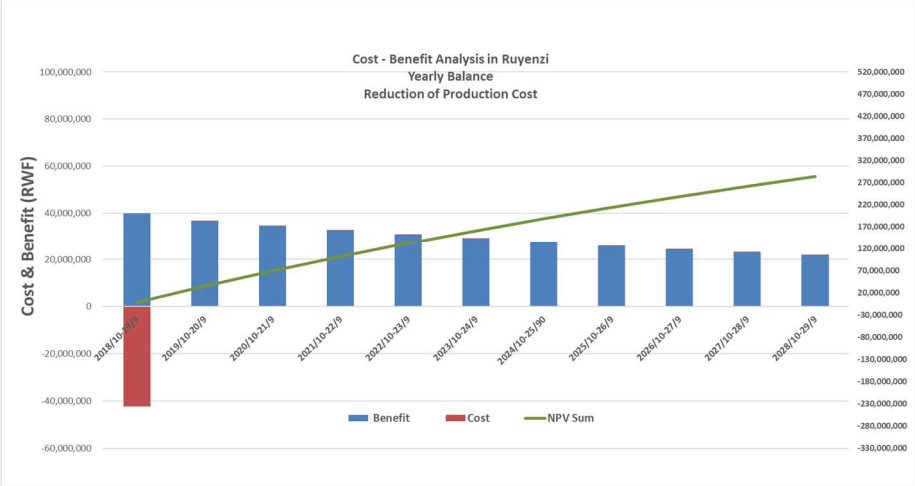


Table 2.71 Cost-benefit calculation for Ruyenzi: Case B

B: Reduction of Production Cost

Cost (DMA Formation, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

	Year	Benefit			Cost			NPV (Benefit-Cost)	Effect of the Project (Accumulation)				Discount Rate %	6.0
		WP	WoP	WP	WP	WoP	Balance		Benefit	Cost	NPV Sum	B/C	Conversion Factor	1/(1+i)^n
1	2018/10-19/9	40,036,192	0	40,036,192	50,356,400	7,937,280	-42,419,120	-2,382,928	40,036,192	-42,419,120	-2,382,928	0.9	0	1.000
2	2019/10-20/9	36,633,391	0	36,633,391	7,416,453	7,488,000	71,547	36,704,938	76,669,583	-42,347,573	34,322,010	1.8	1	0.943
3	2020/10-21/9	34,559,803	0	34,559,803	6,996,654	7,064,151	67,497	34,627,300	111,229,385	-42,280,076	68,949,310	2.6	2	0.890
4	2021/10-22/9	32,603,588	0	32,603,588	6,600,617	6,664,293	63,677	32,667,264	143,832,973	-42,216,399	101,616,574	3.4	3	0.840
5	2022/10-23/9	30,758,101	0	30,758,101	6,226,997	6,287,069	60,072	30,818,174	174,591,074	-42,156,326	132,434,748	4.1	4	0.792
6	2023/10-24/9	29,017,077	0	29,017,077	5,874,525	5,931,197	56,672	29,073,749	203,608,151	-42,099,654	161,508,497	4.8	5	0.747
7	2024/10-25/90	27,374,601	0	27,374,601	5,542,005	5,595,469	53,464	27,428,065	230,982,752	-42,046,190	188,936,562	5.5	6	0.705
8	2025/10-26/9	25,825,095	0	25,825,095	5,228,307	5,278,745	50,438	25,875,533	256,807,847	-41,995,752	214,812,095	6.1	7	0.665
9	2026/10-27/9	24,363,297	0	24,363,297	4,932,365	4,979,948	47,583	24,410,880	281,171,144	-41,948,169	239,222,975	6.7	8	0.627
10	2027/10-28/9	22,984,243	0	22,984,243	4,653,174	4,698,064	44,890	23,029,132	304,155,387	-41,903,280	262,252,107	7.3	9	0.592
11	2028/10-29/9	21,683,248	0	21,683,248	4,389,787	4,432,136	42,349	21,725,596	325,838,635	-41,860,931	283,977,704	7.8	10	0.558
								0.19	NPV/Billing					



The results of the analysis are as follows:

- In Kadobogo and Ruyenzi, the calculation of the NPV and B/C values clearly shows the effect of the NRW reduction activities (NPV>0 and B/C>1) in each area, although the time required for the effect to emerge differed between the two areas.
- Benefit in Case A (Increase in the water bill revenue) is higher than that in case B (Reduction of O&M cost). Only the results of Case A are described in the following.
- In Kadobogo, the net benefit was generated from the 2nd year of the implementation of the NRW reduction activities because the effect of the activities exceeded the implementation cost. (B/C, the ratio of accumulated benefit to accumulated cost, is more than 1.0.) In Ruyenzi, B/C exceeded 1.0 in the 1st year.
- The B/C values in the two areas in the fifth year will be high (3.6 in Kadobogo and 7.7 in Ruyenzi). At the same time, the cumulative net benefits of about 100 % and about 190 % of the annual billed water charges will be generated in Kadobogo and Ruyenzi, respectively (water billing reaching RWF101,650k in Kadobogo, and RWF147,925k in Ruyenzi).
- The average annual net benefits in the ten years will be approx. 28 % and 36 % of the annual billed

water charges in Kadobogo and Ruyenzi, respectively.

- The NRW rate of 25 % has been achieved in Kadobogo with the NRW reduction by 12%. In Ruyenzi, the achieved NRW rate was 58 % with NRW reduction by 10%. However, the cost-benefit analysis has revealed that the investment in the NRW reduction activities has produced a sufficient effect on NRW reduction by the reduction of 10% even where an achieved NRW rate was high such as Ruyenzi.

In conclusion, the investment in NRW reduction activities had sufficient effect when the activities reduced the NRW rate to a certain degree (by approx. 10 %) even if the rate was very high like in Ruyenzi (68 %). Therefore, it is important to actively promote cost-effective activities, such as the reduction of high water pressure (installation of PRVs), surveys and repair of water leakage (underground water leakage, in particular), and replacement of distribution and service pipes.

The poor quality of service pipes and high pressure in Ruyenzi prevented the achievement of the target NRW rate of 25%. NRW reduction activities in this pilot area need to be continued to address this issue. Small-bore HDPE pipes require replacement as they often cause water leaks. WASAC should replace the existing pipes as soon as possible, with the materials procured for assistance to measures against COVID-19.

2) Verification of the effect of individual reduction activities of the pilot projects

The table below outlines the result of the cost-benefit analysis pertaining to the effect of water pipe replacement and PRV installation on leakage reduction in each pilot project area. Both activities succeeded in recovering the investment cost in three to 14 months. Indeed, they showed quick effect as benefit exceeded cost at an early stage. Calculation sheets can be found in Attachment 5.

Table 2.72 Cost-effectiveness of PRVs and water pipe replacement (investment recovery evaluation)

Kadobogo

Reduction activity	Site	Investment recovery evaluation			Effect on Qmnf
		No. of months	NPV (RWF)	B/C	m3/h
Water pipe replacement	PM1	10	96,125	1.0	2.28
PRV installation	PM2	14	17,702	1.0	0.43
	PM3	3	297,547	1.1	3.64

Ruyenzi

Reduction activity	Site	Investment recovery evaluation			Effect on Qmnf
		No. of months	NPV (RWF)	B/C	m3/h
PRV installation	PRV1	3	811,166	1.3	4.68
	PRV2	13	79,323	1.0	1.14
	PRV3	8	230,210	1.1	0.72

3.15 The action team summaries activities and results from Activities 3.1 to 3.14, prepares the completion report on the pilot project for Pilot Area 1, and submits it to the management team.

Based on the experience and results of the pilot projects, the JICA Expert Team has completed the preparation of the completion report and explained and submitted it to WASAC. The knowledge and lessons learned in the Pilot Project activities have been reflected in 5YSP.

- Pilot Area 1 : Submitted to WASAC in October 2019.
- Pilot Area 2 : Submitted to WASAC in January 2020.

3.16 The action team holds a workshop and presents the completion report of the pilot project prepared by Activity 3.15 to WASAC and other concerned parties.

The action team invited the heads of Kacyiru and Nyarugenge Branches that were responsible for the water services in Pilot Areas 1 and 2, respectively, to a seminar held on February 14, 2020. The results of the pilot project were announced at the launch of the final evaluation report on the Project.

3.18 Action team prepares manuals on methods and use of survey equipment learned through the implementation of the pilot project, and holds seminars in order to share them with WASAC and other concerned parties.

It was decided to set up the manual preparation team of the pilot project inside WASAC and prepare the manuals in coordination with this team.

On January 29, 2019, a manual-preparation meeting (kick-off) was held, and then regular meetings were held. However, this activity was interrupted due to the influence of measures to prevent infection of COVID-19 and busy situation of counterpart in daily work. Experts reviewed it and submitted it to WASAC in May 2020.

3.19 Action team disseminates the manual and use of survey equipment to the activity of whole branches.

The Pilot Project Completion Report and the NRW-reduction Manual have already been prepared. WASAC shall hold an in-house workshop to disseminate the report and manual in WASAC as part of 5YSP,

(4) Activities relating to Output 4

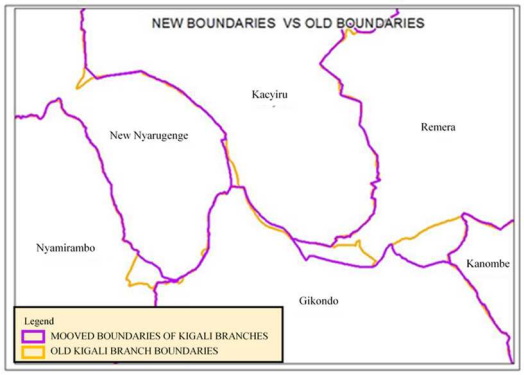
[Establishment of a system to accurately measure NRW rates at 4 branches in Kigali]

4.1 Isolation plan of 4 branches prepared by WASAC will be reviewed and revised as necessary.

This Project was aimed at achieving hydraulic isolation of the water distribution networks of the four target branches (Kacyiru, Gikondo, Nyarugenge, and Nyamirambo) and constructing a system for simultaneous monitoring of the NRW rates at the six branches in Kigali, including the two branches which were covered in the SUSWAS project (Remara and Kanombe). In addition, it was decided to calculate the NRW rate with Excel-formatted software using the flow rate data obtained thereby.

The JICA expert team, WASAC GIS team, and branch staff who were in charge of the water distribution network collaborated in the close survey to demarcate the branch-to-branch borders for hydraulic isolation of the four branches (Nyarugenge, Gikondo, Kacyiru and Nyamirambo). The location of the borders was determined following further consultation on the result of the survey at the Project Management Meeting held on October 7, 2016.

As a result, there were some changes to the positions of the borders, and approximately 1,800 branch-to-branch adjustments of customer registrations were required. The numbers of the resulting transfers of customers between branches are outlined in the table below. Adjustments to the customer registration list were to be made in accordance with the timeline for the procurement and installation of equipment to build the monitoring system. WASAC convened a meeting in November 2019 with WDO and CSO of the branches and other parties concerned to begin coordinating the posting of customer registrations.



Before	After	Number
Kacyiru	Gikondo	4
Kacyiru	Remera	15
New Nayrugenge	Kacyiru	11
New Nayrugenge	Namirambo	435
Gikondo	Remera	1,314
TOTAL		1,779

Fig. 2.29 Change of borders, and the number of customers moving betwen four branches in Kigali

4.2 Based on the isolation plan prepared by Activity 4.1, exact locations for the installation of electromagnetic flowmeters and pressure gauges are determined by field survey.

The field surveys were carried out along the demarcated borders to determine the locations of flowmeters required for the hydraulic isolation and designed the entire monitoring system.

The flow rate monitoring system consists of devices for measuring data (flowmeters and pressure gauges) installed on-site, and data collection equipment installed at WASAC Headquarters. The data measured on-site is transmitted to the data collection equipment via a mobile telephone transmission network (GPRS). The data collection equipment is a server that carries out data collection, accumulation, and display. The data information is in a text format, so WASAC processes it in an Excel table, and calculates the NRW rate for each branch.

In addition, it was planned to incorporate measurement data of the existing electromagnetic flowmeter s (26 locations) of the SUSWAS project into the system built by this project. Unfortunately, however, the SUSWAS project's 26 meters are currently not working. The concept of a monitoring system is shown in the figure below.

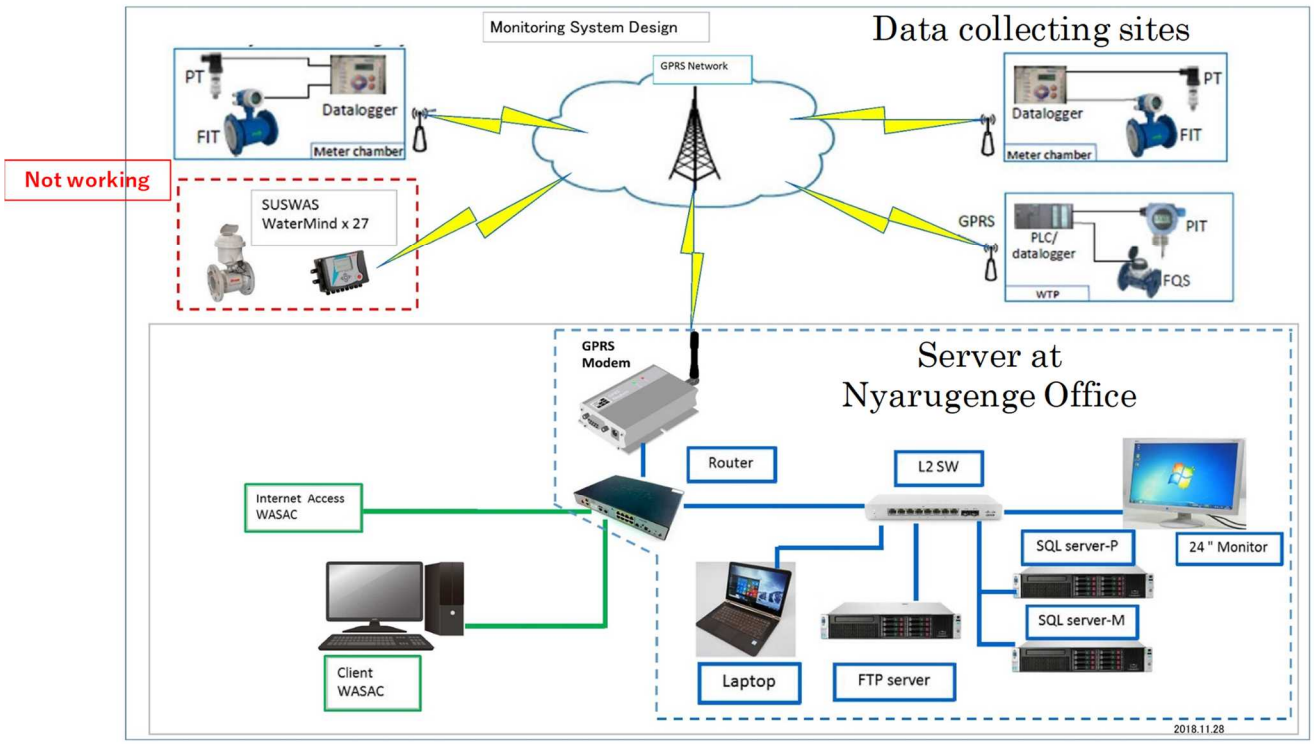


Fig. 2.30 Overview of the monitoring system

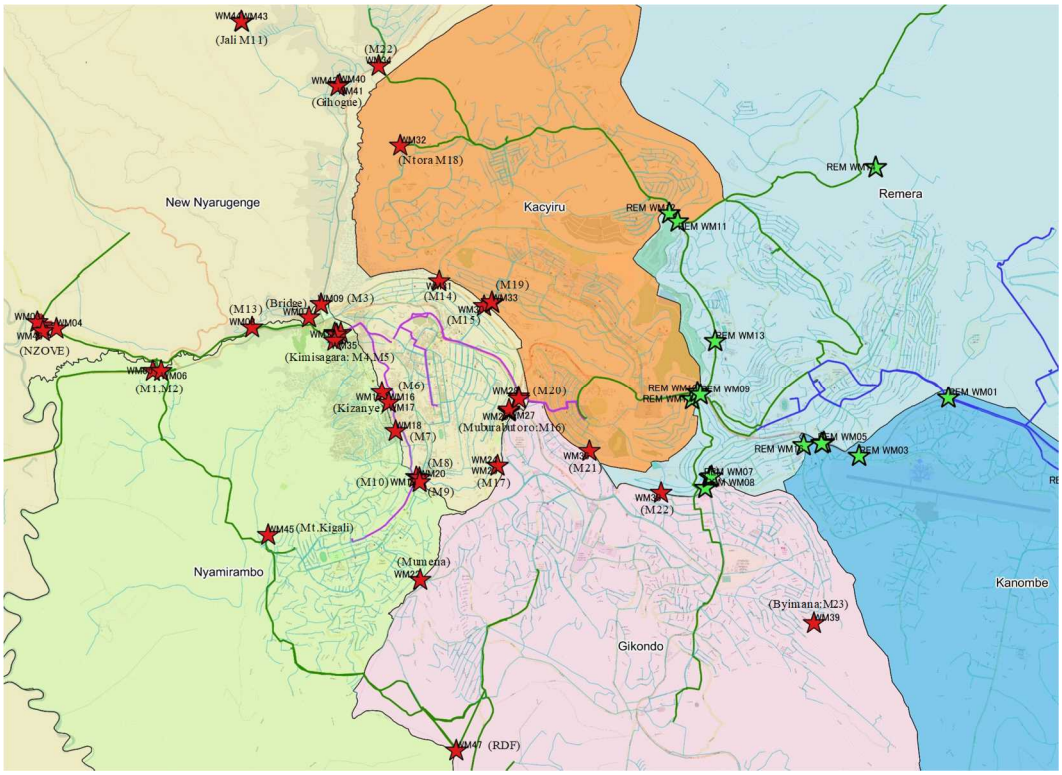


Fig. 2.31 Flow measurement position diagram

(red: flowmeter installed in this project, green: flowmeter installed in SUSWAS)

The flow rate measurement positions are at 8 water sources (water treatment plants, pumping stations) and the hydraulic isolation points of water pipes straddling the branch borders.

