1.8 Effect Evaluation

NRW Reduction in Kadobogo

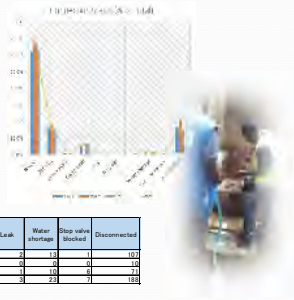
NRW rate in Kadobogo

NRW Breakdown	Commercial Loss		Physical Loss	
	Loss related to meter	Illegal water use	Visible Leak	Invisible Leak
%	4-8%	2-5%	25-30%	

Note: Baseline NRW rate is estimated at 37.2%

On-site meter calibration

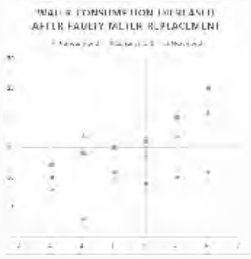
- Observation: *1) number of faulty&blocked meters (7.1%), 2) Normal meters (63.1%) , 3) Disconnected (15.2%)*
- Meter error: *1) more than plus or minus 5% (16.7%)*



	Normal	Error>5%	Meter blocked	Faulty meter	Illegal	No meter	Leak	Water shortage	Stop valve blocked	Disconnected
PM1	428	117	8	40	3	2	2	13	1	107
PM2	34	8	0	0	0	0	0	0	0	10
PM3	319	80	3	35	2	0	1	10	6	71
Total	781	205	12	75	5	2	3	23	7	188

Meter replacement

- Water consumption before and after: *1) contribution to water consumption, 2) trend of water consumption*



POO	No	Previous month	Current month	Next month
202216584	5	10	20	17
203511534	2	3	14	12
203512623	4	9	18	14
202211274	1	10	12	8
204712515	6	11	23	21
203514534	3	11	15	11
	Average	54	102	88
	Ave Increase Rate	1.76		
	Ave Water Consump	357	L/ day/ connection	

Leak Detection in Kadobogo (1)

Date	Area	Dia.	Pipes	Causes	Leak rate (L/hour)	Visible or Invisible
22-Mar	PM3-2	25	HDPE Tertiary	High Pr. & Low Qlty Pipe	1,500	Invisible
25-Mar	PM3-2	25	HDPE Service	High Pr. & Low Qlty Pipe	2,000	Visible
25-Mar	PM3-2	25	HDPE Service	High Pr. & Low Qlty Pipe	50	Visible
27-Mar	PM3-2	25	HDPE Tertiary	High Pr. & Low Qlty Pipe	60	Visible
2-Apr	PM3-2	25	HDPE Tertiary	High Pr. & Low Qlty Pipe	50	Visible
4-Apr	PM1	90	PVC Secondary	High Pr. & subsidence	10,000	Visible
5-Apr	PM2	50	HDPE Sercondary	High Pr. & Low Qlty Pipe	7,000	Visible

Leak Detection in Kadobogo (2)

Date	Area	Dia.	Pipes	Causes	Leak rate (L/hour)	Visible or Invisible
13-Apr	PM3-3	25	HDPE Service	High Pr. & Low Qlty Pipe	1,800	**Invisible**
23-Apr	PM3-1	90	PVC Secondary	High Pr. & heavy load	1,500	Visible
24-Apr	PM3-1	25	HDPE Service	High Pr. & Low Qlty Pipe	4,500	**Invisible**
Total					28,460L/hour (Invisible: 7,800L/hour)	

Note:
1) Leak detected in the past one month totals to 28,460L/hour(20,490M3/month), equivalent to 2.6 times of total NRW in Kadobogo, 7,940M3/month
2) Invisible leakage, 7,800L/hour, accounts for 70% of the total NRW

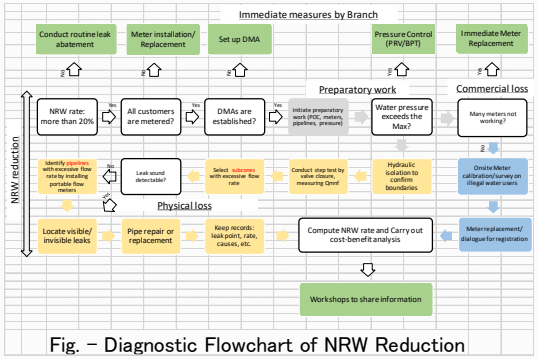


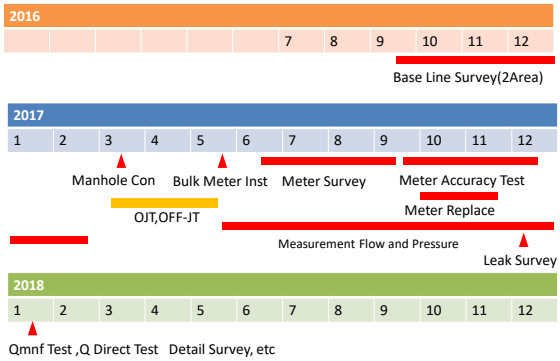
Fig. – Diagnostic Flowchart of NRW Reduction

Thanks for attention!

Progress Report

Leak Detection ,
Pressure Management,
Flow Management

Project Pilot Area Activity



Basic Activity

Kadobogo Map

Kadobogo Isolate Design

Kadobogo Commercial Data Base Check

Collectivity	2	32	776	810
Commercial Services	4	117	3354	3475
Domestic Use	39	2593	73125	75757
Government Institution		9	243	252
Government Institutions	2	9	255	266
Industry		4	141	145
Public Tapes		3	163	166
Public Tapes (Borne Fountaine)	1	4	152	157
(空白)		4	225	229
総計	49	2775	78443	81267

Re Sub Zone Isolate Check 13/12-14/12/2017



Kadobogo Manhole Construction




Kadobogo Bulk Meter Installation


Commercial Loss Activity

Kadobogo Meter Survey


Kadobogo Meter Survey Summary


Summmary of inventry survey on Pilot Area 1 (KADOBOGO)

			PM1	PM2	PM3	Total
TOTAL Customer No.			587	27	490	1,104
Leakage Survey	Leak Sound		3	2	5	10
	Visible		4	8	6	18
	Invisible		0	0	1	1
Another Data	Meter Position	Road	30	0	15	45
		Inside	475	22	425	922
	Destruction		1	0	2	3
Installation status of Meter	Visible	Readable	481	21	423	925
		Unreadable	5	0	4	9
	Invisible	Readable	4	0	6	10
		Unreadable	0	0	0	0
	Glass Broken		6	0	3	9
	Lid damage		120	7	111	238
	Water leak		0	0	0	0
	Vertical		1	0	0	1
	Horizontal		493	23	442	958
	Meter Box		197	13	201	411
Result of Meter Accuracy Test	Replacement		0	0	0	0

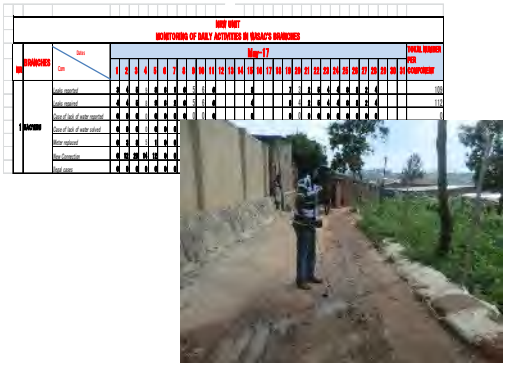
Kadobogo Meter Accuracy Test

Kadobogo Meter Replace

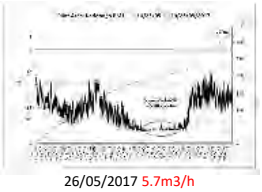
Physical Loss Activity
Flow Data Monitoring
Pressure Data Monitoring

Kadobogo Leakage Survey

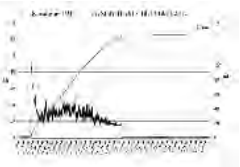
Kadobogo Leakage Repair



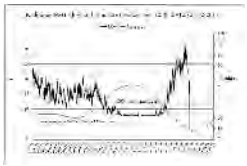
Kadobogo Qmnf Comparison PM1



26/05/2017 5.7m3/h



10/11/2017 Failure

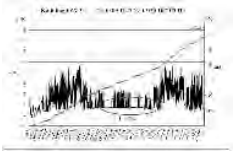


21/12/2017 7.8m3/h

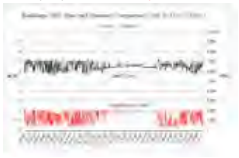
Cause?

Kadobogo Qmnf Comparison PM2

8/06/2017 0.21m3/h



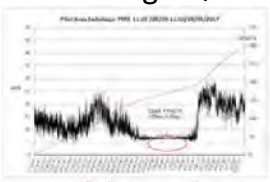
10/11/2017 1.4m3/h



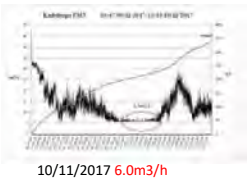
21/12/2017 3.3m3/h

Cause？

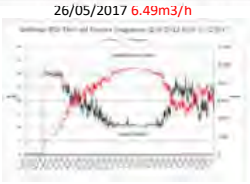
Kadobogo Qmnf Comparison PM3



26/05/2017 6.49m3/h



10/11/2017 6.0m3/h

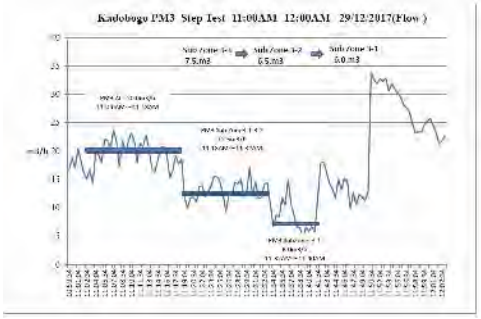


21/12/2017 10.8m3/h

Cause？

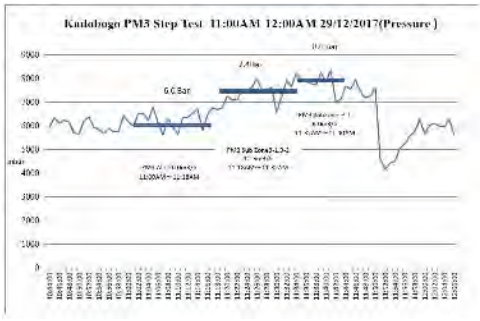
Kadobogo Qmnf Step Trial Test PM3

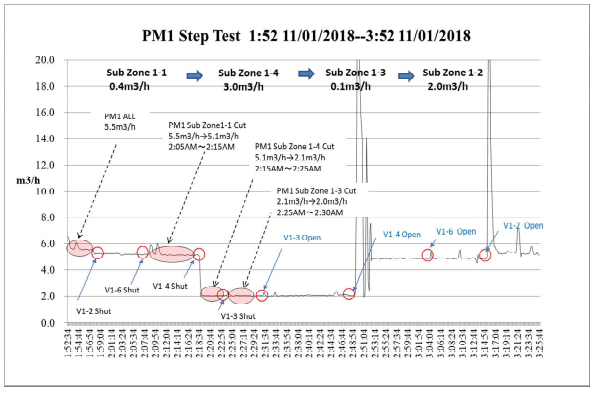
Flow



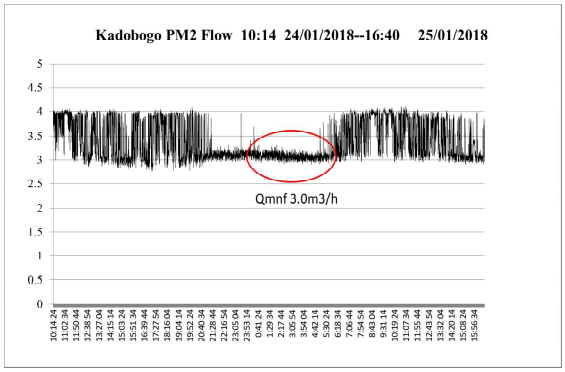
Kadobogo Qmnf Step Trial Test PM3

Pressure

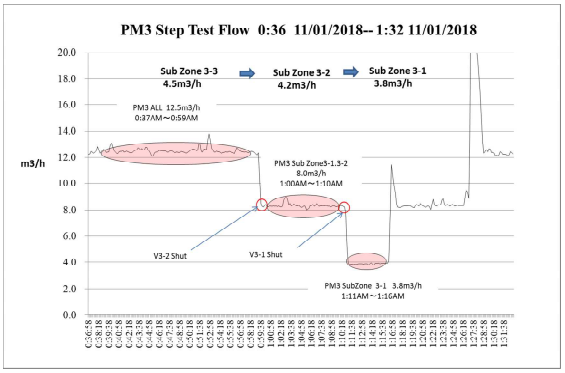




Step Test PM2

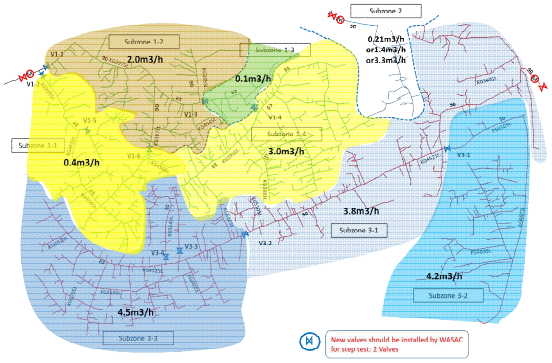


Step Test PM3

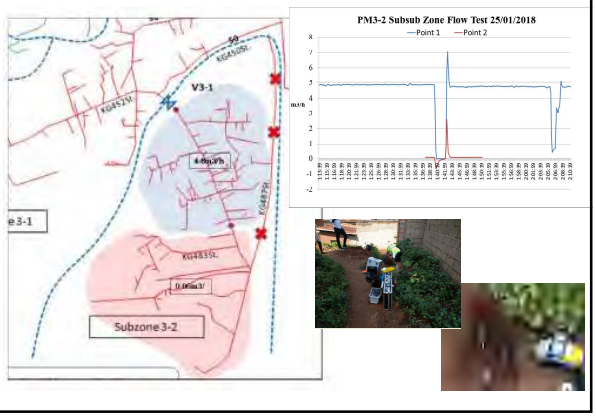


Result Qmnf Map

Kadobogo Subzone Map(11.01.2018)



PM3-2 Subsub Zone Detail Survey



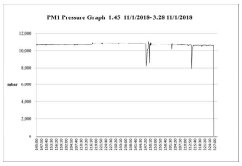
Pressure Management Activity

PM1 Pressure Data

22/11—23/11/2017 Max10bar Min7bar

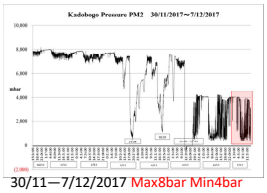
Failure

20/12/2017

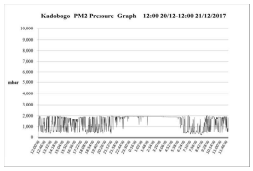


11/1/2018 Max10.5bar

PM2 Pressure Data



30/11—7/12/2017 Max8bar Min4bar

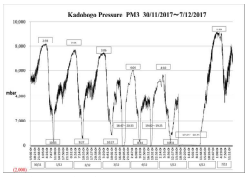


21/12/2017 Midnight Max2bar

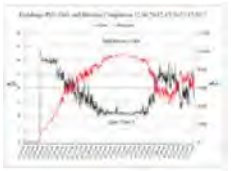
Failure

11/1/2018 Step Test

PM3 Pressure Data



30/11—7/12/2017 Max9bar Min6bar



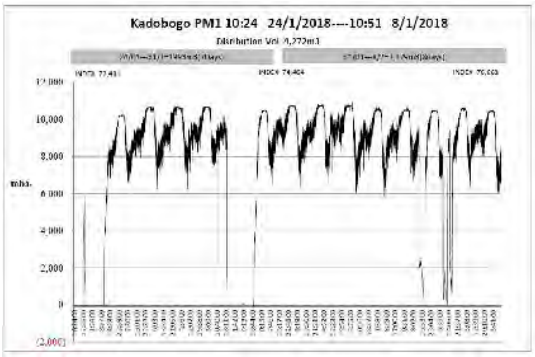
20/12—21/12/2017 Midnight Max9.66bar

29/12 Step Test daytime6-7.5-8.0bar

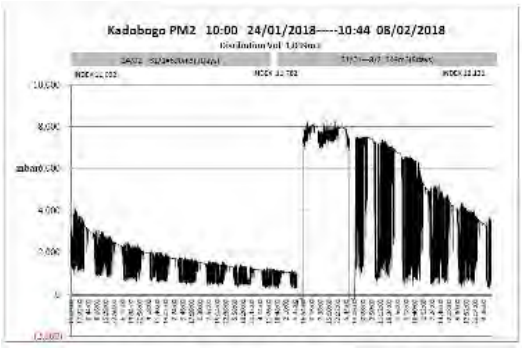
Failure

11/1/2018 Step Test

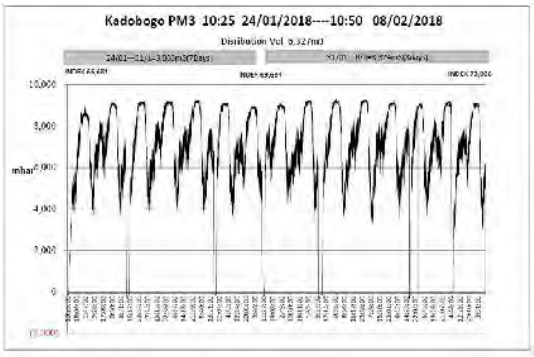
PM1 2week Pressure Data



PM2 2week Pressure Data



PM3 2week Pressure Data



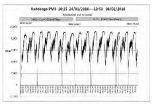
PM3 Pressure Reducing Improvement

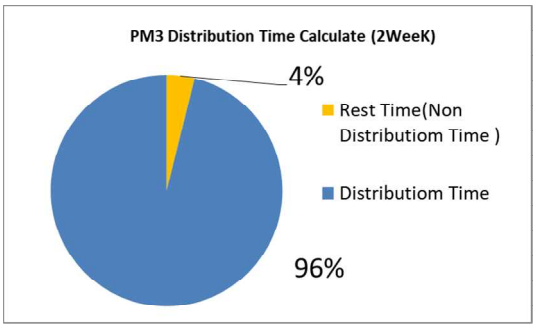
3:13:00	9264
2:52:00	9265
3:07:00	9265
2:01:00	9266
2:30:00	9266
2:32:00	9268
2:51:00	9268
2:16:00	9271
4:06:00	9271
1:59:00	9274
3:02:00	9275
1:41:00	9277
3:01:00	9277
2:57:00	9279
1:56:00	9280
1:49:00	9282
1:40:00	9285
1:48:00	9290
	7130.267