The procured equipment is composed of: 38 flowmeters including 35 electromagnetic flowmeters, one ultrasonic flowmeter and two mechanical flowmeters; 29 pressure gauges; 27 data loggers; and 23 reinforced concrete manholes to install the equipment. A list of equipment for the monitoring system can be found in Attachment 6.

4.3 Manholes are constructed as appropriate

On October 31, 2016, a joint meeting of NRW, GIS, and water network operation maintenance teams was held to decide on the composition of equipment to be procured and the installation sites of 23 concrete manholes to install the equipment.

The construction work of the manholes was delayed due to delays in the procurement of equipment by the local contractors, flooding of sites during the rainy season, changes in construction sites, etc., but the construction was completed on September 10, 2018, and handed over to WASAC on February 28, 2019.

4.4 Electromagnetic flowmeters and pressure gauges are procured and installed for isolating 4 branches.

Initially, we decided to make a local tender at Kigali for the procurement of monitoring equipment, but the tender failed in October 2017 because the tenderer's financial management situation and technical specifications of the offered equipment did not meet the tender requirements. Then, in May 2019, WASAC- and JICA held discussions on reviewing the schedule for the procurement and installation of equipment. JICA decided to hold another tender for a blanket contract including the installation work. The tender was made at the JICA headquarters in July 2019, and a contract with a Japanese provider was concluded on September 20.

In October 2019, the Kick-off meeting was held in Kigali and the procurement work was started. The timeline for the procurement and installation was modified as the Japanese contractor had made some changes to the works to be performed in view of the result of a field survey. Subsequently, JICA decided to suspend the project activities on-site as it banned the Japanese engineer to travel to Rwanda in March 2020 because of the COVID-19 pandemic. The construction work was resumed a year later in March 2021, when the transmission of COVID-19 came under adequate control.

The system construction, which had been delayed significantly from the original schedule at the commencement of the Project, was finally completed in September 2021. Pre-SAT and SAT of the monitoring system, except for the following equipment, and O&M training for WASAC staff were conducted from the end of August to the beginning of September 2021.

- ✓ Measuring and transmission equipment at Manholes M3, M7 and M19 and the data receiving and processing server at the Headquarters connected thereto
- ✓ Equipment installed at Manholes M4, M19, M22 and M23, where no passing water was observed at the time of inspection in September 2021
- ✓ Flowmeter WM12 installed at the Kimisagara treatment plant, which could not be inspected as no service code had been provided
- ✓ Equipment defects that occurred after the pre site acceptance test (Pre-SAT) in September 2021.

The Japanese contractor submitted a partial completion report to WASAC (with inspection completed on 90% of the equipment, apart from some flowmeters) and received a partial completion certificate on September 9, 2021. All concerns will have to be dealt with until the regular inspection to be conducted in six and 12 months. The warranty period of the system is one year from the date on the partial completion certificate.

It should be noted that the following issue remains unresolved pertaining to flowmeters on the

WASAC side. WASAC shall have to install flowmeters at the 16 locations mentioned below as per the milestones articulated in the minutes of the 6th SC meeting, to enable the inclusion of the data measured by them in the system. Thus, data on the volume of distributed water have not been made available for all branches so far (as of January 2022).

- ✓ Replacement of existing malfunction meters for isolation of Kanombe and Remera (5 locations).
- ✓ Installation of meters at newly increased branch boundary crossing points by the AfDB project (11 locations).

WASAC is required to promptly complete the transfer of customer registrations, which has only been performed partially.

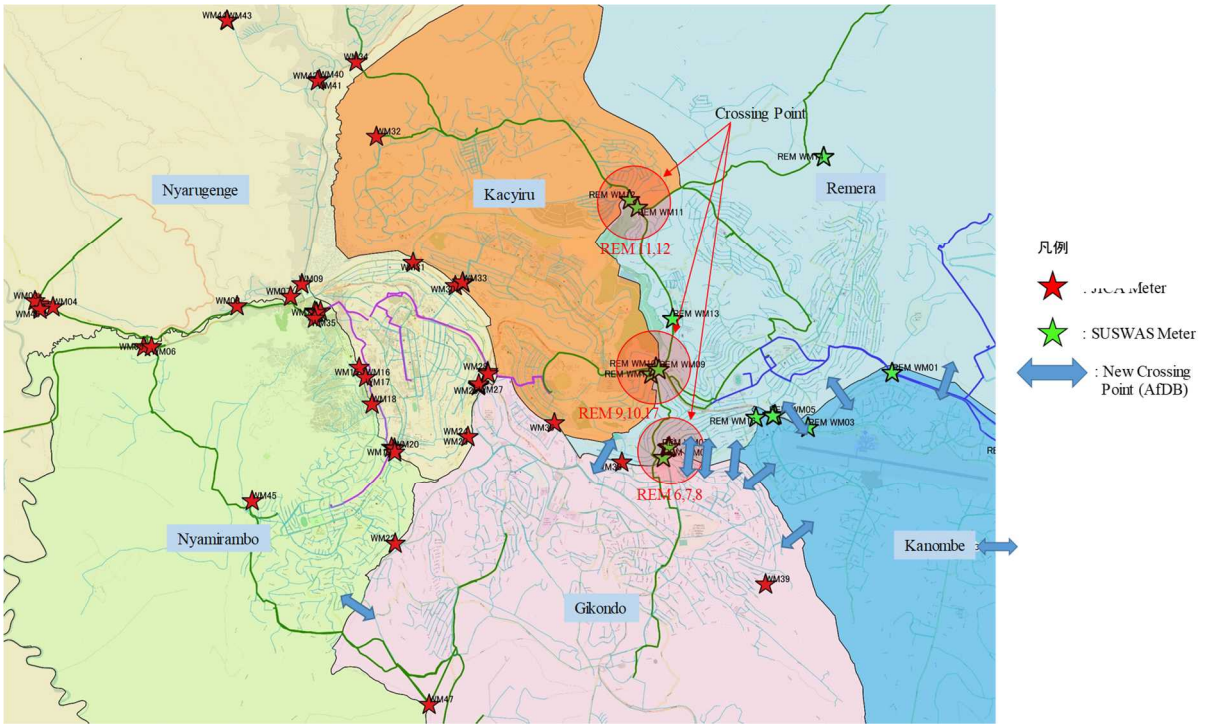


Fig. 2.32 Points requiring flowmeter replacement (5) and new flowmeter installation (11)

Schedule of Installation and Replacement of Flowmeters

Electromagnetic Frow Meter		2021			2022										
Contents	Contents	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
SUSWAS (5 places)+ New Crossing Pipelines (11 Places)	Tendering	—														
	Procurement		—	—	—	—										
	Installation						—	—	—	—						
NRW Calculation		△	△	△	△	△	△	△	△	△	△	△	△	△	△	△
Periodical Maintenance by Takaoka							▲						▲			
Present Project Period		—	—	—												
Extension of Project Period					—	—	—	—	—	—	—	—	—			

Fig. 2.33 Milestones of flowmeter installation

4.5 System input to each of 4 branches is measured.

After the construction (partial completion) of the monitoring system, water distribution measurement data have been sent once a day to the server. The NRW rate for each branch will be calculated from these data. The NRW rates thus obtained will be leveraged for the review of 5YSP as it serves as an indicator for NRW reduction activities at individual branches.

4.6 Based on the results of Activity 4-5, NRW rates for each branch are calculated and reported.

A draft version of the NRW rate calculation software had been developed in November 2019. Details of the calculation software, method of use, and training schedule were explained to key persons in DUWSS, which is the main department that will use the software, and other departments involved in the maintenance of the water distribution networks, and they understood the explanation. After the partial completion of the monitoring system in September 2021, three months of OJT on the system, which was improved and customized for WASAC, was conducted for WASAC staff. They calculated the NRWs rate of August, September and October 2021 using the billing data of CMS and the distribution flow data of the monitoring system in the OJT.

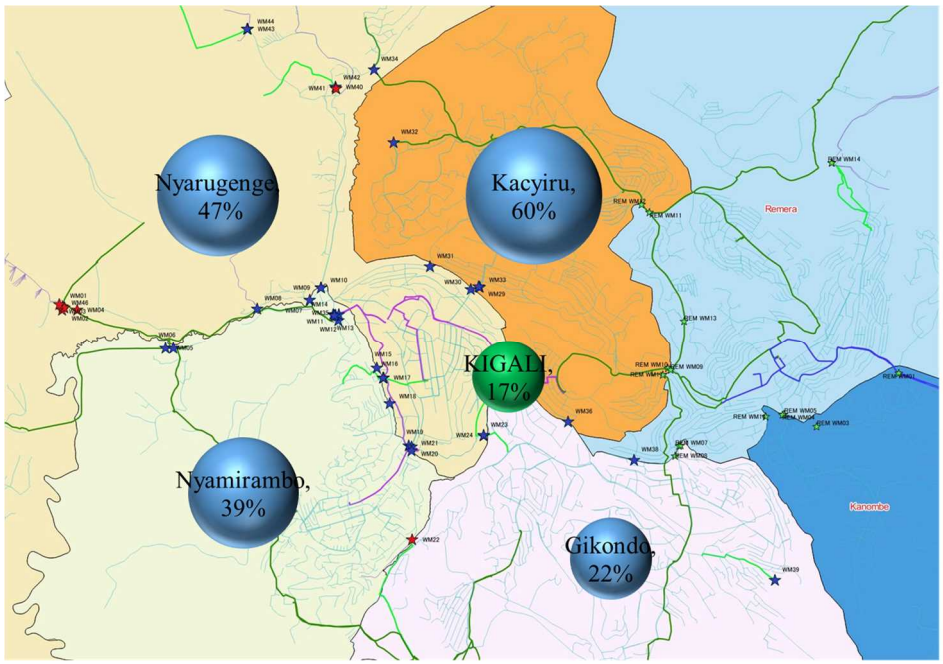


Fig. 2.34 Presentation of the calculated NRW rates

(5) Project Operation

1) Communication

Communication among the Project experts and the counterparts has been satisfactory. The Project set communication platforms such as weekly progress meetings, management team meetings, SC meetings, workshops and briefings in daily operation to share among all the Project-related persons the state of and challenges in the project implementation and, as much as possible, relevant knowledge and information.

In addition, the long-term expert stationed in Kigali contributed to bridging communication between the counterparts and the short-term experts while they were not in Rwanda.

2) Monitoring

The monitoring of the Project activities including the pilot project has been conducted by the counterparts and the experts simultaneously. The results of the monitoring have been shared at the various meetings mentioned above. Motoring results were analyzed and recorded on the monitoring sheets every six months. In other words, the Project has strategically utilized “monitoring” as an opportunity for the practical exercise on the “systematic implementation of measures to reduce NRW” in the framework of the activities for Output 1, which led to PDCA cycle exercises. The counterparts and experts continued to monitor the progress of and challenges in the project implementation following 5YSP. The monitoring contributed to the upgrading of the counterparts’ skills of collection/analysis of data, reporting and presentation.

2.2 Achievement of the Activity

The "Project Terminal Evaluation" was conducted by the team of JICA headquarters from June 10, 2020, to August 2020. JICA conducted it remotely from Japan because a business trip ban had been issued to prevent the COVID-19 Pandemic. The meeting on Terminal Evaluation Report was held on August 5th with the participation of the CEO of WASAC and the minutes of meeting (M/M) describing the outcome of the meeting were concluded between the two parties.

After that, the work in Rwanda resumed in March 2021, almost all the activities had been completed in November 2021, about a year after the terminal evaluation was conducted, and the final steering committee (SC) meeting was held on November 25.

The "achievement of the output of activities" described in this chapter shows the results confirmed in the final SC meeting, taking into account the achievement of activities in the past one-year period, based on the results of the evaluation in the terminal evaluation survey (M/M of Terminal Evaluation dated August 5, 2019). The table below outlines the results.

Table 2.73 Project purposes and outputs
(Terminal Evaluation of the project as of August 2020 and evaluation as of November 2021)

Narrative Summary	Objectively Verifiable Indicators	Achievement
Overall Goal WASAC conducts NRW reduction measures as planned for Kigali city.	NRW rate of Kigali city （year 2022/23 : 25 %)	The achievement in 2020/21 is 42.2%.
	In order to achieve the target, large initial investment is required to carry out large-scale NRW reduction work. It takes time to achieve the target.	
Project Purpose WASAC's capacity is enhanced to conduct NRW reduction measures as planned for Kigali city.	1:5-year Strategic Action Plan for NRW reduction is approved by the Minister of Infrastructure.	1:5YSP was approved by the Board of Directors of WASAC on April 27, 2018. The MININFRA is aware.
	2:Annual action plan regarding NRW reduction of each branch is reflected in annual action plan of WASAC	2:Each branch has an annual plan for NRW reduction activities.
	3:The management at WASAC recognizes the effects of NRW reduction, and approves the budget of each branch for implementing annual action plan for NRW water reduction	3: WASAC management recognizes the effect of reducing NRW, and the results of the pilot project are being deployed outside the pilot areas. However, the budget has not been executed as planned.
	<u>Almost achieved (Almost achieved)</u> ✓ WASAC's capacity to conduct NRW reduction measures as planned for Kigali city is enhancing. ✓ On the other hand, the activities of the annual action plan are not backed by the budget and have not achieved this target.	
Outputs Output 1 Planning capacity of NRW reduction of WASAC is enhanced.	1:5 year Strategic Action plan is reviewed and updated, taking into account the results of the Pilot Project.	1: 5YSP has been updated based on the results of the pilot project. 5YSP is carried out with set monitoring indicators.
	2:All the project achievements are shared by WASAC and other concerned parties by holding seminars.	2 : The achievements are shared within WASAC and with MINIFRA through workshops, seminars, SC, etc.

Narrative Summary	Objectively Verifiable Indicators	Achievement
	<u>Achieved (achieved)</u> ✓ In the process of formulating a 5YSP, the results of questionnaires and measures to address the issues listed in the workshop were grouped, and the five main components of the action plan were determined. Monitoring has been carried out as planned to date. ✓ The PDCA cycle of planning, implementation, monitoring and evaluation, revision and renewal starting from the extraction of issues has begun to be fostered, and the "planning capacity" aimed at this achievement has improved.	
Output 2 Basic knowledge, skills and technique on NRW control are acquired by WASAC.	1:More than 300 number of trainees receive training.	1: A total of 596 of trainees received the training.
	2:WASAC human resource development plan includes training programs prepared by the project.	2: The NRW reduction activity manual was created, but the training program in it has not been incorporated into WASAC training courses in cooperation with WASAC DSS.
	<u>Almost achieved (Almost achieved)</u> ✓ The training has been systematically conducted not only for Action Team mainly of engineers but also for Management Team mainly of managers, and the target that is "acquisition of basic knowledge, skills, and technique on NRW control by WASAC staff" has been achieved. ✓ Although the manual was prepared, it has not reached the stage of "WASAC human resource development plan includes training programs prepared by the project", which is expected as the final output.	
Output 3 WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.	1:NRW rates are reduced at each pilot area as follows: Pilot Area 1: from 37% to 20% and Pilot Area 2 from 68% to 25%.	1: The achieved values were area 1:25% and area 2:56%, and the target value could not be achieved. However, the effectiveness of the activity was confirmed by the evaluation of the cost-benefit, and the result obtained from the activity is large.
	2:Action team members share experiences at workshops regarding implementation of the pilot projects.	2:Shared.
	3:The action team prepares a completion report of the pilot project.	3: Completion reports of Pilot Projects 1 and 2 have been prepared.
	<u>Almost achieved (Almost achieved)</u> ✓ Through implementation of the pilot project, WASAC has learned effective NRW reduction methods (DMA formation, on-site test of customer meter, leakage survey (flow rate and pressure measurement), leakage detection, high pressure control (pressure survey, PRV installation), replacement plan of distribution and service pipe, installation supervision, customer location map, etc.). ✓ The practical field work skills of WASAC staff, which are the essential goals of this achievement, have greatly enhanced. ✓ Although the reduction of the NRW rate did not reach the target, it was confirmed by the analysis on cost-benefit that there was an financial benefit on measures to reduce NRW in the pilot area.	
Output 4 4 branches in Kigali establish the system to measure NRW rates accurately.	1:NRW rate of each branch is periodically monitored and reported in PIP (Performance Improvement Plan) every month.	1: The procurement and installation of the equipment for the monitoring system have almost been completed, except for the warranty period. OJT on NRW rate calculation has been completed. The only remaining task is the installation of flow meters, to be performed by WASAC.

Narrative Summary	Objectively Verifiable Indicators	Achievement
	Almost achieved (not achieved) ✓ Although the procurement of the equipment and materials and installation of the system were delayed due to the COVID-19 Pandemic, the establishment of the monitoring system has almost been completed except for the installation of several flow meters and related equipment. ✓ The installation of 16 flow meters, for which WASAC is responsible, has not yet been carried out. ✓ The rearrangement of customer registrations due to partial replacement of branch-to-branch boundaries, for which WASAC is responsible, has not been completed.	

Note: The result of Terminal Evaluation is shown in the parentheses.

2.2.1 Degree of Achievement of Expected Output

(1) Output 1 Planning capacity of NRW reduction of WASAC is enhanced.

1) Indicator 1-1: 5YSP is reviewed and updated, taking into account of the results of the Pilot Project.

Indicator 1-1 was achieved.

The preparation of this 5YSP began in August 2016 in the framework of JICA technical cooperation to strengthen the capacity of NRW control in WASAC. This exercise involved WASAC's directorates, unit, branches and water treatment plants through interviews, questionnaires and field visits. 5YSP was developed following a series of workshops. WASAC started the implementation of 5YSP in July 2018.

In July 2019, the Project held a review workshop inviting primary members including managers and heads to update the 5YSP based on the achievements of the pilot project, lessons learned and the result of monitoring of 5YSP performed over the year. The workshop concluded that activities should be continued with reference to a set of indicators (PRVs installed, customer meters replaced, customer inspections conducted and customer meters tested for accuracy). Those indicators have served as criteria for implementing and monitoring 5YSP from the second year onward.

WASAC was scheduled to continuously review and update the plan with the official approval of WASAC's Board of Directors, but in September 2021 after three years of implementation of 5YSP, a revised version of 5YSP was prepared in September 2021 after implementation for three years based on the implementation status of 5YSP, the results of the pilot project and recommendations of the JICA's study on "Project for Water Supply Master Plan for City of Kigali".

The following additional activities have been implemented:

- The results of the pilot project recognized the importance of high water pressure control, and

pressure management activities were added to PDM at the third Steering Committee (SC) meeting in August 2018.

- As an urgent activity, high water pressure control (PRV installation) and reservoir management (FV installation) were decided at the management level (management meeting and SC meeting) and deployed outside the pilot area in Kigali City (PRV 10 sites, 9 reservoirs). Similarly, procurement of the potable on-site test meter for all branches were decided, and 26 sets were procured.
- The inventory of reservoirs in Kigali was updated. This resulted in the identification of defective points, some of which benefited from the procurement of FVs as part of the support for measures against COVID-19.
- Equipment and materials to repair leaks on distribution and service pipes, materials for replacing water pipes and FVs were additionally procured as measures against COVID-19.

2) Indicator 1-2: All the project achievements are shared with WASAC and other concerned parties by holding seminars.

Indicator 1-2 was achieved.

All the progresses and challenges the Project encountered are being shared though various workshops, seminars, management meetings, and SC meetings.

MINIFRA as a major stakeholder has participated in SC meetings. Information and lessons of the Project have been well shared. The final seminar was held in November 2021 at the margins of the 7th SC meeting to review all the achievements of the Project. And, in November 2021, a seminar by the Water Sector Working Group, which was scheduled to be held in March 2020 but had been postponed due to measures against the COVID-19 infection, was held.

3) Overall assessment:

Output 1 was achieved.

It may be said that the Project has achieved the Output 1 as of the Terminal evaluation, as WASAC's planning capacity has been upgraded. Through the Project activities, the counterparts are now accustomed to apply efficient approaches to the identification of challenges for NRW reduction and countermeasures thereto, such as questionnaire surveys, workshops and other information collection/analysis tools.

In the course of formulating the 5YSP, the counterparts together with the experts systematically followed the effective/efficient planning processes. They managed to determine five areas (42 countermeasures and 133 work items) as key components of the 5YSP by grouping the many potential

countermeasures proposed at workshop. They also prioritized the work items based on the expected effect on NRW reduction, developed a working schedule and designated responsible departments. It was decided that 5YSP should be implemented, and progress monitored, under this organizational setup. The monitoring has been performed as planned until now. Monitoring results have been well recorded and presented as reports by quarterly basis. In other words, confirming the series of such planning and monitoring steps, it can be evaluated that the cycle of Plan-Do-Check-Action, PDCA cycle, has been well applied in WASAC's job place.

At the quarterly monitoring sessions, challenges and perceived issues were shared within WASAC, including through a workshop involving all branches nationwide. Top executives are highly interested in the monitoring report, as some workshops were held to share the monitoring result at the request of the CEO or DCEO. This exercise also helped the leadership share the challenges facing WASAC.

5YSP has been updated reflecting the result of its implementation in the past 3 years, findings from the pilot project, and observations from the Project for Water Supply Master Plan for City of Kigali. All the progresses and challenges the Project encountered was shared through various workshops, seminars, project management meetings, and SC meetings. And, MINIFRA as a major stakeholder has participated in SC meetings. Information and lessons of the Project have been well shared.

4) Way Forward

Necessity for organizational and institutional changes

The organizational gaps have been identified through the implementation of the 5YSP. Therefore, it is necessary to consider organizational structure to promote the implementation of 5YSP.

WASAC management recognized the importance of the organizational change and the re-structuring process is on-going. WASAC proposes to have a team in charge of NRW in each branch and request for the following personnel increase in the 5YSP update report.

- Quick and quality repairs of distribution and service pipes, for big 10 branches (1engineer and 2 technicians for each branch).
- Inspection of, and enforcement measures against water theft, for NRW unit (2 officers and 3 operators).
- Leak detection activity of NRW unit (2 engineers and 3 operators).

Revision of New Connection Policy and a Standard Enforcement Policy.

The New Connection Policy was formulated in January 2019 as a revised version of the Requirements for Water Distribution and House Connection due to the emergency to comply with the regulatory

agency (RURA). Later, it was observed the need to have the new connection policy revised again in order to ensure customers procured material are in good quality. This is because it has been confirmed that most of leaks are coming from poor quality service pipes. WASAC should review the new connection policy and the enforcement of its implementation.

(2) Output2 Basic knowledge, skills and technique on NRW control are acquired by WASAC.

1) Indicator 2-1: More than 300 number of trainees receive training.

Indicator 2-1 was achieved.

The Project has conducted many types of trainings. The total number of trainees counted to 596 as of the Terminal evaluation.

Table2.74 Number of training subjects and trainees by the field of training

Training field	Number of trainings conducted	Number of trainees attended
GIS	4	62
Hydraulic analysis	7	15
Leak detection	3	205
Repairing pipes and installation of connection services	13	167
Customer meter reading and customer services	27	93
Other (Excel, table calculation, etc.)	6	54
TOTAL	60	596

Note: Number of trainees are the total figures of participants for each training.

2) Indicator 2-2: WASAC human resource development plan includes training programs prepared by the project.

Indicator 2-2 was not achieved.

The Support Service Department, DSS, is in charge of training plan and implementation in WASAC in accordance with its human resource development plan. The training program widely covers various technical topics, inviting internal trainers as well as external trainers from other organizations.

At WASAC, the DSS is responsible for the planning of training. The training program developed by this project should be integrated into the overall framework of WASAC's training program. Indeed, the indicator requires that manual-based activities be a part of the training program of WASAC so that all staff members of the corporation may be equipped with skills required for NRW control. Enhanced coordination between the NRW unit and the DSS was required.

Table2.75 Training courses for NRW reduction

No.	Courses
1	Overview of NRW reduction activities
2	Water pressure management
3	Water distribution management
4	Leak detection and repair
5	Reinstallation of water service pipes
6	Management of distributing reservoir
7	Management of water distribution volume
8	Management of billing data and customer meters
9	Monitoring of NRW rate
10	Preparation for NRW reduction works
11	Operation and maintenance of survey equipment

Following discussions with the NRW unit, primarily responsible for NRW reduction activities, the conclusion was drawn that the training required by the project could be provided without being built into WASAC's training courses for the reasons listed below. For some subjects, including leak detection and surveys on water pressure control, however, problems emerged from the shortage of relevant staffs at branches and the lack of survey equipment. The restriction of movement between branches, introduced in early 2020 to check the spread of COVID-19, also worked as an obstructive factor.

- ✓ Core persons of the dissemination of the manual on NRW reduction activities have been trained in the NRW project.
- ✓ The training can be conducted mainly by NRW Section staff of DUWSS, regardless of the WASAC training course implemented by DSS. The NRW Section is capable of providing on-site guidance to each branch on leak detection and reservoir surveys.
- ✓ The person in charge of database compilation (on billed water consumption, water production and NRW volume) at DUWSS convene branch employees to provide guidance on the analysis of commercial data.

3) Overall assessment:

Output 2 was almost achieved.

The Project provided various trainings not only to the Action team members, most of whom are technical staffs, but also to the Management team comprising directors and managers. As of the Terminal evaluation, the training program prepared by the Project had not been integrated into WASAC's overall training program because the necessity of the integration had not been recognized

for the aforementioned reasons. The achievement of the capacity development is summarized as follows:

Table 2.76 Attainment level on skills development

Technical field	Achievements of technical capacity development
Management	✓Counterparts are now capable of understanding what NRW is about, and developing and implementing 5YSP for NRW reduction.
GIS database	✓Although delays in GIS data development at ESRI and the introduction of ArcGIS prevented the provision of training thereon, it was possible to ensure the upgrading of skills for updating and leveraging GIS data. ✓Counterparts are now able to update GIS data including customer and pipe network data and new customers' data. They can also share GIS data by QGIS and Google Earth. ✓Method to construct and analyze ArcGIS Geometric Network is also mastered at primary to middle-class level.
Hydraulic analysis	✓Although a delay in the introduction of hydraulic analysis software (Mike Urban) prevented the provision of training thereon, it was possible to ensure that counterparts understand the basic theory of the hydraulic analysis. ✓Counterparts are now able to conduct hydraulic analysis with use of application EPANET and Mike Urban.
Leak detection	✓OJT on leak detection: Counterparts learned through individual training and pilot project OJT about flow rate and pressure measurement skills most required in leak detection as well as how to use relevant equipment. However, application issues remain depending on the equipment due to the configuration and irregularity of the existing water distribution network. ✓Counterparts understood well the theory of ultrasonic flowmeter and its usage. They are now able to determine the amount of water leakage by measuring the Quantity Minimum Night Flow, Qmnf, and to narrow down the location of the water leak by step tests or direct measurement on the pipeline. ✓The management of equipment storage was also improved.
Repairing pipes and installation of connection services	✓Counterparts realized the disadvantage of their practices to connect pipes with which they had been familiar for long time, and learned the new connection practices. Improvements are observed in techniques such as screw thread cuttings.
Meter reading and customer services	✓Training on meter reading, water billing and customer services: Counterparts learned how to test meter accuracy on-site through pilot project OJT. Training was also provided to 20 branches using additional on-site test meter equipment. ✓Counterparts are now able to handle test meter for inspection whether customer meter functions correctly or not. ✓Crucial points to take care of when conducting meter reading, water billing, and customer services are well recognized.

4) Way Forward

The basic knowledge and application techniques on NRW control have been acquired through individual training in various project activities and OJT. However, the training program developed by

the project has not been incorporated into WASAC's internal training program, thus precluding the widespread use of the manual. That said, the core persons of the dissemination of the manual on NRW reduction activities have been trained in the Project. Therefore, the training can be conducted mainly by NRW Section staff of DUWSS.

Once the personnel structure of WASAC is enhanced, with new field staff members assigned to sections involved in NRW reduction in branch offices and the headquarters, the corporation will be ready to provide training on its own. At that time, it will be required of WASAC to develop internal training courses using the manual on NRW reduction, which is an output of this project, and to integrate them into the annual plan under 5YSP.

(3) Output3 WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.

1) Indicator 3-1: NRW rates are reduced at each pilot area as follows: Pilot Area 1: from 37% to 20% and Pilot Area 2 from 68% to 25%.

Although the target was reached temporarily in Pilot Area 1, both areas failed to attain the targets in the long term. NRW was reduced by 12% and 10% in the two areas, respectively.

Table 2.77 NRW rates for the pilot projects

Pilot area	Baseline value	Target value	Attained value	Reduction
Area 1: Kadobogo	37%	20%	25%	12%
Area 2: Ruyenzi	68%	25%	58%	10%

Indicator 3-1 was not achieved.

The targets were not attained for the reasons mentioned below:

The pilot areas were faced with the problem of high water pressure in terms of both water distribution blocks and the isolation of water transmission pipe and distribution pipes.

It was pointed out from the beginning that there is a problem in the method of water distribution of water distribution from the highest point of the area to the whole downstream direction in the area where the altitude difference is large, and the method of branching the water distribution pipe directly from the transmission pipe with high pressure.

Since the cause is a haphasic water distribution plan that does not take into account the large topography of the difference in elevation, fundamental measures must be taken from the review of the water distribution plan, but the renovation of existing facilities became large and fundamental measures could not be taken in this project to deviate from the scope of the technical support project.

It also has to be admitted that the target was set at an unrealistic level in the first place.

Pilot Area 1: Kadobogo

The area was divided into three sub-blocks. Each block was fed by a bypass pipe of the reservoirs (Fawe and Gacuriro) located on the transmission pipeline running from the Ntora to Remera reservoirs, or by direct branching off from the transmission pipeline, resulting in high pressure at the branching points. A PRV was therefore installed at each branching point.

The installed PRVs turned out to be effective, temporarily bringing down the NRW rate to the target of 20%. However, the PRVs installed in sub-blocks PM 2 and 3 developed mechanical problems in June 2019 and the water pressure has not been controlled as planned ever since. Only the PRV installed in sub-block PM1 has been functioning well. The maintenance of installed equipment is thus crucial to keep the NRW rate which was reduced after the installation of the equipment for NRW reduction activities.