2week Average Pressure 7.1Bar

Pressure Reducing

1day Average 4.0Bar





PM3 Improvement Calculate

	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
PM3	4,142	3,965	3,250	1,669	2,025	4,245	4,942	5,871

Total Vol =5,871m3/Month

Pressure =10.8Bar→7.1Bar

PM3 Real Pressure =10.8Bar+2.5Bar=13.3Bar

PM3 Average Pressure = $\sqrt{\frac{7.1\text{Bar}}{13.3\text{Bar}}}$ =0.73

PM3 Qmnf Total Vol =12.5m3/h × 0.73=9.125m3/h

Re Total Vol =9.125m3/h × 24 × 30=6,570m3/Month

PM3 Reducing Pressure = $\sqrt{\frac{4.0\text{Bar}}{7.1\text{Bar}}}$ =0.75

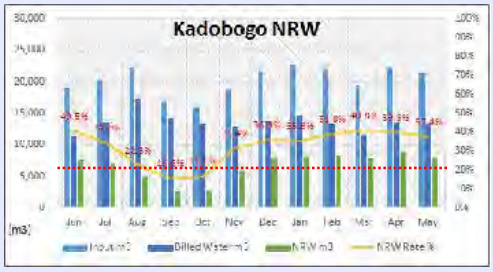
Reducing Re Total Vol =5,871m3/h × 0.75=4,403m3/Month

Difference Vol =5,871m3－4,403m3=1,468m3/Month

Topic-H6:
Pilot area NRW & reduction activities

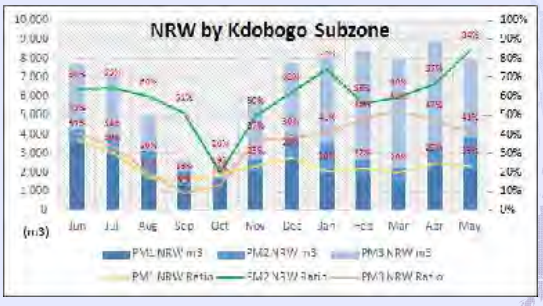
Kyowa Engineering Consultants, Co., Ltd.

KADOBOGO NRW Ratio on May.2018 (Target:20%)

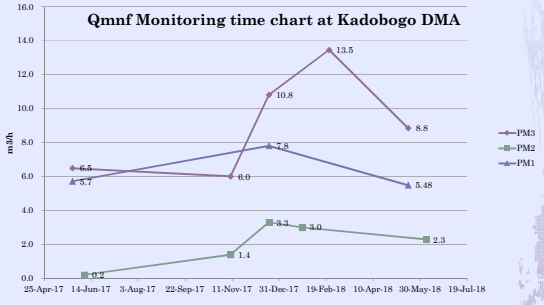


Ave.NRW m3 =6,700m3（NRW37.4%） → 4,000m3（NRW20%）
6,700m3-4,000m3＝2,700m3
2,700m3 X RWF323＝RWF 872,100 / month

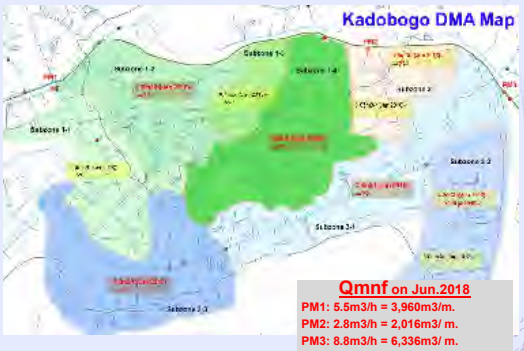
Kadobogo NRW Ratio by Subzoneon May.2018



Qmnf Monitoring

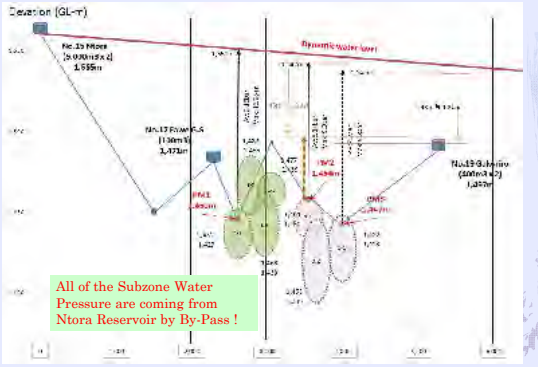


Qmnf & Step Test at Kadobogo



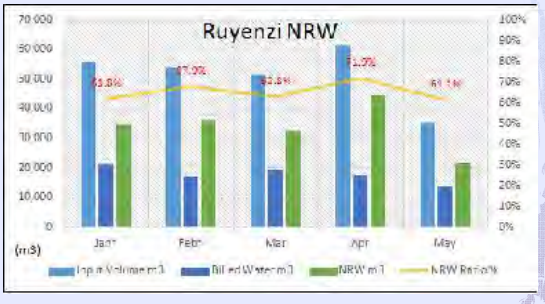
Qmnf on Jun.2018
PM1: 5.5m3/h = 3,960m3/m.
PM2: 2.8m3/h = 2,016m3/ m.
PM3: 8.8m3/h = 6,336m3/ m.
TOTAL: 17.1 m3/h = 12,312m3/ m.
NRW m3 : 11.1 m3/h = 8,003m3/m.

Pressure condition at Kadobogo

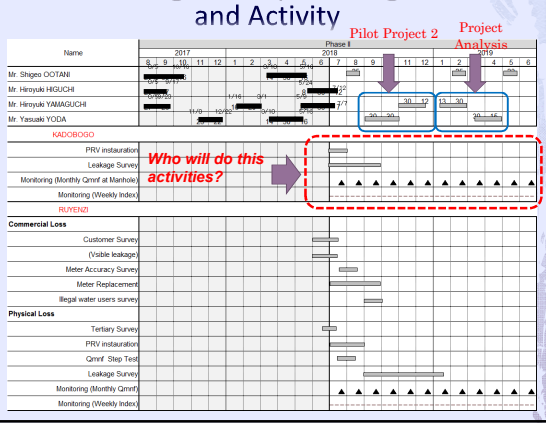


All of the Subzone Water Pressure are coming from Ntora Reservoir by By-Pass !

Ruyenzi NRW Ratio on May.2018 (Target = XX%)



Remaining JICA Expert Assignment and Activity



Missing process on determination of billing volume

- Total No. of Replaced Meter = 290 meters
- Monthly Consumption per customer ≒ 20m3
- Loss m3 of Meter Replacement ≒ 20 / 2 = 10m3

- <u>Total Loss m3 on Meter Replacement:</u>

  290 meters x 10 m3 = 2,900m3
- <u>In RWF:</u>

  2,900m3 x RWF 323 = RWF 937,600

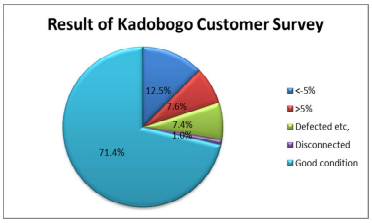
IF WASAC don't take measure,
WASAC will lose your income.

Findings through the pilot activities

Outline of the pilot area (Kadobogo)

On-site meter testing

On-site meter testing



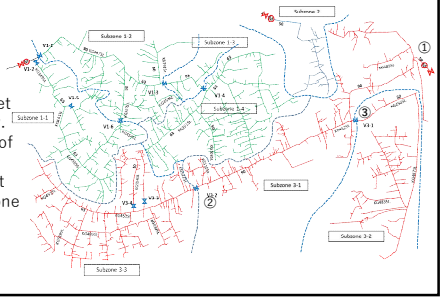
	Meter Error		Defected etc,	Meter to be Replaced	Good condition	Disconnected	Total Surveyed
	<-5%	>5%					
TOTAL	148	90	88	326	845	12	1183
	12.5%	7.6%	7.4%	27.6%	71.4%	1.0%	100%

Step test

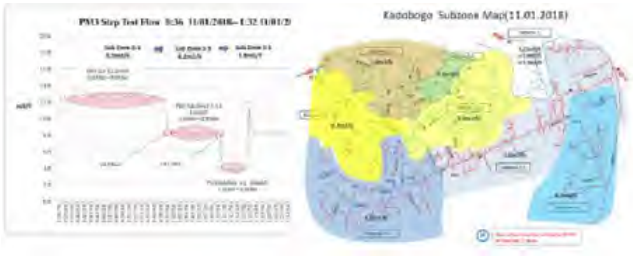
To measure the leakage volume of the subzone, Step test is useful.

① Install the UFM at inlet and measure the flow.
② Close a valve at inlet of subzone.
③ Close another valve at inlet of another subzone
④ Open the valves

※Night time is ideal to conduct Step test.



Step test



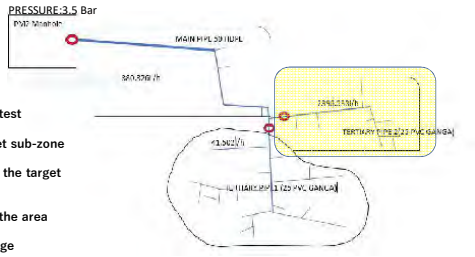
Leak detection

[List of Invisible Leakage found and repaired]

Date	Area	Dia.	Pipes	Causes	Leak rate (L/hour)	Visible or Invisible
22-Mar	PM3-2	25	HDPE Tertiary	High Pressure & Low Quality Pipe	1,500	Invisible
13-Apr	PM3-3	25	HDPE Service	High Pressure & Low Quality Pipe	1,800	Invisible
24-Apr	PM3-1	25	HDPE Service	High Pressure & Low Quality Pipe	4,500	Invisible

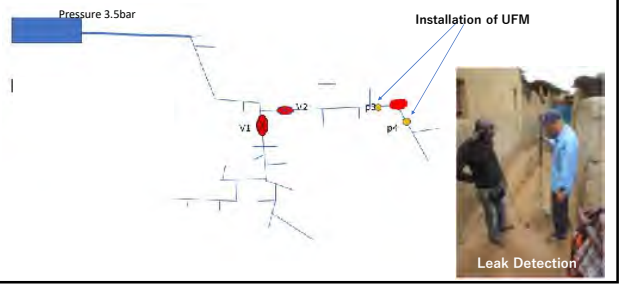
Also, many visible leakage were found and repaired during the survey.

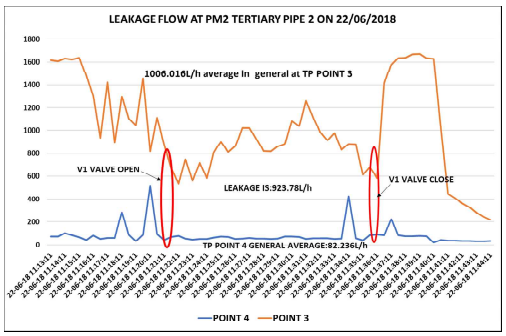
Invisible Leakage Survey



1. **Conduct step test**
2. **Decide a target sub-zone**
3. **Install UFM in the target sub-zone**
4. **Narrow down the area**
5. **Find the leakage**

Invisible Leakage Survey





Water balance

[Water Balance in Kadobogo]

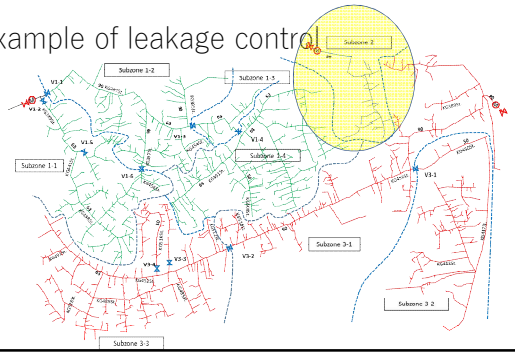
NRW Breakdown	Commercial Loss		Physical Loss	
	Loss related to meter	Illegal water use	Visible Leak	Invisible Leak
%	4-8%	2-5%	25-30%	

Note: Baseline NRW rate is estimated at 37.2%

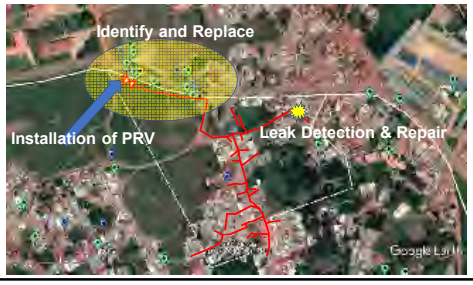
Example of leakage control

- Identification of pipes to be replaced
- Pipe Replacement
- Pressure management
- Leak Detection & Repair

Example of leakage control



Example of leakage control



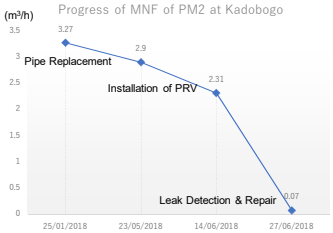
Example of leakage control

Identification of pipes to be replaced

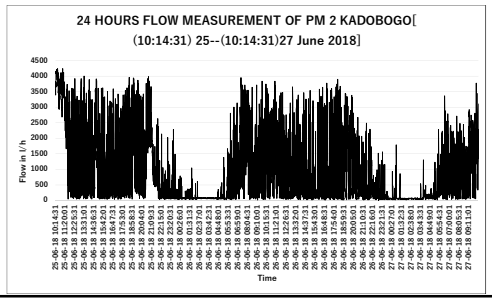
Pipe Replacement

Pressure management

Leak Detection & Repair



Example of leakage control



To reduce leakage

• Pressure management

(In case of PM2)

Pressure : 7.5bar →4.0bar by installing a PRV

MNF : 2.9m^3/h→2.3m^3/h (20% was reduced)

Leakage : 30%×20%＝6% (6% of NRW can be reduced)

To reduce leakage

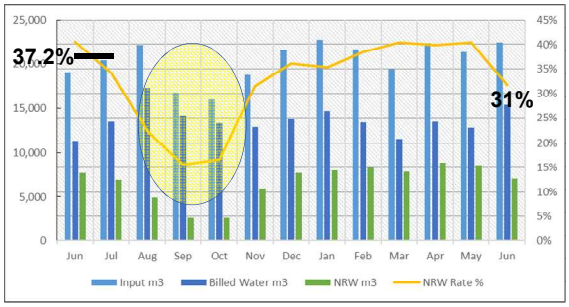
• Service Pipe

- **Most of the leakage comes from service pipes.**
- **We need to do something to change the situation.**

[Quality of Material]

[Way of Repair]

Kadobogo NRW Trend



Summary

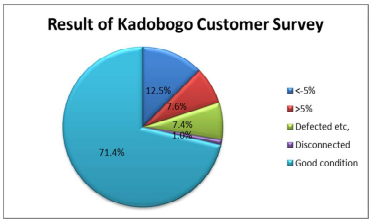
- Importance of customer meters management.
- Necessity of statistical information such as leakage point, cause, materials, pressure etc.
- Effectiveness of pressure management
- Quality of the service pipe

Findings through the pilot activities 【Output 3 】

Pilot area 1 (Kadobogo)

On-site meter testing

On-site meter testing



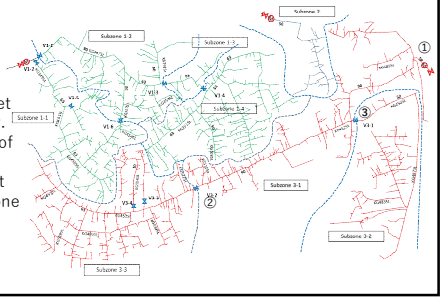
	Meter Error		Defected etc,	Meter to be Replaced	Good condition	Disconnected	Total Surveyed
	<-5%	>5%					
TOTAL	148	90	88	326	845	12	1183
	12.5%	7.6%	7.4%	27.6%	71.4%	1.0%	100%

Step test

To measure the leakage volume of the subzone, Step test is useful.