Pilot Area 2: Ruyenzi

This area was also divided into three sub-blocks. The water pumped from the Nzobe treatment plant had been delivered to other areas through a bypass pipe to the Ruyenzi reservoir in pilot area 2. Main sub-blocks of the area were fed with high-pressure water directly distributed from this water transmission pipe. As the result, the PRVs were effective in reducing the high water pressure to some extent, but the positive effect was found only in a limited area due to the large elevation difference within the area. Therefore, the target NRW rate was failed to reach.

Yet, the following insights were obtained:

- ✓ In Pilot Area 1, the NRW rate temporarily dropped below the target of 20%, but since June 2019, the NRW rate has increased again due to PRV failure. The rate subsequently stabilized at around 25%, leading us to recognize the importance of maintaining installed PRVs. The 20% target would be attainable with adequate maintenance.
- ✓ In Pilot Area 2, the NRW rate stayed far above the 25% target. Given the extremely high water leakage rate of 68%, installing PRVs on existing distributing pipes would only have limited impact on leakage control. Although PRVs proved the effect in parts of the area, their effect on the reduction of the NRW in the whole area is limited if a topography has large differences of elevation, unless more meticulous pressure regulation is introduced. However, the trial operation of PRV in the pilot project showed that it was possible to reduce NRW volume to some extent (14%) by lowering the pressure in nighttime.

- ✓ In a water distribution area with a large elevation difference, it is necessary to take account of its topographic condition and control water pressure based on elevation. The area should be divided into several blocks with different elevation by means of installation of new reservoirs should be carried out with rearrangement of distribution pipes and the replacement of service pipes. There is a limit to the effect if the water leakage reduction measures are advanced by the certain facility alone.
- ✓ The water distribution system needs to be reviewed where water is distributed through a bypass tube to a reservoir.
- ✓ At the same time, the result of the cost-benefit analysis has proved that even where the NRW rate is as high as 68%, like in Ruyenzi, investment in NRW reduction activities is effective if the NRW rate can be reduced to some extent (about 10%). It is therefore important to actively promote activities with substantial investment effect, such as the reduction of high water pressure (installation of PRVs), leak detection and repair (underground leakage in particular) and the replacement of distribution and service pipes.

2) Indicator 3-2: Action team members share experiences at workshops regarding implementation of the pilot projects.

Indicator 3-2 was achieved.

- ✓ Experience was shared among the Action Team members through pilot area activities and workshops.
- ✓ Experience in the pilot project activities was also shared with the Management Team at weekly meetings, workshops and SC meetings, among others, thus raising awareness of the effective actions and challenging activities identified as a result of project activities.
- ✓ A further workshop was held after the preparation of the completion report on the pilot project. In the same manner as the indicator 1-2, the Action Team members shared experiences and lessons through workshops and a variety of meetings.

3) Indicator 3-3: The action team prepares a completion report of the pilot project.

Indicator 3-3 was achieved.

The completion reports of the pilot project were already prepared to WASAC by the JICA experts. They were reviewed and finalized through workshops. The reports were submitted to WASAC in October 2019 for the Pilot Area 1 and in February 2020 for the Pilot Area 2.

4) Overall Assessment:

Output 3 was almost achieved.

Although the NRW reduction activities did not achieve the initial targets in the pilot areas, activities and work procedures effective on NRW reduction could be identified. The target value was temporarily achieved in Area 1. Although the NRW rate were reduced by only about 10% in both pilot areas, the cost-benefit analysis revealed the feasibility of the NRW reduction activities. In order to achieve the overall goal of the project, such effective activities should be promoted actively. The following insights were obtained in the course of pilot project implementation:

- ✓ Importance of facility planning mindful of NRW, and requirements for the monitoring of NRW and maintenance of relevant equipment on the development of infrastructure for water distribution networks
- ✓ Concept of NRW activities and customer services in the 5YSP activities (composition of NRW: percentages of Real Loss and Apparent Loss)

The aim of this Output is to enhance capacity to respond to issues on the ground and conduct activities, directly using the technical knowledge obtained in Output 2. The Action Team members shared experiences and lessons at workshops and a variety of meetings.

Through the implementation of the pilot project, the primary cause of NRW for WASAC was found to be water leakage. As it became clear that top priority in reducing water leakage lay in measures against high water pressure and improvement in the quality of water distribution and service pipes and workmanship, appropriate measures, such as the installation of PRVs and the replacement of existing distributing and service pipes, were taken to reduce water leakage. In this process, it was also found that the conventional leakage repairs were ineffective unless accompanied by measures against high pressure.

Specifically, the counterparts learned techniques for: formulation of DMAs (hydraulic isolation of a service area and installation of measuring equipment); on-site testing of customer meters; water leakage survey (flow rate and pressure measurement); leak detection; high water pressure control; planning of replacement of distribution and service pipes; construction management; and creation of customer location maps, among others. They also renewed their awareness of the importance of meter replacement to maintain customer service. For example, WASAC used to recognize water leakage repair as a standalone task, but now they understand the organic links among the activities that they conducted as part of the pilot project, and recognize the necessity of strategically conducting reduction activities. They also learned how to establish hydraulic isolation in a service area required as the

preparation of DMA formation install measuring equipment such as flow meters, and organize customer information.

Through those OJT activities in the pilot project, the counterparts at WASAC learned effective techniques for NRW reduction. Furthermore, they performed a cost-benefit analysis on pilot project activities and confirmed that the measures taken to reduce NRW were financially viable. Having recognized the importance of responding to existing issues, WASAC recognized that taking precautionary measures in the stages of the planning and designing of a water distribution network is most important in preventing the emergence of NRW.

(4) Output4 4 branches in Kigali establish the system to measure NRW rates accurately.

1) Indicator: NRW rate of each branch is periodically monitored and reported in PIP (Performance Improvement Plan) every month.

Indicator 4 was almost achieved.

- ✓ The equipment procurement and installation that was contracted out to a Japanese contractor began in October 2019. According to the schedule at that time, the monitoring system was to be completed in June 2020, but the work was suspended in March 2020 as an anti-COVID measure. The work resumed as COVID-19 came under control. Despite some delays in the procurement and installation of equipment, the construction of the monitoring system was mostly completed in September 2021, with the exception of equipment maintenance.
- ✓ WASAC, for its part, is now proceeding with the procurement of 16 flow meters and the adjustment of customer registrations emanating from the partial relocation of branch-to-branch borders.
- ✓ Calculation of the NRW rate was commenced after the completion of the system. Guidance was provided on how to use NRW rate calculation software with data obtained from the monitoring system.

2) Overall assessment:

Output 4 was almost achieved.

The monitoring system to measure NRW rates has mostly been completed except for the installation of part of the required equipment. Training on the NRW rate calculation system has also been completed.

3) Way Forward

WASAC cannot calculate the NRW rate in each branch since the flow meters listed have not been installed by WASAC at the sites mentioned below. WASAC must install the 16 flow meters as soon as possible to incorporate the data measured by them into the monitoring system. At the same time WASAC should complete the re-registration of the customers affected by the border relocation to ensure the accuracy of the NRW rate calculation.

- ✓ Sites on the branch border between Kanombe and Remera: (5 sites)
- ✓ Site on the new branch borders created by the AfDB project (11 sites)

2.2.2 Achievement of Indicators on Project Purpose

(1) Attainment level on the Indicator

1) Indicator 1: 5-year Strategic Action Plan for NRW reduction is approved by the Minister of Infrastructure.

Indicator 1 was achieved.

The 5YSP for NRW reduction was approved on the 27th April, 2018 by the WASAC's Board of Directors, and recognized by MINIFRA.

2) Indicator 2: Annual action plan regarding NRW reduction of each branch is reflected in annual action plan of WASAC

Indicator 2 was almost achieved.

As the impact of the NRW reduction activities in the pilot areas is recognized, some of them are being replicated outside the pilot areas. Now, each branch has an annual action plan for NRW reduction activities, including plans for PRV installation, meter replacement, and leakage survey, which comprises a part of the annual action plan of the entire WASAC. In addition, each branch will need to develop an implementation plan based on more detailed surveys, planning and design and to conduct more specific activities based on the plan.

3) Indicator 3: The management at WASAC recognizes the effects of NRW reduction, and approves the budget of each branch for implementing annual action plan for NRW water reduction

Indicator 3 was not achieved,

The WASAC Management fully recognized the effectiveness of the NRW reduction measures through

the pilot project and already extended the same countermeasures, such as installation of PRVs and FVs, accuracy check of flow meters, customer survey and analysis, and on-site testing and replacement of customer meters, outside of the pilot project areas. The budget for the NRW reduction activities has been included in the annual Action Plan of WASAC.

Although WASAC Headquarters approved the annual action plan, the budget allocated to the NRW reduction works in the plan is lower than the planned budget. As things stand, the budget is not appropriately allocated to the implementation of NRW reduction activities by. The activities of the annual action plan are therefore not backed by the budget and the action plan has not been fully implemented.

(2) Overall assessment

The Project purpose was almost achieved.

Towards the Project purpose "enhancement of WASAC's capacity to conduct NRW reduction measures", the Project adopted a four-pronged approach consisting of: Output 1) planning; Output 2) acquisition of basic skills and techniques; Output 3) application of skills and techniques, and Output 4) establishment of NRW rate measuring system. As the achievement status of Output 1 shows, WASAC has been steadily implementing and monitoring NRW works in accordance with the 5YSP using the PDCA cycle. For Output 2, WASAC's staff members have acquired knowledge and skills in a series of training. Regarding Output 3, the capacity to cope with actual situations/challenges in the field has also been enhanced through the pilot project. As for Output 4, only the maintenance of the NRW rate measuring system remains.

On the other hand, it has to be pointed out that actual budget allocation is not sufficient to implement the NRW reduction activities per the annual action plan. Since WASAC cannot increase its revenue without raising basic water rate as an independent corporation, it cannot alleviate this problem with its self-help efforts. The insufficient budget allocation for the NRW action plan is a major obstacle to the use of the technical capacity acquired in the Project.

In conclusion, although the Project has not solved the challenges on budgetary allocation, the Project activities successfully led to the enhancement of the capacity of WASAC. Thus, the Project purpose is evaluated "almost achieved."

(3) Way Forward

WASAC's insufficient annual budget does not cover all its NRW reduction activities. As the initial

investment (CAPEX) required for the NRW reduction is huge compared with the currently available budget of WASAC, WASAC should seek external funding sources for the NRW reduction

2.2.3 Attainment Level on the Overall Goal

Attainment level as of FY2020/21 stands at 42.2% (43.3% nationwide), pointing to difficulty in attaining the overall goal on the NRW rate.

The reason for the increase in the NRW rate is that, despite the increase in supply capacity due to the expansion of water distribution facilities measures to reduce NRW have not been advanced in a wide area and also water distribution facilities have not been reorganized considering the topography with large elevation differences.

Table 2.78 Target and actual NRW rate

FY	5 YSBP NRW rate target (nationwide)	5YSP Year of implementation	5YSP NRW rate target (Kigali)	Actual NRW rate (Kigali)
2018/19	35%	Year 1	35	36.9
2019/20	32%	Year 2	34.4	40.3
2020/21	30%	Year 3	30	42.2
2021/22	28%	Year 4	28	-
2022/23	25%	Year 5	25	-

Note: Monitoring started in July 2019 (2019/20, Q1); target for FY19/20 was revised from 32% to 34.4%.

Chapter 3 Output of Other Activity

3.1 Support for Countermeasures Taken Against COVID-19

WASAC made a request to the JICA Rwanda Office on June 11, 2020, for assistance to mitigate the risk of the infection and spread of COVID-19. In response, JICA studied the components of the request and their content and concluded the minutes of meeting on the contents of the assistance with WASAC on July 22 (see Attachment 7). The minutes included the following two assistance activities to be implemented in this NRW Project.

- Procurement of materials and equipment for Reduction of Intermittent Water Supply.
- Emergency water supply to people with limited access to clean water.

(1) Procurement of materials and equipment for Reduction of Intermittent Water Supply.

The contents of the equipment and materials were decided as: “Materials for leakage repair: pipe and fittings with small diameter for network leakage repair in Kigali city,” “Service pipes: materials for the replacement of the existing sub-standard pipes in Ruyenzi” and “Floater Valves: FVs for installation in reservoirs in Kigali”. The counterparts and local project staff conducted an equipment survey in consultation with the expert through online teleconferencing, and prepared a BoQ of the selected materials and equipment.

Competitive bidding among local suppliers was held to select the contractor for the procurement. Materials and equipment, worth about 193,000 USD in total, were procured and handed over to WASAC on November 9, 2021.

Table 3.1 Breakdown of procured materials and equipment

Item	Contents	Details	Amount (USD)	Inspection	Handover
Item 1	Pipe and Fittings for Network Repair (Materials for leakage repair)	・PPR pipe, DI clamp saddle, PVC socket, PPR socket, GS Nipple, GS Bend, Ball valve: for six branches in Kigali City for half year ・Drilling Machine: 6 sets ・Manual pressure testing pump: 6 sets	72,837	Done (June 17, 2021)	Done
Item 2	Service Pipe for replacement in Ryenzi Pilot Area	HDPE pipe DN50, PPR pipe 1",3/4", Screwed clamp, Nipple, Adaptor, Union, Ball valve, Tee, Elbow, Reducer, Bulk meter: for total length of pipe 5,300m	34,000	Done (June 10, 2021)	Done
Item 3	Floater Valve	Floater Valve, Gate valve and fittings: for 11 reservoirs in Kigali	85,725	Done (Oct. 15, 2021)	Done
Total			192,562		

Materials for water leakage repair were selected based on the record of past repairs and present stock of materials in the warehouse of WASAC, taking the WASAC’s request into consideration. As most

leaks in the network have occurred on small-diameter service pipes with a diameter of 63 mm or less, this size of diameter was applied as the condition for procurement, in an amount equivalent to the pipes actually used by the six branches in Kigali in six months.

Regarding service pipes, it was decided to procure materials for replacing the service pipes and distribution pipes in Pilot Area 2 (Ruyenzi) as requested by WASAC. The result of the leakage survey conducted in the pilot project and locations of newly detected water leaks were analyzed to identify the types and diameters of pipes from which water leaks frequently. From the results of the analysis, the locations where the replacement of service pipe is urgently required were identified. In this pilot area, despite the measures taken against NRW, *e.g.*, water leakage repair (only for surface leakage) and PRV installation, the NRW rate could not be decreased less than 58% (the baseline of 68 %). Therefore, the replacement of service pipes was expected to be a conclusive effective measure. The procurement of additional equipment, including drilling machines for pipe connection and manual hydrostatic pressure tester for the installation of small-diameter pipes was also provided.

As overflow countermeasures of reservoirs, a plan for the installation of floater valve of reservoirs in Kigali was formulated based on the result of the functional surveys.

WASAC scheduled for installation of the procured equipment in accordance with the milestone shown on the following. Utilization of these items will be contributed to the implementation of the 5YSP.

Schedule of installation and use of the Equipment and Materials procured for COVID-19 response

Item	Contents	Process	2021		2022					
			Nov	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Item 1	**Pipe and Fittings for Network Repair (Materials for leakage repair)**	Handover								
		Use								
Item 2	**Service Pipe for replacement in Ruyenzi Pilot Area**	Handover								
		Resources preparation								
		Installation								
Item 3	**Floater Valves for 11 reservoirs and related accessories**	Handover								
		Equipment's Installation								
		Rwezamenyo (Nyamirambo)								
		Burema (Nyamirambo)								
		Mataba (Nyamirambo)								
		Camp Militaire Hill (Nyamirambo)								
		Golf 7 (Gikondo)								
		Fawe Girls School (Kacyiru)								
		Jabana (Nyarugenge)								
		Rwankuba (Nyarugenge)								
		Azam Bas Via Mettito (Remera)								
		G8 Rwahama/Kibagabaga (Remera)								
		G8 Rwahama/Karenge (Remera)								

Fig. 3.1 Timeline for use and installation of procured materials and equipment

(2) Emergency water supply to people with limited access to clean water

Emergency assistance was provided in those areas in WASAC's water distribution network with insufficient water supply by installing temporary water tanks to be fed by water tankers. The JICA Office procured temporary water tanks to be installed on the sites designated by WASAC, while the WASAC installed the tanks on those sites as public taps. Twenty-three sites in the area covered by the four WASAC branches in Kanombe, Remera, Kacyiru and Nyarugenge were selected based on the results of an on-site survey and the discussion on the survey results that WASAC and JICA had. Twenty-five reinforced plastic tanks were procured and installed as temporary tanks.

The JICA expert team outsourced the water transportation to the sites of public tap to two private service providers in Kigali who owned water tankers and managed their work. Potable water was supplied from the Kimisagara Water Treatment Plant. Water was loaded to the tankers at the water station created in the Kimisagara Plant and transported into the temporary tanks at the 23 public tap sites. The piping materials to be installed on the water tanks (inflow pipe and discharge pipe including water taps), bulk water meters, and portable engine pumps for transferring water from the tankers to the tanks were also procured by the JICA expert team. See Attachment 7 for detail of the water transport operation by the tankers.

The operation started in November 2020, and ended in September 2021 in accordance with the resolution of the 6th SC meeting, with the number of sites phased down depending on the improvement observed in the water supply through WASAC's water distribution network to each site. Water loss during transportation in tankers was 3.0%.

These activities brought the following benefits in the prevention of COVID-19 infection to the resident people.

- ✓ Total water supply volume : 43,233 m^3 (at public taps)
- ✓ Total cost : 259,480 USD (unit water transportation cost 6.0 USD/m^3)
- ✓ Beneficiary households : about 5,200
- ✓ Beneficiary population : about 26,000
- ✓

In September 2021, WASAC started the operation of the new water tanker (capacity: 6m^3) provided by the Project for Water Supply Master Plan for City of Kigali of JICA. The know-how of the water transportation operation accumulated in the activity in the NRW technical assistance project was succeeded to WASAC.

3.2 Water Utility Regional Partnership (WURP) Activities

Under its global agenda, "Securing Sustainable Water Resources and Water Supply," JICA focuses on the creation and sharing of knowledge by water utilities. WASAC concluded an agreement on cooperation with the Lilongwe Water Board (LWB) of Malawi in July 2017, to promote mutual learning on subjects, including NRW reduction.

In November 2018, the first workshop, "Workshop on the Benchmarking of NRW Reduction Measures," was held in Rwanda, with the participation of Embu Water & Sanitation Company (EWASCO) from Kenya, effectively launching the Water Utility Regional Partnership (WURP), a regional coordination framework among water utilities of three countries: Rwanda (WASAC), Malawi (LWB) and Kenya (EWASCO). The second workshop, hosted by LWB was held in September 2019 in Malawi with the theme: "Lessons Learned from Successful and Unsuccessful Cases of NRW Reduction." The third workshop, to be hosted by EWASCO in Kenya in 2021, was put off due to the COVID-19 Pandemic.

Within the framework of the regional partnership, the three member utilities are engaged daily in voluntarily defined activities. The progress is reported in virtual meetings held on a bimonthly basis. The annual workshop also serves as a forum for the final reporting on those activities. The JICA Offices and experts provide the necessary support, including advice on the activities to the partnership activities. The Regional Partnership is making headway, backed by the friendly relationship among the members, and is expected to develop further.

Chapter 4 Project Evaluation

4.1 Evaluation by 5 DAC Evaluation Criteria

The five evaluation criteria used in the analysis for the Terminal Evaluation are described in the table below.

Table 4.1 Description of Five Evaluation Criteria

Criteria	Definitions
Relevance	Degree of compatibility between the development assistance and priority of policy of the target group, the recipient, and the donor.
Effectiveness	A measure of the extent to attain its objectives.
Efficiency	Efficiency measures the outputs - qualitative and quantitative - in relation to the inputs.
Impact	The positive and negative changes produced by a development intervention, directly or indirectly, intended or unintended. This involves the impacts and effects resulting from the activity on the social, economic, environmental and other development indicators.
Sustainability	Sustainability is concerned with measuring whether the benefits of an activity are likely to continue after donor funding has been withdrawn.

Source: JICA Handbook for Project Evaluations (Ver. 2.0), 2021

Each criterion is evaluated using the following five rankings: “high”, “relatively high”, “moderate”, “relatively low”, and “low”.

4.1.1 Relevance: High

The Project is consistent with the policy of the Government of Rwanda and the assistance policy of the Government of Japan for Rwanda. Various Project activities and their outputs are consistent with the needs of the relevant organizations.

(1) Consistency with the policy of the Rwandan Government

The Rwandan mid-long term national development policy, Vision 2020, shows the goal in the Water sector development, as all the nationals can access to safe water by 2020. The policy clearly states: “Rwanda will continue to invest in protection and efficient management of water resources as well as water infrastructure development to ensure that by 2020 all Rwandans have access to clean water”. Although the Vision does not specify the importance of NRW control, it is reasonable to interpret that NRW issues is included in necessary investment on water infrastructure towards realization of the government’s goal.

After the Project started, the government presented a 7 years government program “National Strategy for Transformation 2017-2024” in 2017. The program re-declares that access to safe water of all the nationals will be realized by 2024 through investments in construction, extension and rehabilitation of water supply system.

Moreover, the sectoral policy led by MINIFRA, the National Water Policy (2016), addresses the importance of NRW reduction efforts in order to optimize operational efficiency of water services. Overall, it is evaluated that the Project has been in line with the government's policy.

(2) Consistency with Japanese ODA policy/plan

The Country Assistance Policy for Rwanda in 2017 of the Government of Japan sets the primary goal, "promotion of sustainable growth, poverty reduction and job creation" in alignment with Vision 2020. The policy stresses the significance to assist social service improvement including sustainable safe water supply and sanitation service as one of the assistance priority areas. It notes that "Japan enhances not only the rural water supply but also urban water supply including the capital city of Kigali".

The rolling plan attached to the policy also shows Japan will utilize the technical cooperation scheme in order to improve access to safe water. The Project is placed as one of the key projects in the "Improvement of Water and Sanitation" assistance category. The consistency of the Project with the Japanese assistance policy is confirmed in this context.

(3) Consistency with the needs of WASAC

In the year 2013/14, just before the Project started, the NRW rate in Kigali city had been estimated at 41% mainly due to improper NRW control. Although the government officials including those of MINIFRA and WASAC had recognized the necessity to take counteractions against water leakage, illicit usage and others, WASAC at that time did not have enough technical capacity and experiences to carry out those necessary counteractions.

Under the situation, the Project has transferred skills and techniques in various fields in accordance with the necessity of WASAC. The technical topics covered widely from the planning to the implementation of field works such as leakage detection, repairing pipes, pressure management and others. In parallel with the technical transfer, equipment and infrastructure have also been provided, as necessary, considering the necessity for and efficiency of the field works. Overall, it is evaluated that the Project has met the needs of WASAC.

4.1.2 Effectiveness: Relatively high

The effectiveness of the Project is high because the targets of most of the indicators of the Project Purpose have been achieved.

The Project shows significant achievements in the technical capacity enhancement in 1) planning, 2 acquisition of basic skills and techniques; Output 3) application of skills and techniques, and Output 4)

establishment of NRW rate measuring system. Although the establishment of the NRW rate measuring system was suspended due to the delay in procurement of system equipment, it can be evaluated that the most essential part of the Project purpose has been mostly achieved. The Project has been progressing owing to these contribution factors.

(1) Effect of Water Utility Regional Partnership

The participation of WASAC in the regional partnership workshops with the water utilities of Malawi and Kenya in the Project contributed not only to the expansion of their views and knowledge but also to the enhancement of their motivation to the work.

The Project encouraged to strengthen relationship with water utilities of neighboring countries in the framework of the "Water Utility Regional Partnership" with Malawi and Kenya. The Project supported holding workshops in Rwanda and Malawi where participants proactively exchanged their own experiences related to NRW reduction. The workshops contributed WASAC not only expand their views and knowledge but also enhance motivations to work on NRW reduction.

Table 4.2 Workshops with water utilities of Malawi and Kenya

	Name of workshop	Number of participants	Venue	Water utilities	Date
1	Water utility regional partnership	31	Rwanda	Rwanda (WASAC), Malawi (LWB), Kenya (EWASCO)	From 4 to 9 Nov. 2018
2	Water utility regional partnership	62	Malawi	Rwanda (WASAC), Malawi (LWB, BWB, NRWB, SRWB, CRWB), Kenya (EWASCO), Japan (YWWB)	From 23 to 27 Sept. 2019

Note: Excluding TV conferences and preparation workshops

(2) Flexible Modification of Project Activities and Inputs

The Project gradually figured out more effective measures for NRW rate reduction suitable for the topographic and natural conditions of the project sites while implementing the pilot project. One of them, was water pressure control, to which no reference had been made in the PDM. Indeed, activities and equipment related thereto were not included in the initial plan. Recognizing its importance, the Project added the implementation of water pressure control and the input of equipment to its scope. The pilot project implemented as a result attested to the effectiveness of pressure control. Thus, flexible modification to the project activities did help improve the effectiveness of the Project.

(3) Formulation of 5YSP in Early Stage

The Project formulated the 5YSP by the middle stage of the Project period, and then tried to give actual experiences of the PDCA cycle by use of the Plan as many times as possible. As a result, the

Project enabled WASAC to experiences the PDCA cycle for two years, which led to the capacity development in planning and monitoring. Supposing the case where the output of 5YSP should be determined in the final year of the Project, it can be evaluated that this operation schedule of the Project which set the timing of the formulation of 5YSP at an earlier stage was one of the contribution factors to enhance the planning capacity.

(4) Project Design (Pilot Projects)

The pilot projects were implemented effectively because their design had provided appropriate strategies on what should be tried in the pilot project and how the outcome of the tried activities should be used. In practice, i) the focus was placed on finding and specifying the most effective NRW reduction measures and ii) the specified measures were reflected in the mid– to long-term strategic plan.

The policy of JICA on NRW reduction projects stresses that a pilot project should be conducted for the purpose of finding and specifying the most reasonable and feasible NRW reduction measures for a target area and then reflecting the specified measures in a mid-long term strategic plan. The policy considers this activity as one of the key activities for the improvement of the effectiveness of NRW related projects in the world. The design of the Pilot Project in this Project is exactly in line with this policy's key message and actually produced tangible outputs. This coherence led to the implementation of the Pilot Project on the right track and accordingly to the production of meaningful results.

(5) Coordination with Long-term Experts of the Project

The long-term expert dispatched to and stationed permanently in Rwanda acted as a liaison between the C/P and the expert team. The expert enhanced the exchange of information between them and contributed to the follow-up of the Project activities.

Besides the original technical tasks, the long-term expert enhanced bridging information and relationship between the counterparts and the expert team, and contributed to improving management and follow-up of the Project activities.

(6) Inhibition factors

The following two factors hindered the achievement of the project Outputs and the Project purpose.

- Delay in the selection of suppliers of equipment and materials for the monitoring systems.
- Suspension of and delay in the Work in Rwanda due to the COVID-19 outbreak

The procurement and installation of the equipment for the monitoring system for NRW rate measurement were significantly behind the original schedule, primarily due to the long bidding and

approval processes for selecting equipment on the Japanese side. This led to a delay in the establishment of the monitoring system for NRW rate measurement, and also to an extension of the project period.

Secondly, the COVID-19 outbreak affected the project activities. The experts and the contractor were unable to work in Rwanda from April 2020 until March 2021 because of restrictions on the overseas dispatch of them in the COVID-19 pandemic. The field work such as the installation of the monitoring system was suspended this period. Communications between the Japan and Rwandan sides via the internet continued, but the efficiency of the work was inevitably compromised. The suspension also further delayed the procurement and installation of the equipment for the monitoring systems, further extending the project period.

4.1.3 Efficiency: Moderate.

The Japanese experts were assigned to the relevant technical assistance in the Project efficiently and effectively. The manpower input by the Rwandan side was also appropriate as the counterparts were assigned from all the relevant departments/units of HQs and branches concerned with NRW reduction in addition to the NRW unit.

Meanwhile, the delay in the procurement of the equipment for the NRW-rate measurement system delayed the commencement of the operation of the system and led to the extension of the overall project period. The quantities of some types of training equipment were not enough for the expansion and establishment of the training effects.

The delay in the equipment procurement had a negative influence on the establishment of the NRW rate measurement system, and moreover the entire project period. Overall, the efficiency is evaluated as “moderate”.

(1) Manpower input

Japanese side

The manpower inputs by the Japanese side were appropriate in response to the technical fields the Project targeted. The composition of the expert team, which is made of experts, local staff and a long-term expert enabled the enriching of the contents of the technology transfer and to realize close communication and monitoring.

Rwandan side

The Rwandan side also made efficient manpower inputs for the Project implementation. The counterparts were assigned from all the relevant departments and branch offices in addition to the

NRW unit. As to the extent of engagement in the Project, some counterparts faced difficulties to reserve time for participation in the Project because of conflict with their original tasks. However, even if they had such difficulties, they kept trying to catch up with the Project activities through weekly meetings and other opportunities. Overall, the manpower inputs by the Rwandan side were evaluated appropriate.

(2) Physical input (Equipment and facilities)

Equipment provided by the Project is necessary for the Project activities. It has been well utilized and contributed to the achievement of the Outputs and the Project purpose. The additional inputs such as PRVs and FVs enhanced the effectiveness of the Project activities. On the other hand, the installation of the NRW rate measurement system was delayed due to the long procurement process and the COVID-19 Pandemic, which resulted in the delay in the achievement of Output 4, the establishment of the NRW rate measurement system. Furthermore, from the viewpoint of dissemination of training effect, it is pointed out that the quantities of inputs of some types of the equipment were insufficient.

As an activity for Output 2, the Project conducted intensive training in the repair of leaking pipes for the six WASAC branches with one set of equipment. Branch office staff could not improve the skills after the training because their offices did not have the same types of equipment. If the Project had been able to make additional equipment inputs, training effects could have been observed widely at the branch office levels as well. Overall, the Project had positive parts and provided lessons in the equipment inputs.

(3) Budget

Budget amount and the disbursement timing were appropriate for the Project implementation.

(4) Supplementary effects and duplicated activities

There were no projects which brought supplementary effects to the Project. Instead, information of and lessons learned in the Project were reflected in another JICA project, “Project for Water Supply Master Plan for City of Kigali.” The master plan project makes more emphasis on the importance of water pressure control, and recommends the introduction of block segmentation and implementation of more effective pressure control. The Project also gave useful information and lessons for the preparation of a JICA Grant-aid project, “the Project for Improvement of Water Supply Services in North-Central Kigali.” This observation suggests that the Project made contributions to other projects as an information provider.

4.1.4 Impact: Relatively high

The achievement of the Overall goal, "WASAC continues to apply NRW countermeasures," is prospected. However, it is difficult to achieve the Overall goal by the target year, and it will take more time to do so. Meanwhile, the project had spillover effects on the organizations and the society, such as i) the establishment of the Water Utility Regional Partnership Platform, ii) the provision of the third-country training (to Société des Eaux de Guinée, Guinea water utility), and iii) the mitigation of water supply cutoff in the pilot project areas. Overall, the impact is evaluated relatively high. Negative impacts are not observed.

(1) Organizational aspects

✓ Establishment of water utility regional partnership

A water utility regional partnership was established among the water utilities of Rwanda, Malawi and Kenya with the support of the Project. The partnership has already organized bimonthly TV conferences, where they set common activities for the NRW reduction and present progress and outcome of the activities, as well as in-person workshops in member countries. Such view exchange opportunities are now functioning as an effective platform to teach and learn from one another.

✓ Acceptance of the third-country training from Société des Eaux de Guinée (SEG), Guinea water utility.

WASAC received 4 trainees of the third-country training program from Guinea in December 2019 and explained to them the NRW reduction measures taken by WASAC as well as how to use a variety of equipment. The SEG trainees recognized the importance of their role as a driver of NRW reduction measures and drew inspiration about the way forward.

(2) Social aspects

✓ Mitigation of water supply cutoff at the pilot project area.

A series of NRW reduction measures taken in the pilot project have resulted in the reduction of the frequency of water supply cutoff for leakage repairs. Residents in some districts benefitted from the improved water supply condition.

4.1.5 Sustainability: Moderate.

Considering the following aspects, sustainability is evaluated moderate.

(1) Policy aspect

The Government of Rwanda places "the whole of the Rwanda Population will have access to clean

water" as one of the national goals in Vision 2020 and the following national plan, "National Strategy for Transformation 2017-2024" as well. MINIFRA as a responsible ministry for water services, has also been stressing the importance of NRW reduction. In this line, as the Government of Rwanda is likely to continue stressing the importance of NRW reduction for the realization of "100 % access to clean water" in its policies, the sustainability of the Project in the policy aspect is high.