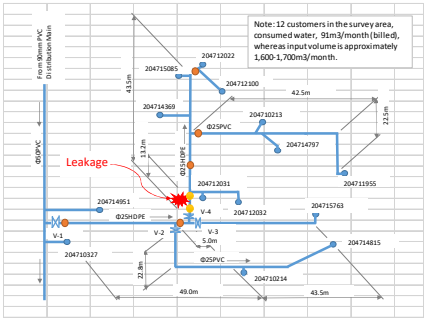
① Install the UFM at inlet and measure the flow.
② Close a valve at inlet of subzone.
③ Close another valve at inlet of another subzone
④ Open the valves

※Night time is ideal to conduct Step test.

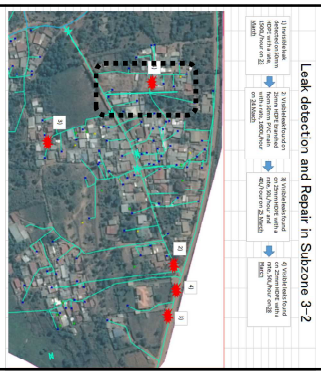


Step test

More detail step test in Sub Zone PM3-2



Sub-zone 3-2



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List of locations of water leakage detected and repaired in this survey

No.	Date	Location	Diameter (mm)	Pipe material	Cause of leakage	Leakage volume (L/hour)
1	22-Mar	PM3-2	25	HDPE tertiary pipe	Invisible	1,500
2	25-Mar	PM3-2	25	HDPE water supply pipe	Visible	2,000
3	25-Mar	PM3-2	25	HDPE water supply pipe	Visible	50
4	27-Mar	PM3-2	25	HDPE tertiary pipe	Visible	60
5	2-Apr	PM3-2	25	HDPE tertiary pipe	Visible	50
6	4-Apr	PM1	150	PVC secondary pipe	Visible	10,000
7	5-Apr	PM2	50	HDPE secondary pipe	Visible	7,000
8	13-Apr	PM3-3	25	HDPE water supply pipe	Invisible	1,800
9	23-Apr	PM3-1	90	PVC secondary pipe	Visible	1,500
10	24-Apr	PM3-1	25	HDPE water supply pipe	Invisible	4,500
Total					Total	28,460L/hour
					Invisible	7,800L/hour x24hrx30day
					Visible	20,660L/hour x24h

Breakdown of Leakage

Leakage	Times	Volume	Input Volume	Rate in NRW
		m3	%	%
Visible	7	1,881	9%	23%
Invisible	3	4,378	21%	52%
Total	10	6,259	30%	75%
m3/100%			20,884	8,345

Note: from March 22 to April 24

Treatment to Leakage

Treatment	Specific Action	Stage	Cost
Preventive	•Replacement of pip •Installation of PRV	•Design, •New construction, •Rehabilitation	High
Corrective/ Symptomatic	•Leak survey/detection and Pipe repair	•Routine work or periodical work	Relatively low, but it depends on frequency

Visible Leakage

Visible Leakage

Invisible Leakage

To reduce leakage

Invisible Leakage

- Service Pipe

- **Most of the leakage comes from service pipes.**
- **We need to do something to change the situation.**

[Quality of Material]
[Way of Repair]

Cause of Big Loss of Water

- The biggest cause of Physical Loss (Leakage) is high hydraulic pressure and poor quality of pipe material.
- The leakage recurs easily even if a leaking pipe was repaired unless an appropriate countermeasure is taken per these two points.
- Visible leakages are found in a high pressure area. It should be assumed that the invisible leakages exists further.
- The invisible leakage continues being left without being known.

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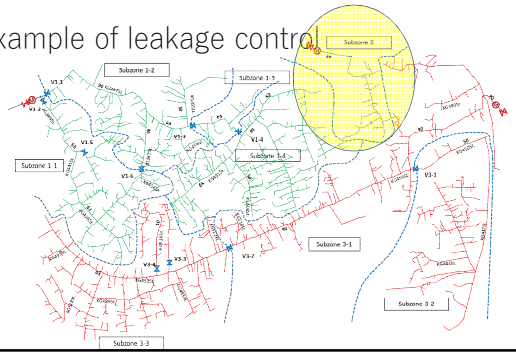
Water balance

[Water Balance in Kadobogo]

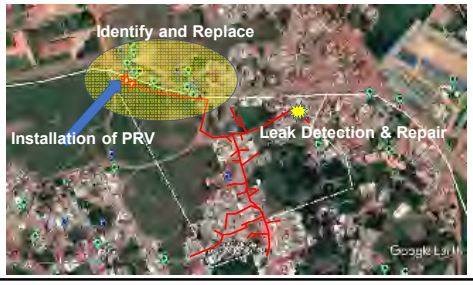
NRW Breakdown	Commercial Loss		Physical Loss	
	Loss related to meter	Illegal water use	Visible Leak	Invisible Leak
%	4-8%	2-5%	25-30%	

Note: Baseline NRW rate is estimated at 37.2%

Example of leakage control

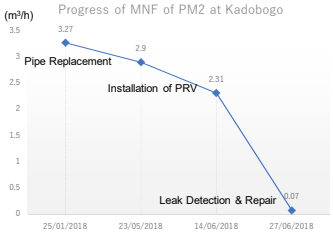


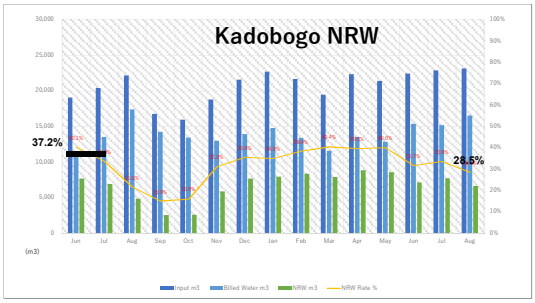
Example of leakage control

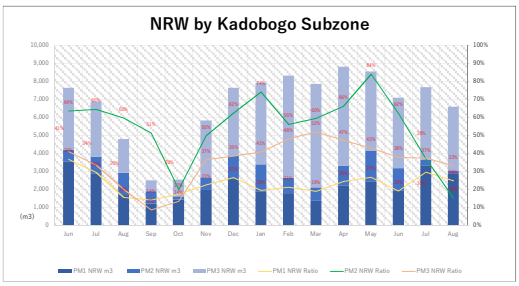


Example of leakage control

- Identification of pipes to be replaced
- Pipe Replacement
- Pressure management
- Leak Detection & Repair







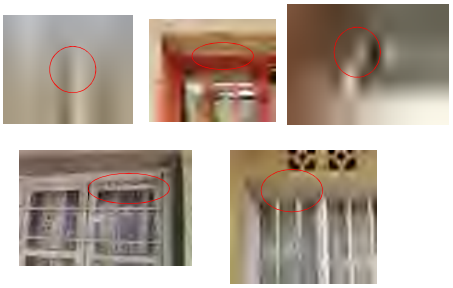
Pilot Area 2 Ruyenzi

Pilot Area 2 Ruyenzi

1. POC Seal on the Front Door

- The POC List and the POC location Map are indispensable basic information for the routine work of WASAC on site and customer data analysis.

Present POC Number



Seal of Cleaning Company

Proposed Seal of WSAC POC

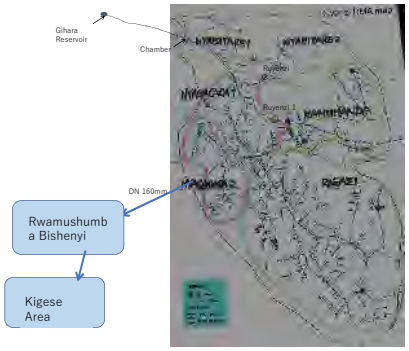
POC Map

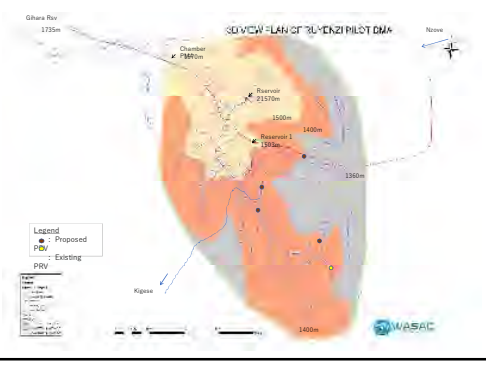
POC List

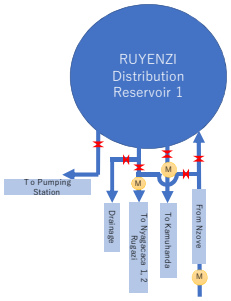
FID	Shape *	No_	Date	WP_No_	POC	East	South	Observatio	xx	yy
		1	18-Apr-18					BRN FNTN	498301	4781750
0	Point	2	5-Mar-18	2	240214800	29.98726	-1.97206		498582.7658	4781961.83
1	Point	3	5-Mar-18	117	240214789	29.98715	-1.97151	Runda sector	498570.5286	4782022.64
2	Point	4	5-Mar-18	118	240216177	29.98717	-1.97154	Police	498572.7535	4782019.323
3	Point	5	5-Mar-18	120	240218239	29.98728	-1.97238		498584.9909	4781926.449
4	Point	6	5-Mar-18	121	240216110	29.98831	-1.97249	no water, Inlet pipe issue	498699.5711	4781914.288
5	Point	7	5-Mar-18	122	240214787	29.98786	-1.97285		498649.5121	4781874.484
6	Point	8	5-Mar-18	123	240214606	29.988	-1.97317		498665.0864	4781839.104
7	Point	9	5-Mar-18	124	240214753	29.98815	-1.97348		498681.773	4781804.829
8	Point	10	5-Mar-18	125	240216286	29.98794	-1.97397		498658.4125	4781750.652
9	Point	11	5-Mar-18	126	240215084	29.98799	-1.97407		498663.9747	4781739.596
10	Point	12	5-Mar-18	127	240215019	29.98777	-1.97404		498639.5012	4781742.912
11	Point	13	5-Mar-18	128	240214844	29.9873	-1.9742		498587.2173	4781725.222
12	Point	14	5-Mar-18	129	240215870	29.98796	-1.97487		498660.638	4781651.144
13	Point	15	5-Mar-18	130	240218304	29.98781	-1.97528		498643.952	4781605.812
14	Point	16	5-Mar-18	131	240214947	29.98847	-1.97559		498717.3724	4781571.538
15	Point	17	5-Mar-18	132	240214995	29.9882	-1.976		498687.3372	4781526.206
16	Point	18	5-Mar-18	133	240215836	29.98788	-1.97581		498651.7594	4781547.213
17	Point	19	5-Mar-18	134	240214539	29.98794	-1.97552		498658.4137	4781579.277

2.Distribution Area of Ruyenzi

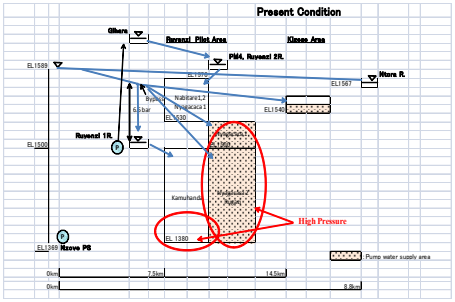
- Big height difference on the terrain + Excess pumping pressure of Nzove PS
- High pressure and pipes with poor material are biggest cause of leakage
- NRW 72% in April, 2018







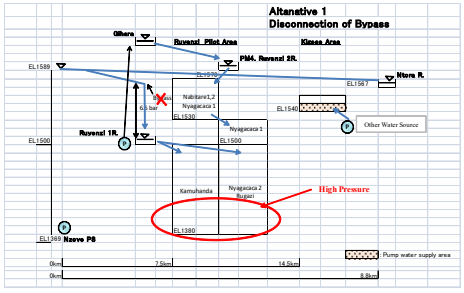
Distribution Area of Ruyenzi



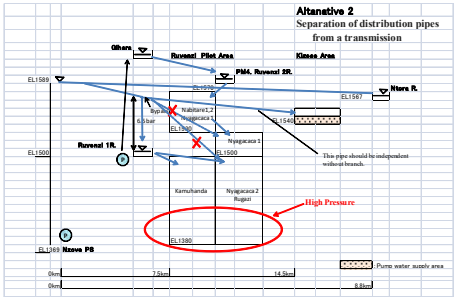
Alternatives for Pressure Reduction

Alternatives	Required Conditions	Period of study and rehabilitation work
1. Disconnection of bypass	• Independent water source and water supply system for Kigese Area	Long
2. Separation of distribution pipes from a transmission pipe	• Adjustment of existing pipeline network	Long
3. Installation of PRV	• Installation of PRVs and small adjustment of network	Relatively Short
4. Intermittent water supply	• Inconvenience of customer in the pump water supply area • Pressure reduction during only the time valve of bypass closed	Short

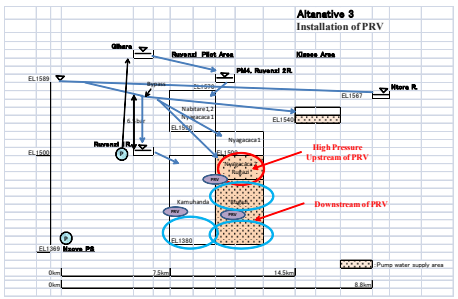
Pressure Reduction Measure



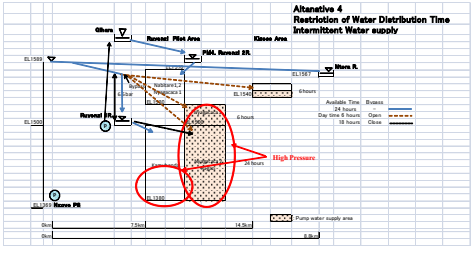
Pressure Reduction Measure

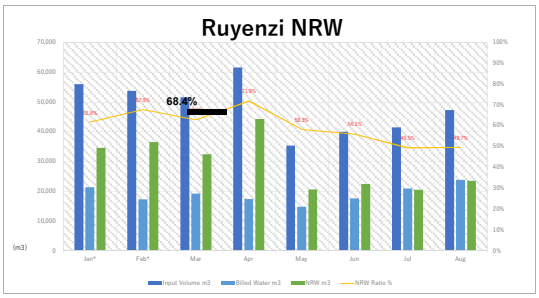


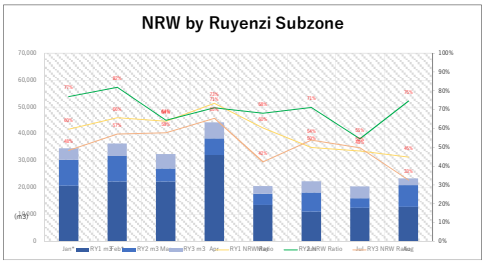
Pressure Reduction Measure



Pressure Reduction Measure







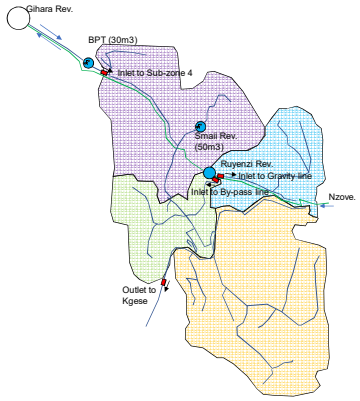
Summary

- Importance of customer meters management.
- Necessity of statistical information such as leakage point, cause, materials, pressure etc.
- Effectiveness of pressure management
- Quality of the service pipe
- Continuous leakage survey (Visible, Invisible)

Weekly Meeting

February 15, 2019

PRV Effect Measurement in Sub-zone RY1 of Ruyenzi

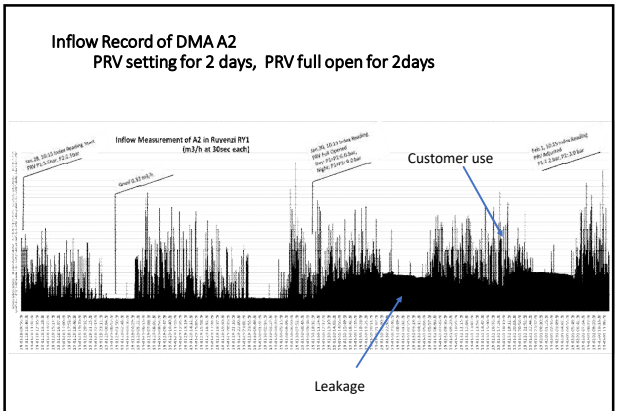


Schedule of the Effect Measurement Survey of PRV in Ruyenzi RY1

PRV1 in RY1 Ruyenzi

Day		1/28	1/29	1/30	1/31	2/1
		Mon	Tue	Wed	Thu	Fri
PRV Pressure P2 (bar)		2.5		Full open Day 6.9 Night 9.0		Adjust. 3.0
Flow Meter Setting/Out		●				●
Customer Meter Index Reading		●	●	●	●	●