(2) Organizational aspect

WASAC has organizational problems. Although it intends to have appropriate organizational composition, it has many vacant posts and the majority of its staff members are temporary workers. There is a deviation between the planed and the actual organizational structures. In order for WASAC to work on NRW reduction measures, the increase in the staff at the headquarters as well as branches is indispensable.

(3) Technical aspect

The technical knowledge and skills of WASAC counterparts have significantly upgraded during the Project period. The next step is to disseminate the knowledge they gained to other staff members in WASAC. For this purpose, WASAC can utilize its internal training system. The internal training system is ready to adopt the training courses on NRW with the training manual developed by the Project. The counterparts are able to work as internal trainers for the courses. The technical capacity of the WASAC staff involved in the Project has improved significantly in the Project period and the internal training system has been established in WASAC. Based on these observations, the Project is evaluated to have a certain level of sustainability in the technical aspect.

(4) Financial aspect

Financial sustainability continues to be a matter of concern. The setting of the water tariff, in which WASAC cannot be involved, affects the amount of the budget of WASAC and eventually the budget allocated to the NRW reduction measures in the current financial framework. The record of the budget allocation in this framework casts doubt on the financial sustainability of the project.

In order to continue NRW reduction activities, firstly, reserving a budget for the operation and maintenance of the water distribution networks is required. Secondly, the budget for countermeasures which the Project claimed effective, namely, the improvement of facilities for water pressure control and replacement of distribution and service pipes (aged and substandard pipes), is necessary.

Although WASAC fully recognizes the necessity to increase its organizational revenue along with raising water tariffs to cover necessary expenses, the regulatory framework on water tariff hikes does not allow WASAC to revise the tariff for its own convenience. Considering this regulatory framework,

more consultations/discussions with relevant authorities are necessary to secure financial sustainability.

Financial sustainability is an important as well as a challenging factor to realize continuous efforts on NRW reduction by WASAC.

4.1.6 Conclusion

The Project took approaches from four (4) aspects, i.e. Output 1: capacity development; Output 2: acquisition of basic skills and techniques; Output 3) application of skills and techniques and its output, and Output 4) establishment of an NRW rate measuring system. Steady progress was confirmed except for the delay in Output 4: establishment of an NRW rate measuring system, indicating the Project almost achieved its purpose.

In addition, the Project showed effective and feasible measures for NRW reduction through lessons learned in the Pilot Project. This is also noted as one of the crucial outputs of the Project. An impact was also observed in the organizational and social aspects. The promotion of regional water utility partnership with Malawi and Kenya is one of the highlights of the impacts that the Project produced.

On the other hand, the Project faced difficulty in the establishment of the NRW rate measurement system due to the prolonged procurement processes, which affected the efficiency of the Project. The sustainability in the technical aspect was generally confirmed, while challenges still exist concerning the sustainability in the organizational and financial aspects.

Overall, the Project has almost achieved its purpose. The strategy and measures for NRW reduction are clearly and mutually shared in WASAC. However, organizational and financial sustainability still remains a concern for the future when those NRW reduction measures are to be implemented. It is necessary to aim at alleviating this concern in order to continue the NRW reduction efforts.

4.2 Challenges for Project Operation

The following shows the issues found in each activity.

(1) Project Purpose: WASAC's capacity is enhanced to conduct NRW reduction measures as planned for Kigali city.

The outcome of the Pilot Project has convinced the WASAC management of the effect of the NRW-reduction activities. Branch have already begun implementing these activities. The annual action plan of WASAC is prepared at its headquarters with the status of services of each branch taken into consideration and the budget is allocated to WASAC based on the plan. However, because the ratio of the allocated budget to the required budget is extremely low (allocation of 19 % of the required budget

in 2019/2020), the action plan of each branch prepared in accordance with 5YSP lacks budgetary backing. Therefore, many activities in the plan cannot be implemented. While each branch needs a more explicit action plan for NRW reduction, WASAC has the following problems in the implementation of such a plan:

- ✓ The budget has not been disbursed as described in the annual action plan;
- ✓ Sufficient surveys have not been conducted for requesting budget for the procurement and installation of the equipment for the NRW-reduction activities;
- ✓ Standard drawings or standard costs that are basic information for the preparation of a budget request has not been prepared.

(2) Output 1 Planning capacity of NRW reduction of WASAC is enhanced.

As the 5YSP has been developed, the plan must be updated each year based on the achievement in and status of NRW reduction in the year for the more effective implementation of the NRW reduction activities. The cost-benefit analysis of the NRW reduction activities implemented in the Pilot Project for the achievement of Output 3 has proved that the activities have relevant effects.

Although the capacity in developing a plan for NRW reduction has been enhanced, the budget allocation to the NRW-reduction activities is not sufficient. WASAC needs to strengthen the communication with organizations that decide water tariffs, including RURA, and convince them of the needs for large initial investment and the revision of the water tariff schedule for the implementation of the NRW-reduction activities.

The formulation of a plan for NRW reduction requires the implementation of a survey of all the facilities in Kigali and other areas (to identify leaky distribution networks requiring pipe replacement and areas of high water pressure and elucidate the functional status of reservoirs). However, the information on the existing facilities has not been fully collected or analyzed despite the complex network of WASAC's infrastructure. The organizational capacity of WASAC needs to be enhanced for the analysis of data, including NRW monitoring data, data of the distribution pipe networks, and customer information, and implementation of surveys of customer meters, measures to reduce high water pressure, replacement of distribution and service pipes, and leakage survey/ detection.

(3) Output 2 Basic knowledge, skills and technique on NRW control are acquired by WASAC.

The preparation of the NRW reduction Manual has been completed. It is important to update it by incorporating the knowledge acquired in the NRW-reduction activities of WASAC as needed. To disseminate the NRW control technology in WASAC, it is necessary to formulate a training program using of the Manual and incorporate the program into the training courses of WASAC in cooperation

with the DSS of WASAC.

Lecturers of the training on each of the 11 selected subjects need to be appointed and the appointed lecturers need to study and develop detailed contents of the training and training materials. It is appropriate to appoint staff members of WASAC in various areas who have taken the training in the Project as the lecturers. At present, the lecturers have not been appointed.

(4) Output 3 WASAC learned how to conduct NRW reduction measures through the implementation of the Pilot Project.

1) WASAC's structure for conducting the activities

In the OJT in the pilot project, WASAC C/Ps learned effective NRW reduction methods. The practical activities, *i.e.*, i) high-pressure control, ii) replacement of distribution and service pipes, iii) surveys and repair of leakages, iv) management of reservoirs, v) management of billing data, and vi) maintenance of customer meters, need to be implemented at each branch office. However, there are the following problems for the implementation of the activities.

- ✓ Insufficient staff and equipment required for the pressure control and leakage surveys;
- ✓ Insufficient and aging distribution network facilities (boundary valves, discharge valves, air valves, float valves for reservoirs, etc.)
- ✓ Insufficient materials and tools required for the replacement and repair of distribution and service pipes
- ✓ Insufficient staff members (technicians, plumbers, and general workers) compared with the total length of the distribution networks and number of the customers
- ✓ Insufficient supply of vehicles and motor bikes required for the management of the water distribution networks
- ✓ Insufficient mobile phones for the work
- ✓ Water rationing that hinders the work
- ✓ Insufficient processing of work reports

Even if a leak is detected, if it is not repaired, then the NRW will not be reduced. However, there are many practical issues regarding performing appropriate repairs in a short time. The branches that are responsible for repairs do not have sufficient materials in stock. As the branches do not have enough budget to purchase the materials, they need to be supplied with the required materials and equipment by the headquarters. However, the branches have not developed procurement plans required for the supply, which does not help ensure adequate budget allocation.

As there is a clear shortage of control valves in the water distribution networks, the installation of such valves at the major branching points in the networks must be promoted. The residents suffer from the suspension of the water supply whenever leakage repair is implemented. The installation of a control valve will reduce the size of an area affected by the suspension for the repair work. The installed valves will also make it easy to conduct the step test in the leakage survey.

2) Efficient use of the surplus water generated by NRW reduction

In materializing the impact of the water leakage reduction activities, it should be noted that there will be no realization of the impact (increased water bill revenue), if the surplus water generated by the activities cannot be used efficiently.

If the surplus water generated by activities in an area is not used by the customers in that area (due to the limited number of customers or the limited demand), it has to be used in another area. But if no water leakage reduction measures are taken in the latter area, the surplus water will end up leaking from water pipes in that area, which is clearly suggested by an analysis in the existing water distribution network in the Pilot Project. Because in the present network condition, the volume of distributed water and the volume of leakage had a stronger correlation than the volume of distributed water and the volume of water consumption.

It is also essential that customer demand (end users) exists for the surplus water, which sometimes requires the extension of service pipes to the place of demand. How to improve the network of distribution and service pipes in order to increase revenue is required the consideration of water service in a wide area. It will be necessary to extend the existing distribution pipes and install new pipes to deliver water to areas where water is in short supply and increase the distribution of water to new areas, or to develop a distribution management method to secure water delivery to those areas.

Thus, leakage reduction measures in one area will not produce an early or tangible result unless accompanied by a series of systematic, strategic, continuous and comprehensive leakage reduction activities in adjacent areas. In this sense, coordination with other ongoing projects for the development of water distribution networks (developed in accordance with the MPs of AfDB and JICA) is crucial.

(5) Output 4 Establishment of a system to measure NRW rates accurately

The monitoring system was largely completed by September 2019, effectively forming the foundation for the NRW rate calculation. The remaining tasks for the Japanese side are to complete the inspection of uninspected equipment at the SATs to be performed six and 12 months after the partial completion in September 2019. And, WASAC side is required to complete the installation of 16 flow meters.

4.3 Insights Obtained from the Project

(1) Breakdown of NRW

The two Pilot Projects revealed that 80- 90 % and 10-20 % of the total volumes of NRW in Kadobogo (Area 1) and Ruyenzi (Aria 2) were physical and commercial losses, respectively. It also revealed that water leakage was a major cause of NRW and the volume of underground (invisible) leakage was large.

Table 4.3 Estimated breakdown of baseline NRW rate (%) in Kadobogo

Item	Commercial losses (20%)				Physical losses (80%)		Total
Cause of losses	Meter error	Billing error at Meter replacement	Illegal consumption	Estimation of volume zero-billed	Surface leakage	Underground water leakage	
Breakdown	0.5	1.2	0.5	5.3	11.9	17.9	37.3%
Loss %	1	3	1	15	32	48	100%

Table 4.4 Estimated breakdown of baseline NRW rate (%) in Ruyenzi

Item	Commercial losses (10%)				Physical losses (90%)		Total
Cause of losses	Meter error	Billing error at Meter replacement	Illegal consumption	Estimation of volume zero-billed	Surface leakage	Underground water leakage	
Breakdown	0.7	2.0	0.7	3.4	61.6		68.4%
Loss %	1	3	1	5	90		100%

(2) Importance of Appropriate Planning of Installation and Appropriate Operation of Trunk Water Transmission and Distribution Facilities

Severely undulating terrain characterizes the topography of Kigali City and houses of residents are existing from on the slopes to the bottom of the hills, so the water transmission and distribution network facilities are extremely complex. The facilities have been constructed having only the purpose in order to transmit and distribute a sufficient volume of water, without consideration against high water pressure. Therefore, there is high water pressure in the existing distribution pipes, which has been leading to frequent leakage.

In order to prevent leakage, a design water pressure should be set, and a water distribution facility should be arranged so that excessive pressure does not occur in the distribution water network and their related facilities. The distribution and service pipes to be used and related equipment have to be tolerant of the design pressure. It is a matter of course that the facilities and equipment need to be installed properly so as to prevent leakage.

(3) Formation of Water Distribution Blocks and Functions of Reservoir

Despite the undulating topography of Kigali, the existing water distribution facilities are not configured to control the high water pressure. For facilities configuration purposes, the water distribution area needs to be

segmented into blocks based on elevation differences, with a certain range of pressure set with reference to the design pressure. However, block segmentation of an existing water distribution network usually requires substantial costs and periods for survey, design and construction works. The configuration of water distribution facilities has to be designed with precautionary measures to prevent NRW (water leakage) from emerging from the planning stage of project implementation.

A reservoir not only controls the volume of water distribution but also reduces the high water pressure used for transmitting water to distribution areas. However, there are many places in the existing pipe network of WASAC where water is transmitted and distributed directly through pipelines that bypass reservoirs, without being temporarily stored in them, to transmit water to some distribution areas at high altitudes. The use of these bypass has led to the distribution of highly pressurized water which is a major cause of the leakage in the distribution networks. Water distribution to a distribution area through a pipe that directly branches off from a transmission pipeline between the treatment plant and a reservoir is also a cause of the high water pressure and water leakage.

While it is recommended to review the distribution blocks with the realignment of the reservoirs, it was necessary to include NRW reduction measures from the beginning of the facility development plan, in principle. The facilities shall not be renovated without consideration of a NRW reduction. The redevelopment of facilities should consider.

(4) Suppression of Water Leakage with Reduction in High Water Pressure (Effect of PRVs)

In the activity of the pilot area, it was verified that the amount of water leakage was reduced by reducing the high water pressure, because the installation of PRV reduced the volume of minimum night flow (Qmnf) and reduced the number of leak points. This is because PRV reduced water pressure of the leaking points in the water distribution area and reduced the leakage of water at each leak point. The water leakage control effect of PRV is high, so that the installation of PRVs shall be recommended for leakage control.

A large proportion of the water leakage is underground leakage. However, it is difficult to detect and repair underground leaks however much effort is made in the survey and detection of such leaks. However, the Pilot Project has revealed that the leakage could be reduced by reducing the water pressure in the distribution pipes without identifying and repairing leaks.

In addition, it has also been revealed that the leakage repair has a limited effect on NRW reduction unless it is accompanied by the reduction in high water pressure. As the experience of WASAC in the leakage repair clearly tells, the repair cannot reduce the volume of leakage if the water pressure in pipes remains high. WASAC had been repairing an average of 10 leaks per month in Kadobogo and 28

leaks per month in Ruyenzi, but as a result of pressure reduction through the installation of PRVs, the number of leaks has clearly decreased.

It should be noted, however, that the reduction of high water pressure is only a measure to control leakage, not to eliminate it completely. The only way to completely eliminate leaks is to properly repair the leaks and renew the pipes. Then, proper pressure control should be carried out to prevent the occurrence of leaks in the installed piping. After the installation of the PRV, it is important to periodically check whether the secondary pressure of the PRV (downstream pressure setting PRV) is properly maintained in order to sustain the regulated pressure.

(5) Management of Volume of Water Distribution

As distribution pipe network is a closed pipeline system, there should be a high correlation between the volume of the water distribution (inflow volume), and the volume of water consumption of the customers (billed volume) in the area. However, the analysis of the correlation between the inflow volumes, billed volume and NRW volume in the Pilot areas in Kadobogo and Ruyenzi revealed a low correlation between inflow and billed, and a high correlation between inflow and NRW

This observation indicates that the amount of water distribution is not linked to the consumption of the customer, and that is larger than the demand of customers. That excessive amount of water distribution is leaking out from the network as leakage. The major causes of the excessive water distribution are the excessively high water pressure at the inflow points and the poor condition of distribution and service pipes in the area which generate the leakage.

Therefore, the volume of leakage in a water distribution area can be controlled by reduce the excessive inflow volume. The installation of PRVs is an effective method to control inflow and leakage volume.

Table 4.5 Correlation between volume of water distribution and volumes of billed water and NRW.

Pilot Area	**Correlation Coefficient (R^2)**				Remarks
Kadobogo	Whole	PM1	PM2	PM3	
NRW Rate%	27	22	38	29	
Input-Billed	0.12	0.63	0.23	0.06	Should be correlated. But actually low.
Input-NRW	0.75	0.64	0.96	0.88	High correlation
Billed-NRW	0.04	0.08	0.43	0.01	No correlation
Ruyenzi	Whole	RY1	RY2	RY3	
NRW Rate%	58	58	62	52	
Input-Billed	0.07	0.01	0.17	0.04	Should be correlated. But actually low.
Input-NRW	0.87	0.89	0.98	0.54	High correlation
Billed-NRW	0.34	0.18	0.29	0.27	No correlation

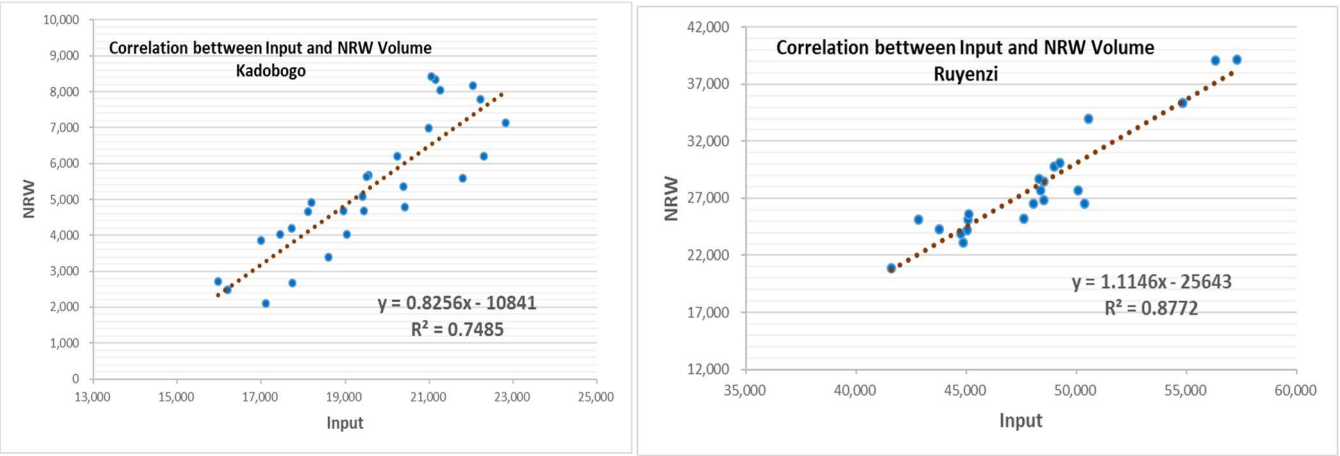


Fig. 4.1 Correlation between the volumes of distributed water and NRW in pilot area

(6) Leakage survey and detection

The importance of measuring the minimum night flow (Qmnf) in the leakage survey was recognized during the implementation of the activities in the Pilot areas. Qmnf measurements can be used for estimating the extent of leakages. The step test can be used for finding an area of large leakage, which leads to the detection of invisible/underground leaks and visible/surface leaks that have not been noticed (or reported). The total volume of leakage from an unnoticed leak point tends to be large because water continues to leak from the point for a long time until the leaking pipe has been identified and repaired. Therefore, water leakage should always be surveyed and monitored.

Leakages tend to recur. Even if a leak is identified and repaired, the leakage often recurs in a different place on the pipe, particularly in areas where low-quality pipes are installed and the water pressure is high. Therefore, it is important to monitor Qmnf and NRW rate regularly and perform a leakage survey whenever an abnormality is found in the monitoring.

However, it is not easy to conduct a leakage survey. The existing pipe network has not been developed systematically. As pipes are installed in a complicated pattern, it is very difficult to detect leakage. The number of valves installed at branching points was small and some of them were not functioning. These circumstances have made flow rate measurement labor-intensive and time-consuming. In other words, much labour and time have to be used for the selection of the sites for UFM installation, excavation at the selected sites to reveal the pipes, installation of new valves or replacement of defective valves for the implementation of the step test, or multi-point measurement with UFMs when and where it is not possible to implement the step test.

Even if leaking pipes were identified, a leak noise correlator could not be used to locate the leak point because it was difficult to find contact points of a sensors on the pipeline and few valves were installed in the distribution network. It was also difficult to detect leak points with an acoustic leak detector

because the pipes in the ground could not be located precisely, the road surface was not paved and resin pipes were used. In the end, the leak points had to be identified by repeated excavation of potential leak sites inferred from depressions in the ground and vegetation.

Because of the poor condition of the distribution network and ancillary facilities mentioned above, it is particularly difficult to find invisible underground leaks. However, many visible leaks that had gone unnoticed were found in the Pilot Project. Therefore, when the results of monitoring the NRW rates and Qmnf suggest the existence of large leakage, it should actively strive to find unnoticed water leakage. Invisible underground leaks may be found in such detection process.

(7) Quality of Material and Installation of Distribution and Service Pipes and Replacement of Leaking Pipes

It has become evident that the cause of the leaks is attributable to small-diameter (HDPE and GSP) distribution and service pipes in most cases. In view of the conditions at installation locations, HDPE pipes that are easy to install are widely used. However, WASAC entrusts the procurement of HDPE pipes to customers and they purchase cheap pipes that do not satisfy the required standards. Because of the poor quality, these pipes are likely to be cracked by high water pressure and leak water. The customers pay little attention to the pressure resistance when they purchase pipes. Rust is a cause of water leakage from GSPs. In some cases, a service pipe is constructed with pipes of different materials (HDPE, PVC, and GSP) and different pressure resistances because of the shortage of piping materials. Water leakage is likely to occur at joints between pipes of different materials on such a service pipe.

WASAC has recognized the importance of procuring materials that satisfy its standards and standardizing types and grades of materials. Therefore, WASAC should stop entrusting the procurement of materials to the customers. Instead, WASAC should procure pipes that satisfy the standards by itself and install them under appropriate work management. WASAC may consider a possibility of contracting out the procurement and installation to contractors qualified by WASAC in the future.

In high-pressure areas, it is naturally desirable to reduce the pressure before installing distribution and service pipes. However, it is not feasible to do so in many cases. In such cases, it is necessary to select piping materials with a guaranteed pressure resistance of 16 bar or more for the installation of distribution and service pipes.

It is necessary to identify sites and volumes of water leaks from leaky distribution and service pipes and replace them. The results of leakage surveys and analysis of leaks in the past and opinions of the staff of branch offices who maintain the distribution pipe network daily should be used for the

identification. As mentioned above, water-pressure control is merely a measure to reduce water leakage. The replacement of leaking pipes is essential for the total elimination of water leakage.

(8) Result of Cost-Benefit Analysis

The Pilot Project in Kadobogo Area has shown that the NRW rate in an area with the current NRW rate of 40 % or less like this area can be reduced to 25 % with pressure control and leakage repair. The NRW rate of the area has been reduced by 12 % from the baseline rate of 37 % to the achieved rate of 25 %. (Although the target of 20 % was temporarily achieved, this rate could not be maintained due to the malfunction of PRVs.) Meanwhile, in Ruyenzi Area where water distribution bypassing a reservoir is performed for water transmission to areas outside the Pilot area, the PRVs controlled the pressure in several selected areas at full time but the wide remaining area only at night. This pressure control had an only limited effect. A comprehensive review of the water distribution methods to enable pressure reduction in the entire area 24 hours a day and to terminate the bypass water distribution, was required in an area where NRW rate exceeds 60 % like Ruyenzi Area. As the result in Ruyenzi Area, reduction the NRW rate by 10% from the baseline value of 68% to the achieved value of 58% was the limit of the trial activity.

Meanwhile, the cost-benefit analysis of the Pilot Project has clearly shown the positive effect of the NRW-reduction activities as the calculation of the net present value (NPV) and cost-benefit ratio (B/C) of the activities gave NPV > 0 and B/C > 1, respectively, although the values differed between years in the two areas. B/C in Kadobogo exceeded 1.0 in the fiscal year following the year in which the implementation of the NRW-reduction activities began as the activities produce a benefit larger than the cost. B/C in Ruyenzi exceeds 1.0 in the fiscal year in which implementation of the NRW-reduction activities began. B/Cs in the fifth year will be as high as 3.6 and 7.7, respectively, in Kadobogo and Ruyenzi. The cumulative benefits in the fifth year are approx. 100 % and 190 % of the annual billed water tariffs in Kadobogo and Ruyenzi, respectively.

In conclusion, investment in NRW reduction activities is duly effective even in an area with a high NRW rate, such as Ruyenzi with the NRW rate of 68% if the activities have reduced the rate by a certain extent (approx. 10 %). Therefore, it is important to actively promote investment-effective activities, for example, water pressure reduction (by installing PRVs), water leakage surveys and repairs (especially of underground water leaks), and replacement of water distribution pipes.

Increasing the volume of billed water by reducing the volume of NRW will generate greater project benefit than reducing the volume of water produced.

(9) NRW reduction activities for the reduction of commercial losses

The absolute requirements for the reduction in the commercial losses are that customer meters are installed at all customers and all the meters work normally. The volume of NRW in an area with a high meter installation rate is small even if the meters have some reading errors. To evaluate the effect of the meter replacement, the totals of the meter errors and the totals of the volumes of billed water in both Pilot areas before and after the meter replacement were compared. As the meter errors could be both positive and negative, it was concluded that the meter replacement had little effect on the NRW reduction.

It has been found that the zero billed water consumption and estimation of billed water consumption account for a larger proportion of the apparent losses than the instrumental errors of the meters. Therefore, NRW reduction requires the reduction of the number of cases of water consumption estimation and zero billed consumption. Correctly reading all meters is the minimum requirement for NRW reduction.

To this end, POC maps should be updated constantly (by entering the data of new customers and correcting the existing data) so that CFOs, who are casual workers, may gain quick access to the meters. CFOs should carry gadgets that enable them to view the POC maps, and POC stickers should be affixed to the gates of customers' houses and buildings. It is necessary to respond quickly to any breakdown and defects of water meters found during the meter reading or reported by customers and to study the cause of abnormal fluctuation of monthly water consumptions.

Staff members of branches perform fieldwork. It is impossible to perform such work functionally and efficiently without full knowledge of the field conditions, including customers, meters and distribution pipe network. Therefore, individual workers must have sufficient experience. However, casual workers employed under one-year employment contracts work as CFOs and plumbers in the branches and they account for about half of the branch staff members. This employment system at the branches must be improved quickly because it has become a great obstacle to the performance of the work of branches.

A defective meter should be repaired or replaced immediately. A meter with an error larger than a permissible range should be replaced to maintain the fairness of the water charge billing among customers. Because of these needs, the meters should be inspected. If it is difficult to inspect a meter, replacing it with a smart meter should be considered.

(10) Improvement of the labor environment of WASAC

1) Reduction of leakage repairs

When the number of water leak occurrences has been reduced by the reduction of high water pressure control, branches will be able to save the time and labor currently used for leakage repair. In addition, the frequency of water supply suspension for leakage repairs will decrease. They will be able to improve customer services and implementation of other NRW reduction activities smoothly using the saved time. This will also improve the motivation of WASAC staff.

2) Surveys at Night

In principle, the leakage surveys, including the measurement of Qmnf, step test and leak detection, are recommended to be performed in the night because there is little water consumption or noise in the night. However, it is recommended not to perform the surveys in the night, if possible, because of the time and labor required for notification to responsible person in charge in WASAC and the district offices, safety control and working time management. While water flowmeters have an automatic data logging function, an external battery will be required when a meter is to be used where the commercial power supply is not available. The step test might be conducted in the hours in the daytime when water consumption is relatively small.

(11) Utilization of Google Earth Map for mapping the location of leakage repair sites

1) Location Map

Plotting the data of past leakage repairs on a map enables visualization of areas prone to leakages and locations of problematic water distribution pipes and the plotted map is useful in the preparation of a leakage survey plan. Kacyiru and Nyarugenge Branches began to measure the x-y coordinates of the sites of leakage repairs and described them in the record sheet by hand in August 2017. Since around June 2018, they have been using personal computers to enter the data into the form provided in the five-year strategic plan (5YSP). Accurate recording and sorting of all leakage repair data in a computer in routine work is essential for the analysis of past leaks and preparation of a work plan for the NRW reduction activities. Microsoft Excel files are a useful tool for data analysis.

When continuous repair of leaks every month has not reduced the number of repairs, it is necessary to install PRVs or replace the distribution pipes. Whether the number of leakage repairs has fallen after such activity was taken should be verified to evaluate the effectiveness of the activity.

2) Inclusion of new customer data in NRW rate calculation

It is necessary to add the monthly billed water consumption of new customers in the area to the

calculation of the NRW rate. However, it is not possible to confirm in which service area a new customer belongs on a map without the x-y coordinates of their POC. The acquisition of the positional x-y coordinate information of a new customer at the conclusion of a service contract will make it possible to decide the service area of the new customer on the Google Earth Map.

Moreover, if a map that presents the GIS data of the borders between service areas is available, it will be possible to verify in which area a new customer belongs. Such a map will enable a CFO, for example, to verify the location of a new customer and give a DMA code to this new POC on-site with a mobile terminal. If a system to give a DMA code to a new customer is developed, such a system will enable automatic calculation of a total billed water consumption in a DMA by CMS, and eliminate the need to collect the data regarding the area from the billed water consumption data for all customers with the VLOOKUP function of Microsoft Excel.

The table below shows the numbers of new customers in 2018. The average numbers of new customers per month amounted to 130 in the whole Nyarugenge Branch area and 12 in its pilot area, much larger than the corresponding numbers for the Kacyiru Branch and its pilot area, 78 and 3 respectively.

Table 4.6 New customers in 2018

Item	Branch	Kacyiru	Nyarugenge
Branch	Year 2018	937	1,560
	Aver. per month	78	130
Pilot Area	Year 2018	37	150
	Aver. per month	3	12

(12) Creation of DMAs and improvement of reservoirs

Although the creation of DMAs is necessary for the calculation of the NRW volume/rate (the maintenance of the water distribution network), it is not recommended strongly because it is very labour-intensive, time-consuming and costly. However, in areas in which a specific arrangement of distribution pipelines allows easy hydraulic isolation (by isolating the distribution pipelines by cutting them or installing valves on them), the creation of DMAs is recommended. While installation of a water flowmeter is required if the amount of water distribution is to be measured in a reservoir, a portable UFM can be used if it is to be measured in a distribution network.

If an activity implemented in the pilot area has been demonstrated to have a positive effect without conducting an evaluation, such activity will produce the same effect in other areas. The NRW reduction activities may include various different types of activities and a DMA may have a large area, such as a DMA for a distribution reservoir.

A reservoir is an important facility for water pressure control and leakage management for NRW reduction, as mentioned above. A plan for the construction of new reservoirs and large-scale renovation of the existing reservoirs will be developed in the preparation of MPs by AfDB and JICA. However, WASAC should examine the current state of the reservoirs and prepare measures for their improvement by itself to address the issues at hand, including the use of bypass pipelines and DMA creation, without waiting for the preparation of plans by AfDB and JICA.

(13) Procedure for NRW reduction

1) Measures against physical losses (leakage)

- WASAC is busy repairing leaks month after month. However, leakages recur after the repairs. It is important to reduce the number of leakage repairs not only for NRW reduction but also for the improvement of the current work conditions in WASAC.
- The cause of the recurrent leakages is high-water pressure. Pressure control by PRVs is an effective means for reducing the leakages immediately in a wide area. However, pressure control has a limited effect on NRW reduction.
- Leakage repair should be implemented after pressure control has been established, otherwise, leakage may recur.
- If NRW increases after the installation of PRVs, a leakage survey should be conducted to find any unnoticed leak points, including those of underground leaks. Also, it should be considered if any causes other than leakage may have increased NRW.
- Excessive water supply far beyond the volume of customer consumption demand is another factor in water leakage. As leakage can be reduced by reducing the excessive water supply, it is important to control the water supply volume.
- Measurements of Qmnf and NRW rate are used for the estimation of the volume of leakage. However, the two estimation methods do not show the same result. Monthly error variance is generated in the estimation by NRW rates because billed consumption data and measurements of water distribution collected in different one-month periods are used for the estimation. The estimation by NRW rates is also influenced by other factors. Therefore, the use of Qmnf measurements is recommended for leakage estimation.
- Although pressure control and leakage repair are expected to reduce the volume of leakage, replacement of poor-quality distribution and service pipes is required for the elimination of leakage.
- Sites at which the replacement of distribution and service pipes is required can be inferred on a

map on which the sites of past leaks are plotted. It is also important to listen to the views of staff members of the branch offices who know the sites well when the sites for replacement are to be decided.