No	POC	Customer Meter Index										Term1	Term2
		1/28	Index	1/29	Index	1/30	Index	1/31	Index	2/1	Index	1/28-1/30	1/30-2/1
1	24021605?	10:13	173.4650	10:39	173.6301	10:15	173.8429	10:19	173.9804	10:15	174.1213	0.3779	0.2784
2	24021906?	10:18	69.5130	10:22	69.6738	10:16	69.7955	10:22	69.9240	10:17	70.0684	0.2845	0.2729
3	24021595?	10:22	548.5635	10:26	548.7084	10:18	549.0543	10:26	549.4645	10:18	549.6815	0.4908	0.6272
4	24021594?	10:54	389.1254	10:57	389.5320	10:49	389.9639	10:57	390.3298	10:47	390.6981	0.8385	0.7342
5	24021595?	10:30	546.8480	10:34	547.0218	10:24	547.1580	10:34	547.3200	10:24	547.6149	0.3100	0.4569
6	24021607?	10:26	347.8170	10:30	348.1116	10:22	348.4000	10:30	348.7868	10:20	349.2038	0.5830	0.8038
7	24021698?	10:47	146.2615	10:54	146.3068	10:45	146.3613	10:54	146.3613	10:45	146.3613	0.0998	0.0000
8	24021599?	10:35	329.0225	10:37	329.0225	10:30	329.0225	10:37	329.0225	10:30	329.0225	0.0000	0.0000
9	24021599?	10:40	331.9978	10:44	332.4374	10:36	332.8668	10:44	333.8402	10:35	334.9868	0.8690	2.1400
10	24021693?	10:37	189.7955	10:40	189.7955	10:33	189.7955	10:40	189.7955	10:32	189.7955	0.0000	0.0000
11	24021600?	10:47	186.3451	10:50	186.4766	10:36	186.6048	10:50	186.7342	10:42	186.9236	0.2597	0.3188
12	24021932?	10:45	47.1357	10:47	47.4076	10:40	47.6236	10:47	47.8723	10:55	48.2193	0.4879	0.5957
13	24021596?	10:49	447.7114	10:49	448.3951	10:49	448.6958	10:49	449.0844	1:49	449.2113	0.9844	0.5155
14	24021594?	10:17	115.7802	10:17	115.8602	10:15	115.9003	10:15	115.9802	10:17	116.0602	0.1200	0.1600
15	24021594?	10:40	426.1317	10:40	426.2995	10:40	426.8459	10:40	426.8652	10:40	427.4164	0.7136	0.5711
16	24021593?	10:43	1.1169	10:43	1.3450	10:44	1.8779	10:44	1.9243	10:44	2.3485	0.7605	0.4711
17	24021597?	10:31	136.4575		136.4575		136.4575		136.4575		136.4575		0.0000
18	24021623?	10:20	606.8958	10:20	607.5193	10:20	608.0367	10:21	608.5171	10:20	608.9875	1.1409	0.9508
19	24021593?	10:34	219.1010	10:34	219.4544	10:34	219.9235	10:34	220.5942	10:33	220.9744	0.8225	1.0509
20	24021596?	10:22	37.5482	10:22	37.8942	10:22	38.2043	10:23	38.4309	10:22	38.7634	0.6561	0.5591
21	24021596?	10:27	246.8662	10:27	247.4695	10:28	247.9081	10:28	248.5196	10:27	249.2205	1.0421	1.3124
22	24021963?	10:50	12.2012	10:54	12.3125	10:51	12.5721	10:52	12.6624	10:52	12.9512	0.3709	0.3791
											Consumption (m3)	11.1921	12.1959
											Inflow (m3)	27.216	52.672
											NRW (m3)	16.0239	40.4771
											NRW Rate (%)	58.9%	76.8%
											Qmnf(m3/h)	0.330	0.700
											Qmnf 2days(m3)	15.840	33.600
											Meter Error (m3)	0.1839	6.8771
											Commercial Loss(%)	0.7%	13.3%
											Physical Loss(%)	58.2%	63.8%

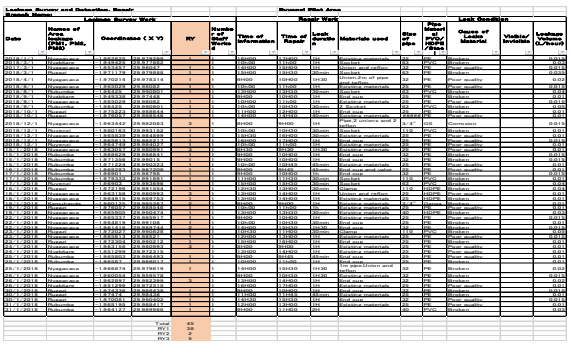


Result of PRV Effect Measurement

Items	Term1 (2days)	Term2 (2days)
PRV P2 Pressure (bar)	2.5	6.0 - 9.0
Inflow (m3)	27.22	52.67
Consumption (m3)	11.19	12.20
NRW (m3)	16.02	40.48
NRW Rate (%)	58.9%	76.8%
Commercial Loss(%)	0.7%	
Physical Loss(%)	58.2%	

Plotting of the Leakage Repair Record in Google Earth Map

- Kadobogo
  Aug. 2017 – Nov. 2018 : 176 leaks, 10 leaks/month
- Ruyenzi
  Jul. 2017 – Dec. 2018 : 561 leaks, 31 leaks/month



Location Map of the Leakage Repair Points in Kadobogo

Location Map of the Leakage Repair Points in Ruyenzi

Points of Attention

- ✓**The target area of the leakage survey and the route position of pipe replacement can be known by the history of the leakage repair.**
- ✓**Recording of the leakage points in Excel Sheet by XY coordinate without error is very important task.**
- ✓**If the record data of XY coordinate are available, it is very easy to make leakage location map by Google Earth.**

Result of Meter Test in Kadobogo

- On-site Meter Test Sep. 2017- Dec. 2017
- Meter Replacement Oct. 2017 – Sep. 2018
  (mainly Dec. 2017- Apr. 2018)

Result of On-site Meter Test					
Sub-zone	Meter Error				Total
	Intorerable	Tolerable	Intorerable	Defected	
	<-5%		5%<		
PM1	82	467	52	49	650
PM2	5	39	5	1	50
PM3	62	339	33	38	472
TOTAL	149	845	90	88	1172
%	13%	72%	8%	8%	100%

Listed number of POC : 1240
Impossible survey: disconnection 12, not enter/ not reach 56

Effect of Meter Replacement 1

Item	Case 1	Case 2
Condition	Existing	After Replacement
Tested Meter	1084	845
Total Error %	-1,508.21	-749.54
Error Average/1084 %	-1.39	-0.69

Case 2: assumption that meter error of the replaced become zero and consumption volume of every customer is same

Improvement Value = 1.39-0.69 = 0.70%

NRW Rate Effect and Term of Redemption of Meter replacement

May, 2018			
Item	Present	Effect	Effect
		x 0.007	0.7%
Billing (m3)	12822	12912	90
Distribution (m3)	21373	21373	
RW Rate (%)	60.0%	60.4%	0.4%
NRW Rate (%)	40.0%	39.6%	0.4%

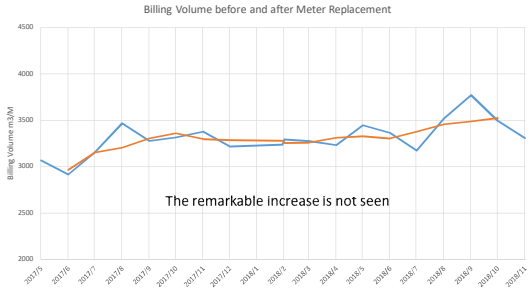
Term of Redemption			
Income/ Cost	Unit (Frw)	Quantity	Frw
Billing Income	565	90	50,850
Meter Cost	30,000	239	7,170,000
Redemption Month			141
Year			12

Result and Policy

- ✓ The meter setting coverage rate of WASAC is already high (nearly 100%).
- ✓ Although the meter test and meter replacement are carried out with expending much labor and time for the purpose of reduction of NRW, the NRW reduction effects is small.
- ✓ When there is the meter error of the plus side, it becomes the opposite effect for NRW reduction.
- ✓ The replacement of the meter should be intended to maintain equitableness and fairness of the billing collection for the customer.
- ✓ The meter which should be replaced or repaired immediately is for the followings.
  - Defected meter (It should be finded at the time of meter reading)
  - Blocked meter (It should be finded at the time of meter reading)
- ✓ About the following meter should be tested and it should be replaced if there is an error more than +-5%.
  - Meter abnormality is found by the analysis of billing volume.
  - When the customer make a complain about a billing amount.
- ✓ The meter should be replaced periodically each around ten years that is redemption period of replaced meter, to maintain meter accuracy as a long-term measures.
- ✓ It might be considered that about the meter in the situation that is hard to get to the meter will be a smart meter.

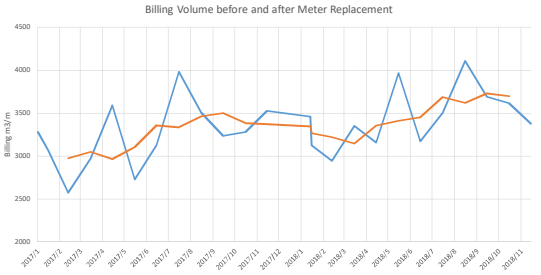
Effect of Meter Replacement 2

Adjusted the replaced month to same Feb. 2018



2017/6	2017/7	2017/8	2017/9	2017/10	2017/11	2017/12	2018/1	2018/2	2018/3	2018/4	2018/5	2018/6	2018/7	2018/8	2018/9	2018/10
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	8	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	22	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

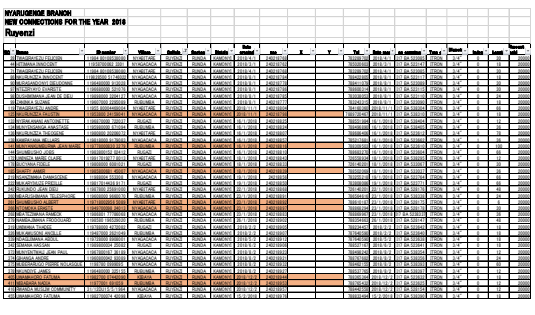
No month adjustment

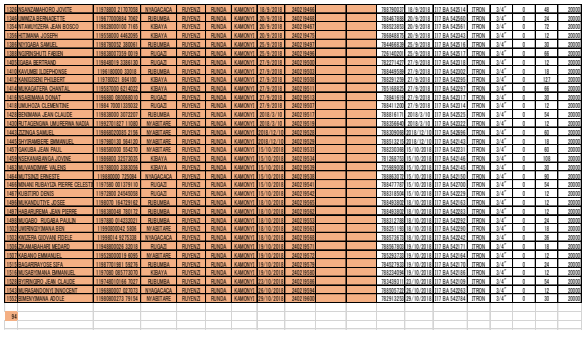


20171	20172	20173	20174	20175	20176	20177	20178	20179	20710	20711	20712	20181	20182	20183	20184	20185	20186	20187	20188	20189	20810	20811	20812
28	27	25	25	39	23	24	36	0	0	23	17	14	14	13	10	13	14	13	13	19	3	13	7
11	7	5	6	9	7	7	8	7	7	5	5	5	5	5	4	4	7	0	0	27	9	7	6
0	0	0	0	0	1	10	10	0	10	12	8	10	5	10	12	14	7	10	12	9	26	10	5
3	10	10	10	0	10	10	11	11	5	10	11	10	7	11	8	10	9	9	9	7	0	13	11
7	0	0	0	30	7	6	0	0	0	10	9	0	0	0	0	0	20	0	25	11	8	7	10
2	0	8	7	8	11	5	8	8	8	10	8	10	10	5	0	11	6	11	10	9	10	8	9
67	45	33	44	64	44	36	36	36	29	30	38	47	36	31	38	54	39	42	23	22	19	23	25
13	10	11	12	15	9	10	18	12	8	7	16	10	11	8	10	9	12	8	8	10	13	13	12
0	22	0	0	23	8	8	11	14	10	0	19	12	0	0	30	10	9	13	13	11	15	12	13
26	11	19	29	35	11	18	21	20	27	45	38	31	57	34	37	126	53	38	21	40	49	33	19
7	7	8	5	8	8	7	0	18	0	13	11	7	8	14	8	8	7	8	10	8	11	7	7
20	20	20	20	20	13	0	6	18	20	20	20	20	13	16	0	39	15	16	20	20	16	21	
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	50	33	201	35	27	24	22	54	41
0	0	0	0	0	6	18	0	30	13	0	18	0	0	0	0	0	0	0	0	0	0	0	0
5	12	7	11	6	0	6	0	0	54	18	0	20	0	36	25	22	15	18	22	22	20	15	17
14	9	7	12	10	8	10	14	9	9	9	16	15	15	9	17	9	11	5	10	10	10	10	10
13	14	11	12	13	11	15	16	11	11	9	10	10	11	16	13	16	18	20	23	23	20	21	
23	20	16	15	19	20	20	23	21	19	15	22	16	18	12	15	12	14	14	13	18	16	16	17
0	0	0	0	50	0	23	10	10	11	0	15	15	0	17	0	20	10	10	21	15	14	0	
12	8	10	11	14	9	10	16	10	11	11	13	10	9	6	9	13	12	8	10	11	9	11	10
6	6	4	6	9	0	20	10	9	7	8	6	8	5	6	8	8	6	9	16	8	10	8	8
234	265	167	173	222	94	101	184	165	156	25	177	92	118	67	145	80	182	113	108	200	142	106	108
21	19	18	20	23	19	23	25	20	17	17	21	26	18	15	19	20	17	20	23	22	24	22	21
33	40	31	39	49	35	31	40	35	33	28	39	41	33	32	41	35	31	40	44	43	32	29	28

Problem in the NRW Calculation

- New Customer
- DMA Code of New Customer

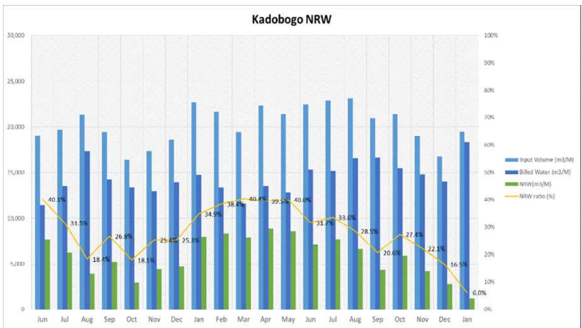

NYARUGENGE BRANCH
NEW CONNECTIONS FOR THE YEAR 2018
Ruyenzi

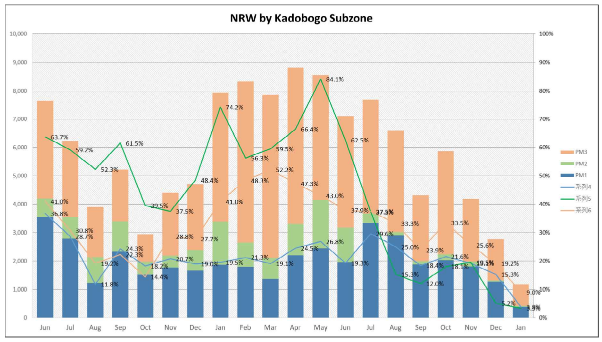


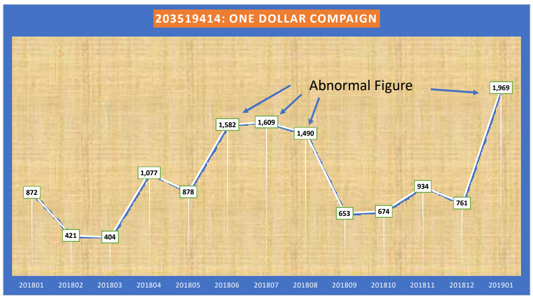
NRW Rate of Pilot Areas
as of January 2019

Kadobogo NRW Rate by Zone

Case 3	2017							2018									Input Volume Rev.15 to 15/190111			
PM Number	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Input Volume (m3/M)	19,054	19,722	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	16,772	19,491
IVave.		20,018	20,156	19,032	17,727	17,442	19,556	20,993	21,270	21,148	21,047	22,049	22,227	22,815	22,304	21,803	20,421	19,040	18,418	
PM1	9,634	9,741	10,309	9,631	8,412	8,537	8,791	9,577	8,391	7,179	8,995	9,134	10,134	11,272	11,607	10,204	9,417	9,410	8,281	10,200
		9,895	9,894	9,451	8,860	8,580	8,968	8,920	8,382	8,188	8,436	9,421	10,180	11,004	11,028	10,409	9,677	9,036	9,297	
PM2	1,049	1,239	1,758	1,730	1,105	1,108	1,489	2,061	1,519	1,243	1,659	2,030	1,978	872	789	965	1,108	892	910	899
		1,349	1,576	1,531	1,314	1,234	1,553	1,690	1,608	1,474	1,644	1,889	1,627	1,213	875	954	988	970	900	
PM3	8,371	8,742	9,212	8,105	6,833	7,721	8,329	11,056	11,767	11,017	11,674	10,209	10,333	10,718	10,742	9,744	10,833	8,689	7,581	8,392
		8,775	8,686	8,050	7,553	7,628	9,035	10,384	11,280	11,486	10,967	10,739	10,420	10,598	10,401	10,440	9,755	9,034	8,221	
Billed Water (m3/M)	11,404	13,500	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	18,316
BWave.		14,093	15,040	15,006	13,534	13,421	13,877	14,008	13,232	12,810	12,633	13,887	14,446	15,685	16,104	16,211	15,628	14,763	15,703	
PM1	6,088	6,947	9,089	7,286	6,882	6,766	7,122	7,710	6,602	5,808	6,790	6,684	8,182	7,930	8,708	8,326	7,384	7,609	7,011	9,814
		7,375	7,774	7,752	6,978	6,923	7,199	7,145	6,707	6,400	6,427	7,219	7,599	8,273	8,321	8,139	7,773	7,335	8,145	
PM2	381	506	839	666	668	692	768	531	664	503	557	322	742	547	668	849	908	718	863	869
		575	670	724	675	709	664	654	566	575	461	540	537	652	688	808	825	830	817	
PM3	4,935	6,047	7,446	6,294	5,847	5,501	6,018	6,524	6,085	5,268	6,152	5,816	6,416	6,698	7,165	7,420	7,204	6,465	6,126	7,633
		6,143	6,596	6,529	5,881	5,789	6,014	6,209	5,959	5,835	5,745	6,128	6,310	6,760	7,094	7,263	7,030	6,598	6,741	
NRW(m3/M)	7,650	6,222	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	2,772	1,175
NRWave.		5,926	5,116	4,026	4,193	4,020	5,679	6,985	8,038	8,338	8,413	8,162	7,781	7,130	6,201	5,592	4,793	4,278	2,715	
PM1	3,546	2,794	1,220	2,345	1,530	1,771	1,669	1,867	1,789	1,371	2,205	2,450	1,952	3,342	2,899	1,878	2,033	1,801	1,270	386
		2,520	2,120	1,698	1,882	1,657	1,769	1,775	1,676	1,788	2,009	2,202	2,581	2,731	2,706	2,270	1,904	1,701	1,152	
PM2	668	733	919	1,064	437	416	721	1,530	855	740	1,102	1,708	1,236	325	121	116	200	174	47	30
		773	905	807	639	525	889	1,035	1,042	899	1,183	1,349	1,090	561	187	146	163	140	84	
PM3	3,436	2,695	1,766	1,811	986	2,220	2,311	4,532	5,682	5,749	5,522	4,393	3,917	4,020	3,577	2,324	3,629	2,224	1,455	759
		2,632	2,091	1,521	1,672	1,839	3,021	4,175	5,321	5,651	5,221	4,611	4,110	3,838	3,307	3,177	2,726	2,436	1,479	
NRW ratio (%)	40.1%	31.5%	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%	16.5%	6.0%
NRWRave.		30.0%	25.6%	21.1%	23.4%	22.9%	28.5%	32.9%	37.9%	39.5%	40.0%	37.1%	35.1%	31.3%	27.6%	25.5%	23.4%	22.0%	14.9%	
PM1	36.8%	28.7%	11.8%	24.3%	18.2%	20.7%	19.0%	19.5%	21.3%	19.1%	24.5%	26.8%	19.3%	29.6%	25.0%	18.4%	21.6%	19.1%	15.3%	3.8%
		25.8%	21.6%	18.1%	21.1%	19.3%	19.7%	19.9%	20.0%	21.6%	23.5%	23.5%	25.2%	24.6%	24.3%	21.7%	19.7%	18.7%	12.8%	
PM2	63.7%	59.2%	52.3%	61.5%	39.5%	37.5%	48.4%	74.2%	56.3%	59.5%	66.4%	84.1%	62.5%	37.3%	15.3%	12.0%	18.1%	19.5%	5.2%	3.3%
		58.4%	57.6%	51.1%	46.2%	41.8%	53.4%	59.6%	63.4%	60.7%	70.0%	71.0%	61.3%	38.4%	21.5%	15.1%	16.5%	14.2%	9.3%	
PM3	41.0%	30.8%	19.2%	22.3%	14.4%	28.8%	27.7%	41.0%	48.3%	52.2%	47.3%	43.0%	37.9%	37.5%	33.3%	23.9%	33.5%	25.6%	19.2%	9.0%
		30.3%	24.1%	18.6%	21.8%	23.6%	32.5%	39.0%	47.2%	49.3%	47.5%	42.7%	39.5%	36.2%	31.6%	30.2%	27.6%	26.1%	17.9%	
POC	1,243	1,247	1,265	1,270	1,266	1,269	1,273	1,281	1,286	1,293	1,295	1,294	1,295	1,295	1,311	1,314	1,315	1,315	1,315	1,343
POCave.		1,252	1,261	1,267	1,268	1,269	1,274	1,280	1,287	1,291	1,294	1,295	1,295	1,300	1,307	1,313	1,315	1,315	1,324	
PM1	637	639	646	647	643	646	647	655	660	662	662	661	661	661	668	669	669	669	669	681
		641	644	645	645	645	649	654	659	661	662	661	661	663	666	669	669	669	673	
PM2	42	42	43	43	43	43	44	44	44	44	44	44	44	44	45	45	45	45	45	47
		42	43	43	43	43	44	44	44	44	44	44	44	44	45	45	45	45	46	
PM3	564	566	576	580	580	580	582	582	582	587	589	589	590	590	598	600	601	601	601	615
		569	574	579	580	581	581	582	584	586	588	589	590	593	596	600	601	601	606	
NRW/POC (m3/M)	6.2	5.0	3.1	4.1	2.3	3.5	3.7	6.2	6.5	6.1	6.8	6.6	5.5	5.9	5.0	3.3	4.5	3.2	2.1	0.9
NRW/POCave.		4.7	4.1	3.2	3.3	3.2	4.5	5.5	6.2	6.5	6.5	6.3	6.0	5.5	4.8	4.3	3.6	3.3	2.1	
PM1	5.6	4.4	1.9	3.6	2.4	2.7	2.6	2.9	2.7	2.1	3.3	3.7	3.0	5.1	4.3	2.8	3.0	2.7	1.9	0.6
		3.9	3.3	2.6	2.9	2.6	2.7	2.7	2.5	2.7	3.0	3.3	3.9	4.1	4.1	3.4	2.8	2.5	1.7	
PM2	15.9	17.5	21.4	24.7	10.2	9.7	16.4	34.8	19.4	16.8	25.0	38.8	28.1	7.4	2.7	2.6	4.4	3.9	1.0	0.6
		18.2	21.2	18.8	14.9	12.1	20.3	23.5	23.7	20.4	26.9	30.7	24.8	12.7	4.2	3.2	3.6	3.1	1.8	
PM3	6.1	4.8	3.1	3.1	1.7	3.8	4.0	7.8	9.8	9.8	9.4	7.5	6.6	6.8	6.0	3.9	6.0	3.7	2.4	1.2
		4.6	3.6	2.6	2.9	3.2	5.2	7.2	9.1	9.6	8.9	7.8	7.0	6.5	5.6	5.3	4.5	4.1	2.4	



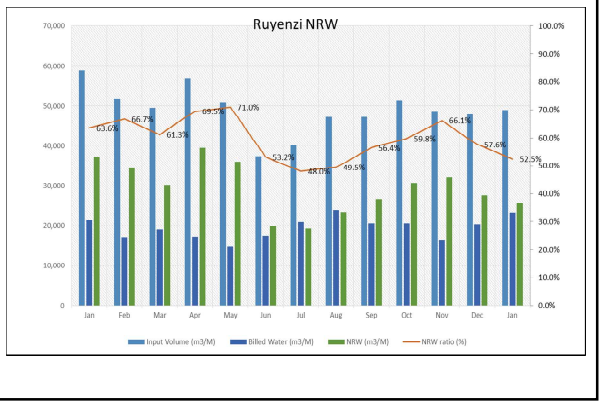


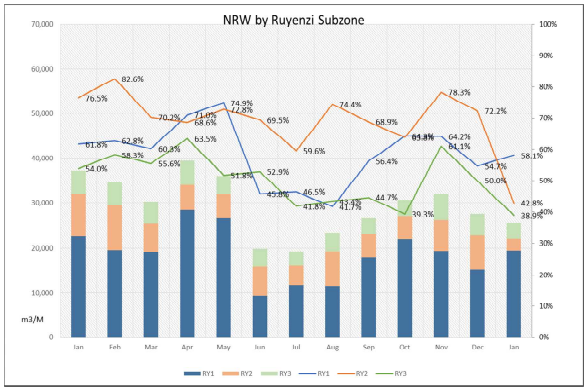


Meter DN2", Children 40-80 persons,
Meter Error +15.8, No replacement

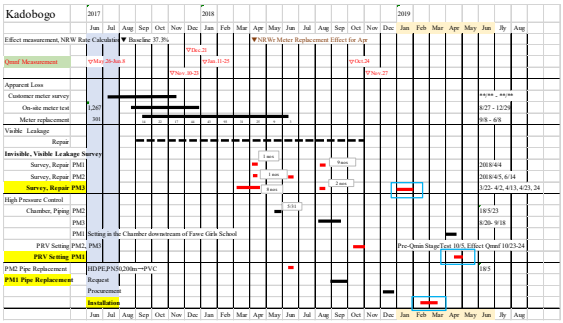
Table-Ruyenzi NRW Analysis

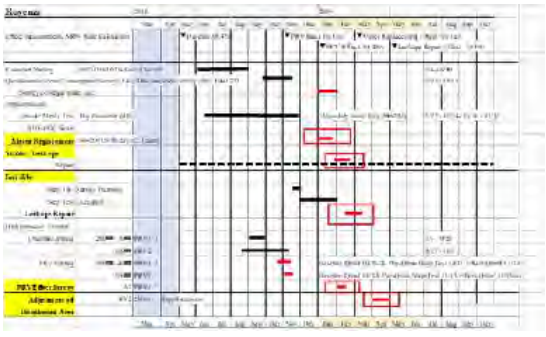
DMA Number	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
												19/02/12	
Input Volume (m3/M)	58,710	51,769	49,484	56,814	50,826	37,437	40,226	47,153	47,161	51,242	48,539	47,923	49,026
IVave.		53,321	52,689	52,375	48,359	42,830	41,605	44,847	48,519	48,981	49,235	48,496	
RY1	36,506	31,146	31,752	40,144	35,550	20,439	25,125	27,140	31,371	34,239	30,247	27,636	33,465
		33,135	34,347	35,815	32,044	27,038	24,235	27,879	30,917	31,952	30,707	30,449	
RY2	12,330	12,070	8,930	8,090	7,290	9,340	7,420	10,750	7,720	7,940	8,790	10,510	6,220
		11,110	9,697	8,103	8,240	8,017	9,170	8,630	8,803	8,150	9,080	8,507	
RY3	9,874	8,553	8,802	8,580	7,986	7,658	7,681	9,263	8,070	9,063	9,502	9,777	9,341
		9,076	8,645	8,456	8,075	7,775	8,201	8,338	8,799	8,878	9,447	9,540	
Billed Water (m3/M)	21,384	17,255	19,166	17,319	14,745	17,530	20,920	23,830	20,559	20,593	16,441	20,318	23,271
BWave.		19,268	17,913	17,077	16,531	17,732	20,760	21,770	21,661	19,198	19,117	20,010	
RY1	13,944	11,593	12,596	11,648	8,909	11,077	13,453	15,831	13,692	12,221	10,833	12,510	14,012
		12,711	11,946	11,051	10,545	11,146	13,454	14,325	13,915	12,249	11,855	12,452	
RY2	2,894	2,095	2,659	2,539	1,984	2,848	2,999	2,757	2,404	2,871	1,909	2,920	3,555
		2,549	2,431	2,394	2,457	2,610	2,868	2,720	2,677	2,395	2,567	2,795	
RY3	4,546	3,567	3,911	3,132	3,852	3,605	4,468	5,242	4,463	5,501	3,699	4,888	5,704
		4,008	3,537	3,632	3,530	3,975	4,438	4,724	5,069	4,554	4,696	4,764	
NRW (m3/M)	37,326	34,514	30,318	39,495	36,081	19,907	19,306	23,323	26,602	30,649	32,098	27,605	25,755
NRWave.		34,053	34,776	35,298	31,828	25,098	20,845	23,077	26,858	29,783	30,117	28,486	
RY1	22,562	19,553	19,156	28,496	26,641	9,362	11,672	11,309	17,679	22,018	19,414	15,126	19,453
		20,424	22,402	24,764	21,500	15,892	10,781	13,553	17,002	19,704	18,853	17,998	
RY2	9,436	9,975	6,271	5,551	5,306	6,492	4,421	7,993	5,316	5,069	6,881	7,590	2,665
		8,561	7,266	5,709	5,783	5,406	6,302	5,910	6,126	5,755	6,513	5,712	
RY3	5,328	4,986	4,891	5,448	4,134	4,053	3,213	4,021	3,607	3,562	5,803	4,889	3,637
		5,068	5,108	4,824	4,545	3,800	3,762	3,614	3,730	4,324	4,751	4,776	
NRW ratio (%)	63.6%	66.7%	61.3%	69.5%	71.0%	53.2%	48.0%	49.5%	56.4%	59.8%	66.1%	57.6%	52.5%
NRWRave.		63.8%	65.8%	67.3%	64.6%	57.4%	50.2%	51.3%	55.2%	60.8%	61.2%	58.8%	
RY1	61.8%	62.8%	60.3%	71.0%	74.9%	45.8%	46.5%	41.7%	56.4%	64.3%	64.2%	54.7%	58.1%
		61.6%	64.7%	68.8%	63.9%	55.7%	44.6%	48.2%	54.1%	61.6%	61.1%	59.0%	
RY2	76.5%	82.6%	70.2%	68.6%	72.8%	69.5%	59.6%	74.4%	68.9%	63.8%	78.3%	72.2%	42.8%
		76.5%	73.8%	70.5%	70.3%	67.3%	67.8%	67.6%	69.0%	70.3%	71.4%	64.4%	
RY3	54.0%	58.3%	55.6%	63.5%	51.8%	52.9%	41.8%	43.4%	44.7%	39.3%	61.1%	50.0%	38.9%
		55.9%	59.1%	56.9%	56.1%	48.8%	46.1%	43.3%	42.5%	48.4%	50.1%	50.0%	
POC	1,529	1,593	1,671	1,670	1,680	1,668	1,655	1,642	1,709	1,677	1,688	1,701	1,719
POCave.		1,598	1,645	1,674	1,673	1,668	1,655	1,669	1,676	1,691	1,689	1,703	
RY1	945	998	1,031	1,034	1,036	1,037	1,031	1,038	1,049	1,036	1,038	1,046	1,060
		991	1,021	1,034	1,036	1,035	1,035	1,039	1,041	1,041	1,040	1,048	
RY2	226	231	238	232	238	236	232	233	242	238	236	238	243
		232	234	236	235	235	234	236	238	239	237	239	
RY3	358	364	402	404	406	395	392	371	418	403	414	417	416
		375	390	404	402	398	386	394	397	412	411	416	
NRW/POC	24.4	21.7	18.1	23.6	21.5	11.9	11.7	14.2	15.6	18.3	19.0	16.2	15.0
NRW/POCave		21.4	21.2	21.1	19.0	15.0	12.6	13.8	16.0	17.6	17.8	16.7	
RY1	99.8	84.6	80.5	122.8	111.9	39.7	50.3	48.5	73.1	92.5	82.3	63.6	80.1
		88.3	96.0	105.1	91.5	67.3	46.2	57.3	71.4	82.6	79.4	75.3	
RY2	41.8	43.2	26.3	23.9	22.3	27.5	19.1	34.3	22.0	21.3	29.2	31.9	11.0
		37.1	31.2	24.2	24.6	23.0	27.0	25.1	25.9	24.1	27.4	24.0	
RY3	14.9	13.7	12.2	13.5	10.2	10.3	8.2	10.8	8.6	8.8	14.0	11.7	8.7
		13.6	13.1	11.9	11.3	9.5	9.8	9.2	9.4	10.5	11.5	11.5	





Work Schedule





Progress of the Pilot Projects

May 15, 2019

Evaluation of Project Activity

1. Trends in NRW Rate Reduction
2. Trends in the Number of Leakage Repair
3. Trends in Qmnf Reduction
4. Effect of Meter Replacement
5. Cost Benefit Analysis
6. Activity with High Priority for NRW Reduction

1. Trends in NRW Rate Reduction

✓**Base Line Value of NRW Rate**

Kadobogo : 37% (Average of June and July, 2017)

Ruyenzi : 68% (Average of March and April, 2018)