The actions required to reduce physical losses include:

a. High-water pressure control
   - Setting of standard of maximum hydrostatic pressure
   - Construction and reconfiguration of distribution facilities in strict compliance with the water pressure standards
   - Installation and adequate operation of depressurizing facilities (e.g. PRVs)
b. Use of only piping materials that satisfy the standards and their appropriate installation
c. Replacement of pipes from which leakage has occurred frequently and old and deteriorated pipes
d. Leakage survey (by Qmnf measurement and step test) and repair

2) Measures against commercial losses

The above-mentioned findings of the meter survey suggest that the policy mentioned below is appropriate for meter management.

- It is important to raise the meter installation rate to 100%. However, the rate in the service area of WASAC is already high.
- While it takes time and labor to calibrate and replace water meters, the effectiveness of meter replacement for NRW reduction is small.
- Meter replacement may not always be effective for NRW reduction because the replacement meter may have a positive error.
- The purpose of meter replacement is to ensure the fairness and reliability of billing to customers.
- The following meters should be replaced or repaired immediately:
  Defective meters (to be identified during meter reading); and
  Blocked meters (to be identified during meter reading)
- The meter accuracy test should be carried out in the cases mentioned below. If a meter has an error below -5 % or above +5%, it should be replaced:
  - When analysis of the billed water consumption reveals abnormally high or low billed water consumption;
  - When an abnormal movement of the meter pointer or an abnormal change in the billed water

consumption from the previous reading is found during meter reading;
- When a customer makes a complaint about the billing; or
- When meters are replaced schematically, in which case replacement shall begin from meters where there is high water consumption for reasons of efficiency.

・ Meters should be replaced at regular intervals of approx. 10 years to maintain their accuracy.

・ The possibility of installing smart meters in places where it is difficult to carry out meter reading should be studied.

The actions required to reduce commercial losses include:

a. Maintenance of customer meters
   ・ Calibration of meters based on the result of an analysis of billed water consumption
   ・ Replacement of all broken-down and inaccurate meters
   ・ Periodical meter replacement
b. Improvement of accuracy of water billing
   ・ Accurate meter reading and reduction of estimated billing
   ・ Survey of POCs with zero water consumption and correction of billed water consumption based on the survey result

4.4 Recommendations for the WASAC

(1) Continuation of review and development of the 5YSP

WASAC should review and revise 5YSP prepared in the Project as appropriate and continue developing 5YSPs in the future.

(2) Securing budget for NRW reduction measures (budget to be secured according to the priority of activities)

One of the highlighted outputs of the Project is that effective countermeasures contributing to NRW reduction were clearly presented. The Project also showed that they are sufficiently beneficial in terms of cost-effectiveness. Going forward, WASAC should disseminate this information to other organizations and/or stakeholders including the Rwanda Utilities Regulatory Authority (RURA) which is in charge of the decision of water tariff, policy-making bodies and investment banks, and intensify communication with them for securing required budget.

(3) Increase of staff in WASAC Headquarters and branches (organizational and institutional reform)

The current number of WASAC staffs is insufficient to conduct NRW reduction works in a smooth

manner. Continuous efforts to reinforce staffs are indispensable not only at the headquarters but also at branches.

Due to the character of NRW reduction activities that always involve multiple departments/units and staff widely, the Project has sometimes faced difficulties in working as "one team." Consideration of an ideal organizational structure that enables coordination among all related departments/units in WASAC in NRW reduction is therefore required.

(4) Development of new standards for service pipe connection (revision of service pipe installation standards)

The Project learned that one of the biggest reasons for water leakage is substandard service pipes installed in the WASAC distribution network. At this moment, because each customer who wants to be connected to the WASAC network can purchase their service pipes by themselves, many cheap and substandard pipes were chosen and installed into the network. WASAC should review its policy (Connection Policy, Jan. 2019) and system to ensure the quality of service pipe materials and installation.

For example, Japan has the "Designated Water Supply Works Company System" to ensure the appropriate installation of water supply facilities in conformity with the applicable standards. Service pipe construction work may only be performed by a constructor employing a "Chief Engineer for Water Supply Works", who passed the relevant national examination. Under this system, the designated companies are fully responsible for field surveys, material selection, design, construction control and checks.

(5) Securing of the budget required for the operation and maintenance of provided equipment

A variety of equipment procured in the Project are indispensable for continuous work on NRW reduction. WASAC is required to estimate the necessary budget for its proper maintenance for coming years and accordingly to reserve the corresponding budget. Many of the equipment will need replacement of parts, especially battery parts, with spare parts. Considering these events in the near future, WASAC should secure channels to ensure such repair and the procurement of spare parts, and identify qualified local agents.

(6) Internal training for dissemination of knowledge obtained through the Project (Development of training courses)

WASAC should finalize the "NRW Reduction Manual" drafted by the Project and disseminate relevant knowledge and skills inside WASAC. A training course to this end should be included in the annual internal training program of WASAC organized by DSS. Replenishing the equipment to be

used in the training and making necessary arrangements to allow staff members' participation in the training are the preconditions for such a course. Counterparts trained in the Project can serve as trainers.

(7) Installation and operation of the NRW rate measurement system

The monitoring system to measure the volume of waters distributed by the branches in Kigali was nearly completed in September 2021. The training was also completed on the operation of the software to calculate the NRW rate in the areas served by the branches using the data on the volumes of water distribution and customers' billed consumption obtained by the system. Regular inspections will be performed six and 12 months after the completion of the system by the Japanese contractor responsible for building it.

The WASAC branches cannot yet calculate NRW rates because flow meters to be managed by WASAC are not working or have not been installed at 16 sites. Moreover, some of the customers located near the borders between branches are still to be re-registered. The Japanese procurement contractor will have to complete the inspection of the items that could not be inspected in the acceptance inspection in September 2021 before the regular inspection. In order to ensure regular maintenance, the R/D was modified to extend the project period to September 2022.

Those remaining tasks need to be completed before the first or second regular inspections. Although the system building process is not yet exactly completed, flow rate data at most of the planned measuring sites are available. Under these circumstances, the use of the software for NRW rate calculation should be continued so that staff members may master the skills required for its operation and know the hydraulic condition inside the water distribution network.

The number of flow meters to be installed for the hydraulic isolation at the boundaries of the service areas of branches needs to be increased, as appropriate, depending on the development status of the distribution network. For example, laying of any new distribution pipe straddling the boundaries of two or more branch offices will warrant an increase in the flow rate measurement sites. It will be required to install a new flow meter and integrate it into the data processing system of the server.

The Project for Improvement of Water Supply Services in North-Central Kigali (a grant-aid project) is expected to include a plan to install measurement instruments for a system to monitor flow rates in distribution pipes and the water levels of distribution reservoirs automatically. Going forward, WASAC should consider the possibility of integrating this system into the monitoring system built by this Project.

(8) Continuation and further development of regional partnership platform

While we can expect that activities on the tripartite Water Utility Regional Partnership (WURP) platforms of Rwanda, Malawi and Kenya will progress and continue well, we recommend that WASAC not only keep the platform intact, but also consider from a medium- to long-term perspective how to ensure further development of the platform, working with the partners of Malawi and Kenya.

4.5 Lessons in Project Operation

(1) Project indicators

Fundamental project targets (particularly on the NRW rate) should be set objectively by consideration into the level of contribution. Care should be taken not to set any target at an ideal level that cannot be achieved by a technical cooperation project alone.

(2) Utilization of the monitoring system

The monitoring system was completed after spending substantial amounts of time and money. It is hoped that this be utilized as effectively as planned. The primary objective of the system construction was to monitor the NRW rate at each of the four branches, or, preferably, the six branches of WASAC in Kigali, and use the data of the monitoring for the NRW reduction activities throughout the water distribution network in Kigali.

It should be noted that the configuration of the distribution network in Kigali changes where the network is expanded/rearranged to cope with the increasing volume of water distribution, and that the number of distribution pipes crossing borders between the service areas of the branches may increase every time such a project is executed. This means that the system needs updating by installing additional flow meters and data transmitters for the hydraulic isolation at the borders and by upgrading the server software in such cases. In light of the current status of WASAC's equipment procurement system, it is questionable if WASAC is capable of coping with such activities as the construction of chambers, the installation of flow meters and data transmitters to the data loggers and server, and storage of the additional data captured by the new flow meters in the server.

In addition to the "collection of flow rate data to calculate the NRW rate for each of the four branches in Kigali, WASAC should consider the inclusion of the sensors to be used in the ongoing grant-aid projects of JICA, "the Project for Strengthening Nzove-Ntora Principal Water Transmission Pipeline in Kigali City" and "the Project for Improvement of Water Supply Services in North-Central Kigali," in the monitoring system and the integration of the monitoring system and SCADA planned to be developed by an AfDB-supported project and other assistance projects in a long, with a view to:

- Understanding the hydraulic condition of the existing water distribution network and collecting necessary data for problem analysis and updating it; and
- Monitoring changes in flow rate and water pressure for the surveillance of accidents and water leaks.

Chapter 5 Recommendations for the Achievement of Overall Goal of the Project

WASAC conducts NRW reduction measures in Kigali City as planned.

Indicator: NRW rate of Kigali city (FY 2022/23: 25 %)

5.1 Challenges for Achieving the Overall Goal

Recent years have seen progress in the expansion of the Nzove water treatment plant, the construction/expansion of water treatment plant (Kanzenze and Nzove), and the development of trunk distribution facilities (with the support of AfDB) to enhance the volume of distributed water. Meanwhile, the NRW rate remains high, pointing to the necessity of curtailing water leakage among other NRW reduction measures. Although measures to reduce leakage is a high priority endeavor equivalent to the development of water treatment plants and transmission/distribution facilities, no project has focused on measures to address NRW. Due to budgetary constraints, NRW reduction measures are not on pace to achieve the Overall Goal under 5YSP.

Table 5.1 NRW rate in Kigali

Year	5 Year Strategic Plan		Actual NRW rate	
	Year	Target %	National	Kigali
2017/18			38.9%	36.3%
2018/19	1	35%	38.8%	36.9%
2019/20	2	32%	41.9%	40.3%
2020/21	3	30%	43.3%	42.2%
2021/22	4	28%		
2022/23	5	25%		

The NRW rate of Kigali in 2020/2021 was 42.2%. To achieve the Overall Goal of 25% reduction in NRW by the end of 2022/23, 17.2% reduction of NRW rate is required in the coming two years. Considering the NRW rate for the last 3 years (36-42%), it is not realistic to achieve the target of 25% in the remaining two years of the 5-Year Plan.

By executing this technical cooperation project on NRW, WASAC gained expertise in addressing water leakage as a means of reducing NRW. However, it has not succeeded in reducing NRW throughout the whole wider Kigali area. Although the NRW technical cooperation project experimented with techniques to reduce NRW in the pilot areas and sought to disseminate them across WASAC, it has failed to attain that objective due to organizational and financial challenges inside WASAC and issues inherent in the scope of activities that may be covered by a technical cooperation project.

The pilot areas are small. When discussing how to reduce the NRW rate in the whole city of Kigali, no tangible result can be expected without the reorganization of water supply and distribution facilities (reconfiguration of facilities, isolation/replacement of transmission and distribution pipes, development of reservoirs, extensive replacement of service pipes, etc.) and initial investment covering a wide area. In order to disseminate the outcome of the NRW technical cooperation project throughout the Kigali city, the activities of the NRW reduction should be need to be scaled up to the project base.

Achievement of the Overall Goal is heavily dependent on the availability of budget of WASAC and assistance from development partners. Activities for achieving the Overall Goal should be continued, but it will take substantial time to achieve the goal.

5.2 Policy to Achieve Overall Goal

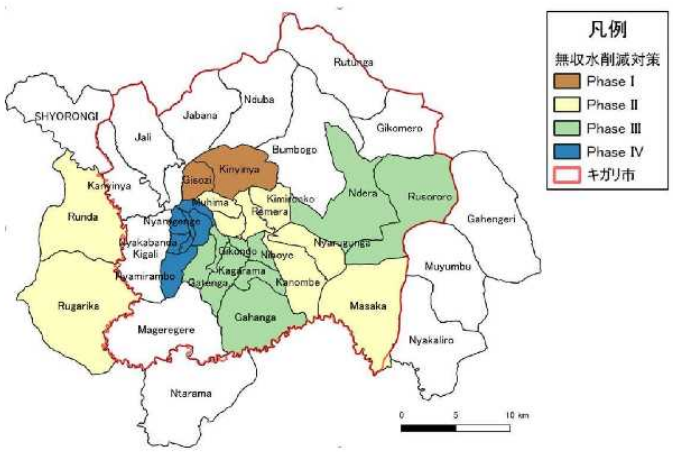
Lessons from the pilot project successfully specified prioritized countermeasures including: i) water pressure control, ii) replacement of distribution and service pipes; iii) water leakage survey/repair; iv) management of water reservoirs v) water billing data management; and vi) customer meter management. However, immense budget is required especially for: i) water pressure control; and ii) replacement of distribution and service pipes (aged and substandard pipes). No sizable investment is included in the budget for the NRW reduction measures presented in 5YSP. Therefore, the achievement of the Overall Goal is heavily dependent on the securement of budget of WASAC from now on.

One of the most important results of the Project is that measures that can be expected to be effective for NRW measures have been clearly laid out. In addition, it was shown that the implementation of these activities is sufficiently beneficial from the viewpoint of cost effectiveness. WASAC should present this fact to, and enhance communication with financing institutions to gain adequate funding for systematic implementation of beneficial NRW reduction activities.

One of the most significant achievements of the Project was the articulation of those effective measures to address NRW. It was also demonstrated that the implementation of those activities brings sufficient benefits from the perspective of cost effectiveness.

The investment plan required to achieve the overall goals of the project by scaling NRW reduction measures to the whole city of Kigali is included in the master plan report (Kigali Water Supply Master Plan). According to the Master Plan (MP), NRW reduction measures for Kigali are based on a long-term investment plan comprising four phases (covering 10 years) in total.

According to MP, NRW reduction measures in Kigali are in Kigali are based on a long-term investment plan covering a total of 10 years, indicating the necessity of investment in facilities financed by government aid and loans. Facility investment is essential including for block segmentation and the reorganization of water distribution and facility investment.



Target Areas	Reconstruction framework	Priority/Phase
Nyarugenge/CBD	The CBD and adjacent areas include the Nyarugenge, the Muhima, and Gitega sectore	Phase IV
Nyamirambo	The area includes the Kimisagara-Rwezamenyo-Nyakabanda to the Mount-Kigali	Phase IV
Kacyiru/North	The area includes the Gisozi, Kinyinya, and a part of the Remera (the Nyarutaruma)	Phase I
Kacyiru/South	The area includes the Kacyiru, the Remera, the Kimironko and the kimihurura	Phase II
Ndera Rusororo	Mainly focus on the reconstruction of the FTZ and the FTZ II through a new rode 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.	Phase III
Runda Rugarika	The area includes existing and newly developing areas in the Runda and the Rugalika sectors	Phase II
Kanombe/Masaka	Reconstruction of the Masaka existing system through the Karenge1 system.	Phase II

This Project

Fig. 5.1 Phasing of NRW reduction as shown in Kigali Water Supply Master Plan

As Phase 1 of such measures, the implementation of the Project for Improvement of Water Supply Services in North-Central Kigali was planned as a grant aid project of JICA, the feasibility study for which commenced in October 2021. According to its findings, NRW reduction is expected to be realized through investment for the reorganization of the transmission/distribution network serving an area straddling the boundaries of the Kacyiru to Remera branch offices, including in the block segmentation of the distribution network and the replacement of distribution and service pipes.

In any phase subsequent to this Project, facility investment for similar activities is essential, but no funding is forthcoming for large-scale facility renovation. As Phase 1, the JICA grant aid project should serve as an opportunity to secure facility investment with government funds/loans, etc.

It is expected that such a large-scale investment plan will help achieve the Overall Goal of the Project: to bring the NRW rate in Kigali down to 25%.

5.3 Risks Involved in Achieving Overall Goal

Going forward, the following risks may come into play in completing the Project by September 2022 and subsequently achieving its Overall Goal:

- Substantial reorganization of WASAC's structure
- Turnover or transfer of counterparts trained by the Project
- Spread of COVID-19 infection
- Shortage of CAPEX budget for NRW reduction activities in absolute terms
- Shortage of vehicles and other logistical support required for the activities
- Staff shortage
- Insufficient ownership or available work hours among WASAC staff