✓**The Targeted Value of NRW Rate**

Kadobogo : 20%

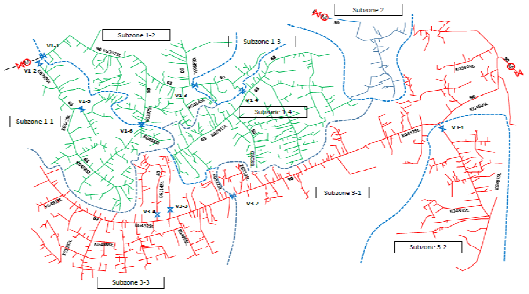
Ruyenzi : 25%

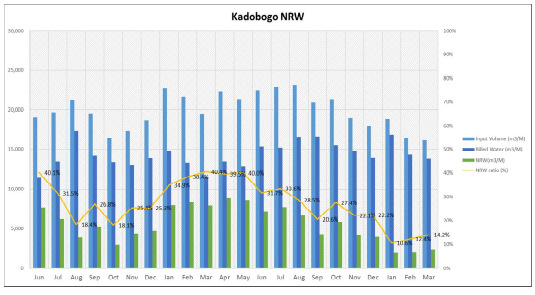
✓ **As of March 2018**

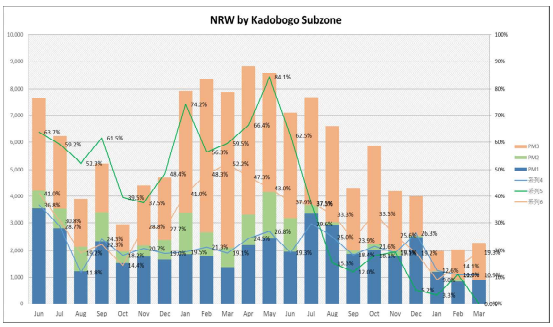
Kadobogo : 14.2% (PM1:10.9, PM2: ≒0.0, PM3:19.3)

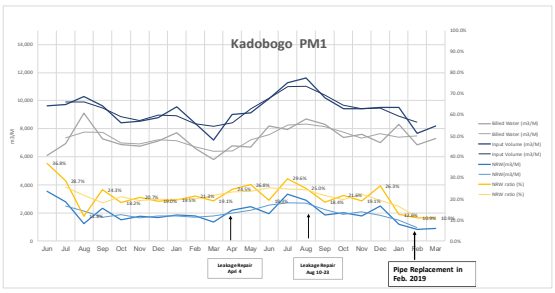
Ruyenzi : 53.4% (RY1:51.3, RY2:54.4, RY3:58.5)

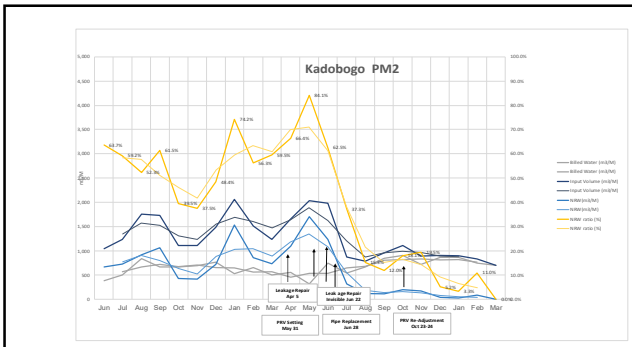
Kadobogo Subzone Map

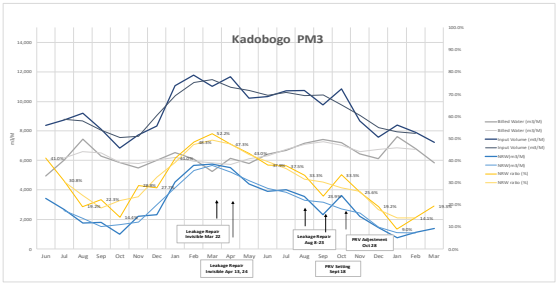


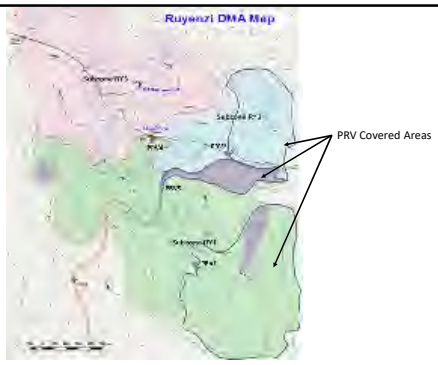


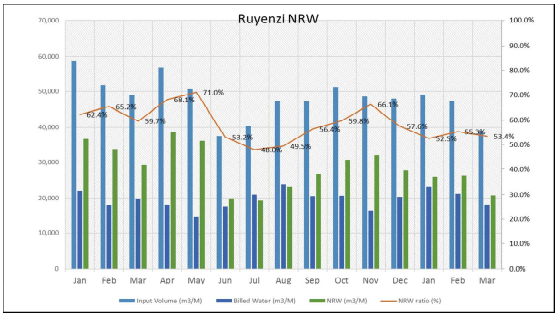


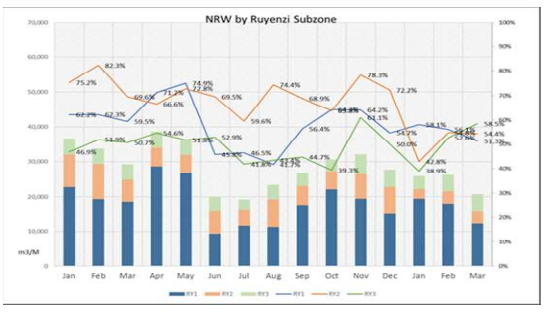

Kadobogo PM1
Leakage Repair Apr 4
Leakage Repair Aug 12-21
Pipe Replacement in Feb. 2019

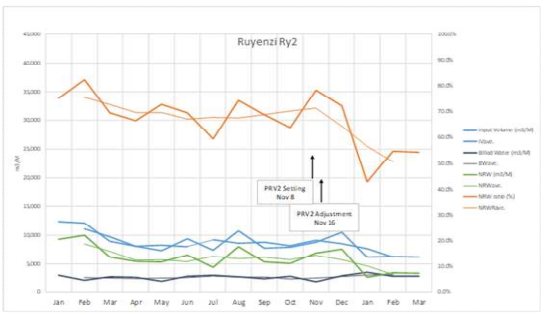

Kadobogo PM2
Leakage Repair Apr 5
Leak age Repair Invisible Jun 22
PRV Setting May 31
Pipe Replacement Jun 28
PRV Re-Adjustment Oct 23-24

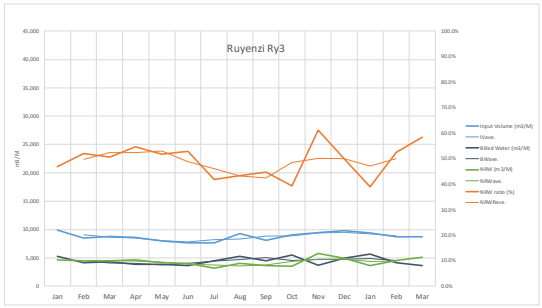

Kadobogo PM3
Leakage Repair Invisible Mar 22
Leakage Repair Invisible Apr 15, 24
Leakage Repair Aug 8-24
PRV Adjustment Oct 23
PRV Setting Sept 18


Ruyenzi DMA Map
PRV Covered Areas


Ruyenzi NRW
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
Input Volume (m3/M)
Billed Water (m3/M)
NRW (m3/M)
NRW ratio (%)


NRW by Ruyenzi Subzone
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar
m3/M



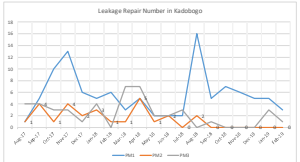


2. Trends in the number of Leakage Repair

Kadobogo Pilot Area

Leakage Repair Number

Month	PM1	PM2	PM3	Total	Note
Jun-17	n/a	n/a	n/a	2	
Feb-17	n/a	n/a	n/a	13	
Mar-17	n/a	n/a	n/a	3	
Apr-17	n/a	n/a	n/a	6	
May-17	n/a	n/a	n/a	15	
Jun-17	n/a	n/a	n/a	8	Baseline
Jul-17	n/a	n/a	n/a	9	Baseline
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	2	0	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	5	0	3	8	
Feb-19	3	0	1	4	
Total	107	27	45	179	
Average	5.6	1.4	2.4	9.4	
Before Sept. 2018	5.8	1.9	2.9	10.6	
After Oct. 2018	5.2	0.0	0.8	6.0	

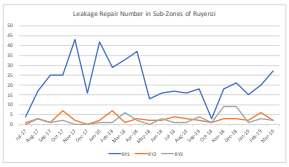


Kadobogo

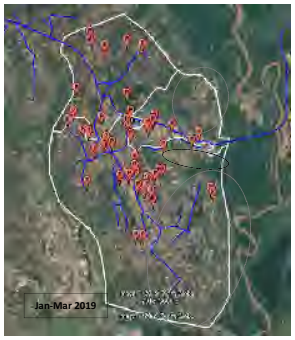
Ruyenzi Pilot Area

Leakage Repair Number

	RY1	RY2	RY3	Total	Note
Jun-17	n/a	n/a	n/a	42	
Feb-17	n/a	n/a	n/a	53	
Mar-17	n/a	n/a	n/a	43	
Apr-17	n/a	n/a	n/a	38	
May-17	n/a	n/a	n/a	30	
Jun-17	n/a	n/a	n/a	32	
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	Baseline
Apr-18	37	3	2	42	Baseline
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	20	6	3	29	
Mar-19	27	2	2	31	
Total	455	56	51	585	
Average	21.7	2.7	2.4	27.9	
Before Oct. 2018	22.1	2.5	1.7	27.8	
After Nov. 2018	20.2	3.2	4.8	28.2	



Ruyenzi



3. Trends in Qmnf Reduction

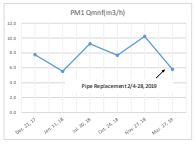
Qmnf Trend

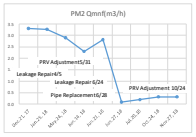
Kadobogo

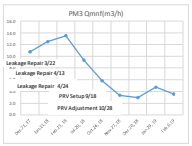
PM1	Qmnf (m3/h)	P (bar)
Dec. 21, 17	7.8	-
Jan. 11, 18	8.5	10.5
Jul. 20, 18	8.2	
Oct. 24, 18	7.7	10.0
Nov. 27, 18	10.2	10.0
Mar. 27, 19	5.8	8.5

PM2	Qmnf (m3/h)	P (bar)
Dec. 21, 17	3.3	2.0
Jan.25, 18	3.3	
May. 24, 18	2.8	
Jun.14, 18	2.3	4.0
Jun.21, 18	2.8	
Jun.27, 18	0.1	
Jul.20,18	0.2	
Oct.24, 18	0.3	2.5
Nov. 27, 18	0.3	2.5

PM3	Qmnf (m3/h)	P (bar)
Dec. 21, 17	10.0	9.0
Jan.11,18	12.5	
Feb.23, 18	13.5	7.5
Jul.20, 18	9.3	
Oct.24, 18	5.0	8.5
Nov. 27, 18	5.5	2.5
Dec. 20, 18	2.9	2.5
Jan.29, 19	4.7	
Feb.6,19	3.5	





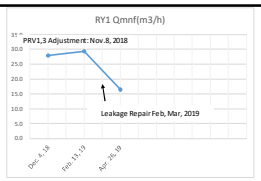


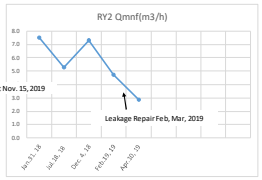
Ruyenzi

RY1	Qmnf (m3/h)	P (bar)
Dec. 4, 18	27.9	
Feb. 13, 19	29.4	
Apr. 26, 19	16.4	

RY2	Qmnf (m3/h)	P (bar)
Jan.31. 18	7.5	
Jul.18, 18	5.3	
Dec. 4, 18	7.3	
Feb.19, 19	4.7	
Apr. l0, 19	2.9	

PRV Adjustment Nov. 15, 2019





Effect of Pressure Management by PRV

Kadobogo (Measurement in Oct. 2018)

Item	PM2	PM3
1. Baseline (Qmnf)	0.74m3/h (7.0bar)	9.44m3/h (7.5bar)
2. Setting Pressure of P2	2.5bar	2.0bar
3. Effect Measurement (Qmnf)	0.31m3/h	5.80m3/h
4. Reduction of Qmnf	0.43m3/h (58%)	3.64m3/h (39%)

Ruyenzi (Measurement in Oct. Nov. 2018)

Item	PRV1	PRV3	PRV2
1. Baseline (Qmnf)	7.48 m3/h (9.1bar)	1.84 m3/h (4.0bar)	3.74m3/h (8.7bar)
2. Setting Pressure of P2	2.5bar	1.0bar	6.0bar
3. Effect Measurement (Qmnf)	1.50 m3/h	0.78 m3/h	2.60 m3/h
4. Reduction of Qmnf	5.98 m3/h (80%)	1.06 m3/h (58%)	1.14 m3/h (30%)

Effect of Pipe Replacement

Kadobogo PM1

Item	PM1-3, -4	Rate
1. Baseline (Qmnf)	5.38 m3/h	100%
2. Effect Measurement (Qmnf)	3.10 m3/h	58%
3. Reduction of Qmnf	2.28 m3/h	42%

PRV Effect Measurement in Sub-Zone RY1 of Ruyenzi

Area A2

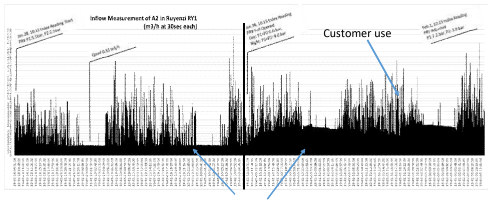
Effect Measurement Survey of PRV1 in A2 of Ruyenzi RY1

Year 2019	1/28	1/29	1/30	1/31	2/1
	Mon	Tue	Wed	Thu	Fri
PRV Pressure P2 (bar)	2.5		Full open: Day 6.0 Night 9.0		Adjust. 3.0
Flow Meter Setting/Off	●				●
Customer Meter Index Reading	●	●	●	●	●

No	POC	Customer Meter Index										Term1	Term2
		1/28	Index	1/29	Index	1/30	Index	1/31	Index	2/1	Index	1/28-1/30	1/30-2/1
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
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
17	240215973	10:31	136.4575		136.4575		136.4575		136.4575		136.4575		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
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
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
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
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
											Consumption (m3)	11.1921	12.1959
											Inflow (m3)	27.216	52.673
											NRW (m3)	16.0239	40.4771
											NRW Rate (%)	58.9%	76.8%
											Qmnf(m3/h)	0.330	0.830
											Qmnf 2days(m3)	15.840	39.840
											Meter Error (m3)	0.1839	0.6371
											Commercial Loss(%)	0.7%	1.2%
											Physical Loss(%)	58.2%	75.6%

Inflow Record of DMA A2

PRV Pressure setting for 2 days, PRV full open for 2days



Result of PRV Effect Measurement in A2

Items	Before Term1 (2days)	After Term2 (2days)
PRV P2 Pressure (bar)	2.5	6.0 - 9.0
Inflow (m3)	27.22	52.67
Consumption (m3)	11.19	12.20
NRW (m3)	16.02	40.48
NRW Rate (%)	58.9%	76.8%
Commercial Loss(%)	0.7%	1.2%
Physical Loss(%)	58.2%	75.6%

4. Effect of Meter Replacement

Kadobogo

- On-site Meter Test   Sep. 2017- Dec. 2017
- Meter Replacement   Oct. 2017 - Sep. 2018
  (mainly Dec. 2017- Apr. 2018)

Ruyenzi

- On-site Meter Test   Sep. 2018 - Nov. 2018
- Meter Replacement   Dec. 2018 - Jan. 2019

Effect of Meter Replacement

Result of On-site Meter Test

Kadobogo

Meter Error Tested					Defected	Total Surveyed
Intolerable			Tolerable	Total		
<-5%	5%<	Sub Total				
149	90	239	845	1,084	88	1,172
13%	8%	20%	72%	92%	8%	100%

Ruyenzi

Meter Error Tested					Defected	Total Surveyed
Intolerable			Tolerable	Total		
<-5%	5%<	Sub Total				
46	40	86	321	407	6	413
11%	10%	21%	78%	99%	1%	100%

Note: Big customer w hoses billing is more than 20m3/month in June, July & August, 2018

Improvement Ratio of Meter Error

Kadobogo

Item	Before Replacement	After Replacement	Improvement
Tested Meter	1084	845	
Replaced Meter	-	239	
Meter Total	1084	1084	
Total Error %	-1,508.21	-749.54	
Average Error %	-1.39	-0.69	0.70

Note: Error of the replaced meter is assumed as zero
Consumption volume of every customer is assumed same

Ruyenzi

Item	Before Replacement	After Replacement	Improvement
Tested Meter	332	246	
Replaced Meter	-	86	
Meter Total	332	332	
Total Error %	-79.46	-143.77	
Average Error %	-0.24	-0.43	-0.19

Note: Error of the replaced meter is assumed as zero
Consumption volume of every customer is assumed same

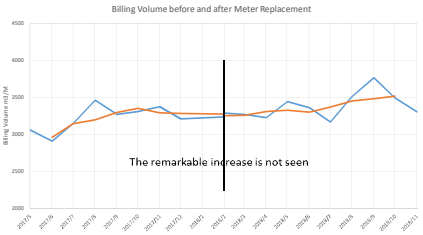
Meter replacement Effect Kadobogo

May, 2018

Item	Present	Effect	Effect
		x 0.007	0.70%
Billing (m3)	12,822	12,912	90
Inflow (m3)	21,373	21,373	
RW Rate (%)	60.0%	60.4%	0.4%
NRW Rate (%)	40.0%	39.6%	-0.4%

Effect of Meter Replacement

Adjusted the replaced month to same Feb. 2018



Kadobogo

2016/10	2016/11	2016/12	2017/1	2017/2	2017/3	2017/4	2017/5	2017/6	2017/7	2017/8	2017/9	2017/10	2017/11	2017/12	2018/1	2018/2	2018/3	2018/4	2018/5	2018/6	2018/7	2018/8	2018/9	2018/10	2018/11	2018/12
39	23	24	38	0	0	22	17	14	14	13	10	13	14	13	13	18	14	13	10	13	14	13	13	13	18	
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	13	12	14	7	10	12	8	28	10										
10	10	0	10	10	11	11	5	10	11	10	7	11	8	10	9	9										
0	30	7	8	0	0	0	10	0	0	0	0	0	0	20	0	25										
8	8	8	8	10	8	10	10	0	0	11	6	11	10	8	10	8										
64	44	36	38	36	29	30	39	47	36	31	38	54	39	42	23	22										
9	10	18	12	8	7	16	10	11	8	10	8	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	11	8	14	8	8	7	8	10	8										
13	0	8	18	20	20	20	20	13	16	0	38	15	16	20	20	16										
0	0	0	0	0	0	0	0	0	50	33	201	35	27	24	22	54										
0	0	8	18	0	30	13	0	0	0	0	0	0	0	0	0	0										
6	0	0	54	18	0	28	0	10	23	22	15	18	22	22	20	15										
14	9	8	9	16	19	19	9	11	9	11	9	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	19	18	12	15	12	14	14	13	18										
0	23	18	10	11	0	15	15	0	17	0	20	10	10	21	15	14										
9	10	16	10	11	11	13	10	11	6	8	13	12	8	10	11	9										
94	101	184	165	156	219	177	92	118	87	145	80	182	133	108	300	142										
23	19	23	25	20	17	17	21	20	18	19	18	20	17	20	22	22										
48	35	31	40	35	33	28	39	41	33	32	41	35	31	40	44	43										
0	14	0	0	0	8	4	7	8	6	6	8	5	2	8	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	20	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										

Monthly Average Billing Volume (m3/month)

Before Replacement	After Replacement	Increase Volume	Increase Ratio
3,314	3,334	20	0.60%

Meter Test Result

- ✓**The meter setting coverage rate of WASAC is high.**
- ✓**However the meter test and meter replacement were carried out with expending much worker and time, the NRW reduction effects was relatively small.**
- ✓**When there is the meter error of the plus side, it becomes the opposite effect for NRW reduction.**
- ✓**The replacement of the meter should be intended to maintain equitableness and fairness of the billing collection for the customer.**

Meter to be Replaced

✓**The meter which should be replaced or repaired are**

- **Defected meter**
- **Blocked meter**
- **Aged meter**

✓**About the following meter should be tested and it should be replaced if there is an error more than ±5%.**

- **Meter abnormality is found by the analysis of billing volume.**
- **When the customer make a complain about a billing amount.**

NRW? Caused by Zero Consumption

- Kadobogo : 5% of Inflow, 15% of POC
- Ruyenzi : 4% of Inflow, 17% of POC

(Average May 2018-Apr 2019)

Kadobogo

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

Ruyenzi

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

5. Cost Benefit Analysis

- ✓ Cost, Benefit: With Project – Without Project
- ✓ Evaluation Index of the Project Effect
  1. NPV: Net Present Value
  2. B/C: Cost Benefit Ratio (CBR)
- ✓ Discount Rate for the NPV calculation = 6.0%
  1. CPI Rwanda = 5.00% (average for the past 10 years)
  2. Interest Rate= 6.53%(ditto)
  3. Inflation= 3.82% (ditto)
- ✓ Evaluation Period : every 1 year

✓Project Effect

1. Water Charge of Selling of Surplus Water

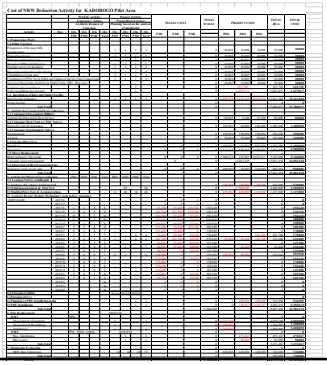
   Water charge unit price: Average of 2018

   Kacyiru Branch : 567 RWF

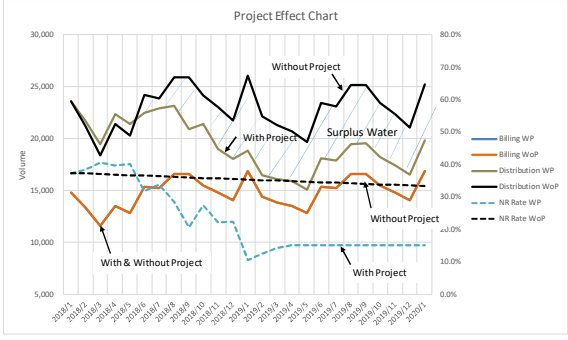
   Nyarugenge Branch: 592 RWF

2. Reduction of Production Cost

   Unit cost of production Nzove : 319 RWF



Cost of NRW Reduction Activities



Kadobogo Pilot Area

Without Project (WoP) — **2% decrease paer Year**

Year	Distribution	Production Cost②	Billing		NRW	
Month	Volume ①		Volume	Billing Price	Volume	Rate
	m3	Frw	m3	Frw		%
		319		567		
2018/1	23,549	7,512,018	14,765	8,371,755	8,784	37.3%
2018/2	21,237	6,774,606	13,351	7,570,017	7,886	37.1%
2018/3	18,370	5,859,917	11,579	6,565,293	6,791	37.0%
2018/4	21,359	6,813,578	13,499	7,653,933	7,860	36.8%
2018/5	20,235	6,454,842	12,822	7,270,074	7,413	36.6%
2018/6	24,145	7,702,193	15,340	8,697,780	8,805	36.5%
2018/7	23,823	7,599,411	15,175	8,604,225	8,648	36.3%
2018/8	25,899	8,261,867	16,541	9,378,747	9,358	36.1%
2018/9	25,916	8,267,264	16,595	9,409,365	9,321	36.0%
2018/10	24,137	7,699,726	15,496	8,786,232	8,641	35.8%
2018/11	22,981	7,330,888	14,792	8,387,064	8,189	35.6%
2018/12	21,694	6,920,455	14,000	7,938,000	7,694	35.5%
2019/1	25,991	8,291,042	16,816	9,534,672	9,175	35.3%
2019/2	22,149	7,065,375	14,367	8,146,089	7,782	35.1%
2019/3	21,272	6,785,822	13,834	7,843,878	7,438	35.0%

Note: NRW Baseline 37.3%

With Project (WP)

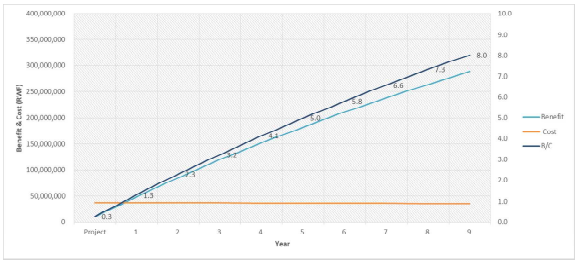
Year/ Month	Distribution		Billing		NRW		Project Effect		
	Volume ②	Production Cost②	Volume	Billing Price	Volume	Rate	Volume ③	Reduction of Production Cost	Selling of Surplus Water
							①-②	Volume③x319	Volume③x567
	m3	Frw	m3	Frw		%	m3	Frw	Frw
		319		567				319	567
2018/1	23,549	7,512,018	14,765	8,371,755	8,784	37.3%	0	0	0
2018/2	21,677	6,914,963	13,351	7,570,017	8,326	38.4%	-440	-140,357	-249,475
2018/3	19,439	6,201,041	11,579	6,565,293	7,860	40.4%	-1,069	-341,124	-606,324
2018/4	22,328	7,122,632	13,499	7,653,933	8,829	39.5%	-969	-309,054	-549,323
2018/5	21,373	6,817,987	12,822	7,270,074	8,551	40.0%	-1,138	-363,145	-645,465
2018/6	22,445	7,159,955	15,340	8,697,780	7,105	31.7%	1,700	542,238	963,790
2018/7	22,862	7,292,978	15,175	8,604,225	7,687	33.6%	961	306,433	544,664
2018/8	23,138	7,381,022	16,541	9,378,747	6,597	28.5%	2,761	880,845	1,565,640
2018/9	20,913	6,671,247	16,595	9,409,365	4,318	20.6%	5,003	1,596,017	2,836,808
2018/10	21,358	6,813,202	15,496	8,786,232	5,862	27.4%	2,779	886,524	1,575,734
2018/11	18,991	6,058,129	14,792	8,387,064	4,199	22.1%	3,990	1,272,759	2,262,239
2018/12	18,000	5,742,000	14,000	7,938,000	4,000	22.2%	3,694	1,178,455	2,094,620
2019/1	18,800	5,997,200	16,816	9,534,672	1,984	10.6%	7,191	2,293,842	4,077,142
2019/2	16,408	5,234,152	14,367	8,146,089	2,041	12.4%	5,741	1,831,223	3,254,869
2019/3	16,120	5,142,280	13,834	7,843,878	2,286	14.2%	5,152	1,643,542	2,921,279

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Unit:RWF — Discount Rate/% 6.0

	Year	Benefit			Cost			Effect of the Project (Accumulation)				Evaluation Period	10
		WP	WoP	WP	WP	WoP	Balance	Benefit	Cost	NPV	B/C	Conversion Factor	1/(1+i)^n
Project	2018/1-12	9,792,908	0	9,792,908	41,515,562	3,994,080	37,521,482	**9,792,908**	**37,521,482**	**-27,728,574**	**0.3**	0	1.000
1	2019/1-12	38,691,661	0	38,691,661	2,953,358	3,168,000	-214,642	**48,484,569**	**37,306,840**	**11,177,728**	**1.3**	1	0.943
2	2020/1-12	36,501,567	0	36,501,567	2,786,187	2,988,679	-202,492	**84,986,136**	**37,104,349**	**47,881,788**	**2.3**	2	0.890
3	2021/1-12	34,435,441	0	34,435,441	2,628,479	2,819,509	-191,030	**119,421,577**	**36,913,318**	**82,508,259**	**3.2**	3	0.840
4	2022/1-12	32,486,265	0	32,486,265	2,479,697	2,659,914	-180,217	**151,907,842**	**36,733,101**	**115,174,741**	**4.1**	4	0.792
5	2023/1-12	30,647,420	0	30,647,420	2,339,337	2,509,353	-170,016	**182,555,262**	**36,563,085**	**145,992,177**	**5.0**	5	0.747
6	2024/1-12	28,912,660	0	28,912,660	2,206,921	2,367,314	-160,393	**211,467,922**	**36,402,692**	**175,065,229**	**5.8**	6	0.705
7	2025/1-12	27,276,094	0	27,276,094	2,082,001	2,233,315	-151,314	**238,744,016**	**36,251,379**	**202,492,638**	**6.6**	7	0.665
8	2026/1-12	25,732,165	0	25,732,165	1,964,152	2,106,901	-142,749	**264,476,181**	**36,108,630**	**228,367,551**	**7.3**	8	0.627
9	2027/1-12	24,275,627	0	24,275,627	1,852,974	1,987,642	-134,669	**288,751,808**	**35,973,961**	**252,777,847**	**8.0**	9	0.592

Act. Cost: NRW Reduction Activity Cost
9,792,908 RWF: Sum of Feb. 2018- Dec. 2018
38,691,661 RWF: Average of Ja. 2019-March 2019 x 12 month x Conversion Factor
Repair 25,440 RWF/Place
WP: Repair 24 places/year x 25,440= 610,560
WP: Qmnf. Step Test 12 timed/year x 210,000= 2,520,000
Total 3,130,560
WoP: Repair 132 places/year x 25,440 = 3,358,080

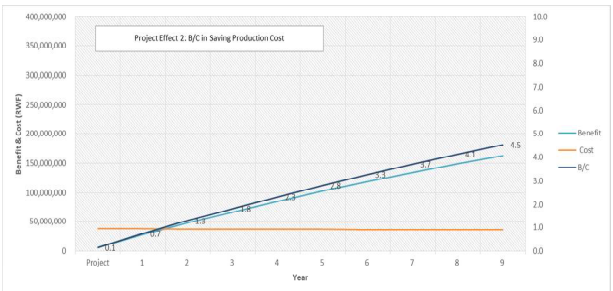


Project Effect 2: Saving of Production Cost by NRW Reduction Activity

Unit:RWF

	Year	Benefit			Cost			Effect of the Project (Accumulation)			
		WP	WoP	WP	WP	WoP	Balance	Benefit	Cost	NPV	B/C
Project	2018/1-12	5,509,590	0	5,509,590	41,515,562	3,994,080	37,521,482	**5,509,590**	**37,521,482**	**-32,011,892**	**0.1**
1	2019/1-12	21,768,324	0	21,768,324	2,953,358	3,168,000	-214,642	**27,277,914**	**37,306,840**	**-10,028,926**	**0.7**
2	2020/1-12	20,536,155	0	20,536,155	2,786,187	2,988,679	-202,492	**47,814,070**	**37,104,349**	**10,709,721**	**1.3**
3	2021/1-12	19,373,731	0	19,373,731	2,628,479	2,819,509	-191,030	**67,187,801**	**36,913,318**	**30,274,482**	**1.8**
4	2022/1-12	18,277,105	0	18,277,105	2,479,697	2,659,914	-180,217	**85,464,906**	**36,733,101**	**48,731,805**	**2.3**
5	2023/1-12	17,242,552	0	17,242,552	2,339,337	2,509,353	-170,016	**102,707,458**	**36,563,085**	**66,144,373**	**2.8**
6	2024/1-12	16,266,558	0	16,266,558	2,206,921	2,367,314	-160,393	**118,974,016**	**36,402,692**	**82,571,324**	**3.3**
7	2025/1-12	15,345,810	0	15,345,810	2,082,001	2,233,315	-151,314	**134,319,826**	**36,251,379**	**98,068,447**	**3.7**
8	2026/1-12	14,477,179	0	14,477,179	1,964,152	2,106,901	-142,749	**148,797,005**	**36,108,630**	**112,688,375**	**4.1**
9	2027/1-12	13,657,716	0	13,657,716	1,852,974	1,987,642	-134,669	**162,454,721**	**35,973,961**	**126,480,760**	**4.5**

Act. Cost: NRW Reduction Activity Cost
5,509,590 Frw: Sum of Feb. 2018- Dec. 2018
21,768,324 Frw: Average of Ja. 2019-March 2019 x 12 month



Individual Activity

Monthly Effect of the Individual Activity

Activity	Qmnf Effect	Appearance of the Effect		
	m3/h	Month	NPV (RWF)	B/C
Kadobogo				
Pipe Replacement				
PM1	2.28	8th	1,186,196	1.2
PRV Setup				
PM2	0.43	6th	258,324	1.3
PM3	3.64	2nd	1,177,220	1.7
Ruyenzi				
PRV Setup				
PRV1	5.98	1st	342,168	1.2
PRV2	1.14	10th	308,829	1.1
PRV3	1.06	3rd	373,155	1.4

Kadobogo Pilot Area
Pipe Replacement in PM1

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Replacement	0	6,710,100	50,000	6,660,100	0	6,660,100	-6,660,100	0.0
1	930,787	0	50,000	-50,000	930,787	6,610,100	-5,679,313	0.1
2	930,787	0	50,000	-50,000	1,861,574	6,560,100	-4,698,526	0.3
3	930,787	0	50,000	-50,000	2,792,361	6,510,100	-3,717,739	0.4
4	930,787	0	50,000	-50,000	3,723,148	6,460,100	-2,736,952	0.6
5	930,787	0	50,000	-50,000	4,653,935	6,410,100	-1,756,165	0.7
6	930,787	0	50,000	-50,000	5,584,722	6,360,100	-775,378	0.9
7	930,787	0	50,000	-50,000	6,515,509	6,310,100	205,409	1.0
8	930,787	0	50,000	-50,000	7,446,296	6,260,100	1,186,196	1.2
9	930,787	0	50,000	-50,000	8,377,083	6,210,100	2,166,983	1.3
10	930,787	0	50,000	-50,000	9,307,870	6,160,100	3,147,770	1.5
11	930,787	0	50,000	-50,000	10,238,657	6,110,100	4,128,557	1.7
12	930,787	0	50,000	-50,000	11,169,444	6,060,100	5,109,344	1.8

Repair 1 places/month: Without Project 50,000

Replacement Cost		6,710,100
Production Cost	Frw/m3	334
Water Price	Frw/m3	567
Qmnf(2019/2/6)	m3/h	5.38
Qmnf(2019/3/27)	m3/h	3.10
Surplus Qmnf	m3/h	2.28
Surplus Qmnf	m3/month	1,642
Selling Water	Frw/month	930,787
Production Cost Reduction	Frw/month	548,294

Kadobogo Pilot Area
PRV PM2

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	1,144,935	50,000	1,094,935	0	1,094,935	-1,094,935	0.0
1	175,543	0	50,000	-50,000	175,543	1,044,935	-869,392	0.2
2	175,543	0	50,000	-50,000	351,086	994,935	-643,849	0.4
3	175,543	0	50,000	-50,000	526,630	944,935	-418,305	0.6
4	175,543	0	50,000	-50,000	702,173	894,935	-192,762	0.8
5	175,543	0	50,000	-50,000	877,716	844,935	32,781	1.0
6	175,543	0	50,000	-50,000	1,053,259	794,935	258,324	1.3
7	175,543	0	50,000	-50,000	1,228,802	744,935	483,867	1.6
8	175,543	0	50,000	-50,000	1,404,346	694,935	709,411	2.0
9	175,543	0	50,000	-50,000	1,579,889	644,935	934,954	2.4
10	175,543	0	50,000	-50,000	1,755,432	594,935	1,160,497	3.0
11	175,543	0	50,000	-50,000	1,930,975	544,935	1,386,040	3.5
12	175,543	0	50,000	-50,000	2,106,518	494,935	1,611,583	4.3

Repair 1 places/month: Without Project 50,000

Installation Cost		1,144,935
Production Cost	Frw/m3	334.00
Water Price	Frw/m3	567.00
Effect Qmnf	m3/h	0.43
Effect Qmnf	m3/month	310
Selling Water	Frw/mont	175,543
Production Cost Reduction	Frw/mont	103,406

Kadobogo Pilot Area
PRV PM3

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	1,944,767	50,000	1,894,767	0	1,894,767	-1,894,767	0.0
1	1,485,994	0	50,000	-50,000	1,485,994	1,844,767	-358,773	0.8
2	1,485,994	0	50,000	-50,000	2,971,987	1,794,767	1,177,220	1.7
3	1,485,994	0	50,000	-50,000	4,457,981	1,744,767	2,713,214	2.6
4	1,485,994	0	50,000	-50,000	5,943,974	1,694,767	4,249,207	3.5
5	1,485,994	0	50,000	-50,000	7,429,968	1,644,767	5,785,201	4.5
6	1,485,994	0	50,000	-50,000	8,915,962	1,594,767	7,321,195	5.6
7	1,485,994	0	50,000	-50,000	10,401,955	1,544,767	8,857,188	6.7
8	1,485,994	0	50,000	-50,000	11,887,949	1,494,767	10,393,182	8.0
9	1,485,994	0	50,000	-50,000	13,373,942	1,444,767	11,929,175	9.3
10	1,485,994	0	50,000	-50,000	14,859,936	1,394,767	13,465,169	10.7
11	1,485,994	0	50,000	-50,000	16,345,930	1,344,767	15,001,163	12.2
12	1,485,994	0	50,000	-50,000	17,831,923	1,294,767	16,537,156	13.8

Repair 1 places/month: Without Project 50,000

Installation Cost		1,944,767
Production Cost	Frw/m3	334.00
Water Price	Frw/m3	567.00
Effect Qmnf	m3/h	3.64
Effect Qmnf	m3/month	2,621
Selling Water	Frw/month	1,485,994
Production Cost Reduction	Frw/month	875,347

Ruyenzi Pilot Area
PRV1

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit	NRW Reduction Activity Cost			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit	Cost	NPV	B/C
Installation	0	2,199,107	50,000	2,149,107	0	2,149,107	-2,149,107	0.0
1	2,441,275	0	50,000	-50,000	2,441,275	2,099,107	342,168	1.2
2	2,441,275	0	50,000	-50,000	4,882,550	2,049,107	2,833,443	2.4
3	2,441,275	0	50,000	-50,000	7,323,826	1,999,107	5,324,719	3.7
4	2,441,275	0	50,000	-50,000	9,765,101	1,949,107	7,815,994	5.0
5	2,441,275	0	50,000	-50,000	12,206,376	1,899,107	10,307,269	6.4
6	2,441,275	0	50,000	-50,000	14,647,651	1,849,107	12,798,544	7.9
7	2,441,275	0	50,000	-50,000	17,088,926	1,799,107	15,289,819	9.5
8	2,441,275	0	50,000	-50,000	19,530,202	1,749,107	17,781,095	11.2
9	2,441,275	0	50,000	-50,000	21,971,477	1,699,107	20,272,370	12.9
10	2,441,275	0	50,000	-50,000	24,412,752	1,649,107	22,763,645	14.8
11	2,441,275	0	50,000	-50,000	26,854,027	1,599,107	25,254,920	16.8
12	2,441,275	0	50,000	-50,000	29,295,302	1,549,107	27,746,195	18.9

Repair 1 places/month: Without Project 50,000

Installation Cost		2,199,107
Water Price	Frw/m3	567.00
Production Cost	Frw/m3	319.00
Effect Qmnf(2018/10/24)	m3/h	5.98
Effect Qmnf(2018/10/24)	m3/month	4,306
Selling Water	Frw/month	2,441,275
Production Cost Reduction	Frw/month	1,373,486
Leakage Repair WoP	Times/Month	1
Leakage Repair WP	Times/Month	0

Ruyenzi Pilot Area
PRV2

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	4,895,107	50,000	4,845,107	0	4,845,107	-4,845,107	0.0
1	465,394	0	50,000	-50,000	465,394	4,795,107	-4,329,713	0.1
2	465,394	0	50,000	-50,000	930,787	4,745,107	-3,814,320	0.2
3	465,394	0	50,000	-50,000	1,396,181	4,695,107	-3,298,926	0.3
4	465,394	0	50,000	-50,000	1,861,574	4,645,107	-2,783,533	0.4
5	465,394	0	50,000	-50,000	2,326,968	4,595,107	-2,268,139	0.5
6	465,394	0	50,000	-50,000	2,792,362	4,545,107	-1,752,745	0.6
7	465,394	0	50,000	-50,000	3,257,755	4,495,107	-1,237,352	0.7
8	465,394	0	50,000	-50,000	3,723,149	4,445,107	-721,958	0.8
9	465,394	0	50,000	-50,000	4,188,542	4,395,107	-206,565	1.0
10	465,394	0	50,000	-50,000	4,653,936	4,345,107	308,829	1.1
11	465,394	0	50,000	-50,000	5,119,330	4,295,107	824,223	1.2
12	465,394	0	50,000	-50,000	5,584,723	4,245,107	1,339,616	1.3

Repair 1 places/month: Without Project 50,000

Installation Cost		4,895,107
Production Cost	Frw/m3	334.00
Water Price	Frw/m3	567.00
Effect Qmnf	m3/h	1.14
Effect Qmnf	m3/month	821
Selling Water	Frw/month	465,394
Production Cost Reduction	Frw/month	274,147

Project Effect 1: Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	1,125,048	50,000	1,075,048	0	1,075,048	-1,075,048	0.0
1	432,734	0	50,000	-50,000	432,734	1,025,048	-592,314	0.4
2	432,734	0	50,000	-50,000	865,469	975,048	-109,579	0.9
3	432,734	0	50,000	-50,000	1,298,203	925,048	373,155	1.4
4	432,734	0	50,000	-50,000	1,730,938	875,048	855,890	2.0
5	432,734	0	50,000	-50,000	2,163,672	825,048	1,338,624	2.6
6	432,734	0	50,000	-50,000	2,596,406	775,048	1,821,358	3.3
7	432,734	0	50,000	-50,000	3,029,141	725,048	2,304,093	4.2
8	432,734	0	50,000	-50,000	3,461,875	675,048	2,786,827	5.1
9	432,734	0	50,000	-50,000	3,894,610	625,048	3,269,562	6.2
10	432,734	0	50,000	-50,000	4,327,344	575,048	3,752,296	7.5
11	432,734	0	50,000	-50,000	4,760,078	525,048	4,235,030	9.1
12	432,734	0	50,000	-50,000	5,192,813	475,048	4,717,765	10.9
Repair 1 places/month: Without Project			50,000					

Installation Cost		1,125,048
Production Cost	Frw/m3	334.00
Water Price	Frw/m3	567.00
Effect Qmnf	m3/h	1.06
Effect Qmnf	m3/mont	763
Selling Water	Frw/mon	432,734
Production Cost Reduction	Frw/mon	254,909

Result of Cost and Benefit Analysis

- ✓It was proved in the Pilot Project that the actions of high pressure reduction, pipe replacement and leakage repair are very effective for the cost recovery and for benefit expansion.
- ✓Reduction of high pressure should be performed before leakage repairs. Otherwise leakages repeat again.
- ✓The benefit exceeds cost from the second year and increases year by year as far as good management of pressure control is maintained.

6. Activity with High Priority for NRW Reduction

Result of the Pilot Activity

- High Pressure Management by PRV
- Replacement of Substandard Service Pipe and Distribution Pipe

↓

- High NRW Reduction Effect
- Preventive and Depression Effect to Leakage

Progress and Effect of the Pilot Project Activities

May 29, 2019

1. Trends in NRW Rate Reduction
2. Trends in the Number of Leakage Repair
3. Trends in Qmnf Reduction
4. Effect of Meter Replacement
5. Cost Benefit Analysis
6. Activity with High Priority for NRW Reduction

1. Trends in NRW Rate Reduction

Pilot Area	Kadobogo	Ruyenzi
Base Line	37%	68%
Target	20%	25%
As of Q3 (2018/19)	12%	54%

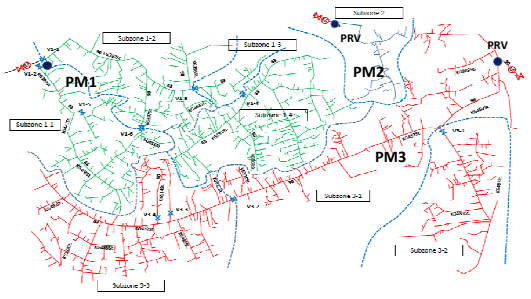
NRW Rate Calculation

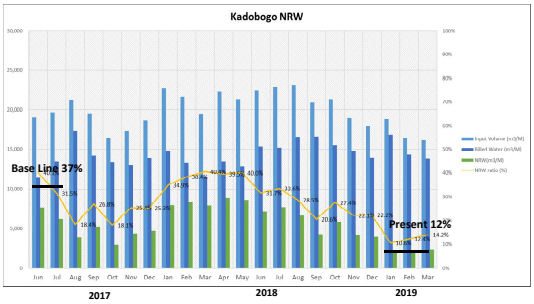
NRW Rate = Billing Amount /Flow Distribution Amount

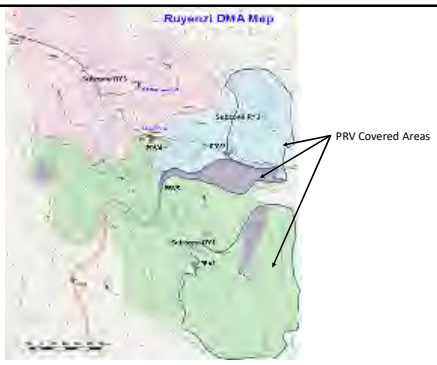
NRW Rate : calculated in DMA (District Metered Area)

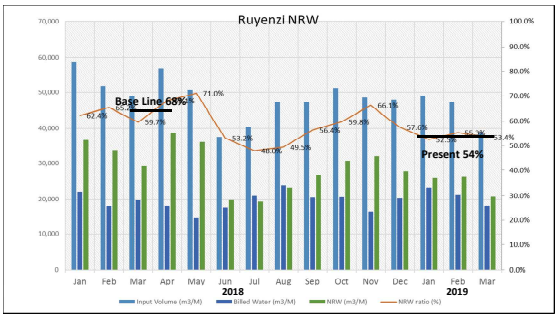
- Monthly Billing Data
  (Update at every month with New customer data)
- Monthly Measurement of Inlet flow

Kadobogo Subzone Map









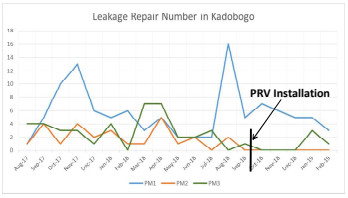
2. Trends in the number of Leakage Repair

Kadobogo

Kadobogo Pilot Area

Leakage Repair Number

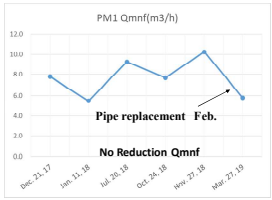
Month	PM1	PM2	PM3	Total
Aug-17	1	1	4	6
Sep-17	5	4	4	13
Oct-17	10	1	3	14
Nov-17	13	4	3	20
Dec-17	6	2	1	9
Jan-18	5	3	4	12
Feb-18	6	1	0	7
Mar-18	3	1	7	11
Apr-18	5	5	7	17
May-18	2	1	2	5
Jun-18	2	2	2	6
Jul-18	2	0	3	5
Aug-18	16	2	0	18
Sep-18	5	0	1	6
Oct-18	7	0	0	7
Nov-18	6	0	0	6
Dec-18	5	0	0	5
Jan-19	5	0	3	8
Feb-19	3	0	1	4
Total	107	27	45	179
Average	5.6	1.4	2.4	9.4
ept. 2018	5.8	1.9	2.9	10.6
Oct. 2018	5.2	0.0	0.8	6.0



3. Trends in Qmnf Reduction

Trend of Qmnf Reduction in PM1

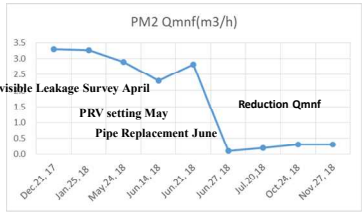
PM1	Qmnf (m3/h)	P (bar)
Dec. 21, 17	7.8	-
Jan. 11, 18	5.5	10.5
Jul. 20, 18	9.2	
Oct. 24, 18	7.7	10.0
Nov. 27, 18	10.2	10.0
Mar. 27, 19	5.8	6.5



No Installation of PRV in PM1 Kadobogo

Trend of Qmnf Reduction in PM2

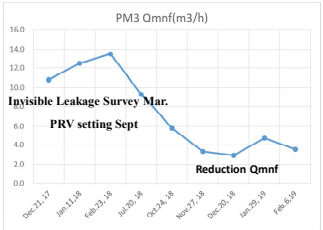
PM2	Qmnf (m3/h)	P (bar)
Dec.21, 17	3.3	2.0
Jan.25, 18	3.3	
May.24, 18	2.9	
Jun.14, 18	2.3	4.0
Jun.21, 18	2.8	
Jun.27, 18	0.1	
Jul.20,18	0.2	
Oct.24, 18	0.3	2.5
Nov.27, 18	0.3	2.5



Installation of PRV in PM2

Trend of Qmnf Reduction in PM3

PM3	Qmnf (m3/h)	P (bar)
Dec.21, 17	10.8	9.6
Jan.11,18	12.5	
Feb.23, 18	13.5	7.8
Jul.20, 18	9.3	
Oct.24, 18	5.8	5.5
Nov.27, 18	3.3	2.5
Dec.20, 18	2.9	2.5
Jan.29, 19	4.7	
Feb.6,19	3.5	



Installation of PRV in PM3

Effect of Pressure Management by PRV

Minimum Night Flow (Qmnf) Measurement

Kadobogo (Oct. 2018)

Qmnf Measurement	PM2		PM3	
	Pressure	Flow Rate	Pressure	Flow Rate
1. Baseline	7.0 bar	0.74 m3/h	7.5 bar	9.44 m3/h
2. Effect Measurement	2.5 bar	0.31 m3/h	2.0 bar	5.80 m3/h
3. Reduction Volume		0.43 m3/h		3.64 m3/h
4. Reduction Rate		58%		39%

Ruyenzi (Oct., Nov., 2018)

Qmnf Measurement	PRV1		PRV2		PRV3	
	Pressure	Flow Rate	Pressure	Flow Rate	Pressure	Flow Rate
1. Baseline	9.1bar	7.48 m3/h	8.7 bar	3.74 m3/h	4.0bar	1.84 m3/h
2. Effect Measurement	2.5 bar	1.50 m3/h	6.0bar	2.60 m3/h	0.8bar	0.78 m3/h
3. Reduction Volume		5.98 m3/h		1.14 m3/h		1.06 m3/h
4. Reduction Rate		80%		30%		58%

Effect of Pipe Replacement 800m, DN 1", DN3/4"

Minimum Night Flow (Qmnf) Measurement

Kadobogo PM1 (Feb. 2019)

Measurement	Flow Rate	Note
1. Baseline	5.38 m3/h	before replacement
2. Effect Measurement	3.10 m3/h	after replacement
3. Reduction Volume	2.28 m3/h	
4. Reduction Rate	42%	

Effect of PRV, Pipe Replacement and Leakage Repair

- ✓It was proved in the Pilot Project that the activity such as high pressure reduction, pipe replacement and leakage repair are very effective for the NRW reduction.
- ✓Reduction of high pressure should be performed before leakage repairs. Otherwise leakages repeat again.
- ✓To sustain the effect of pressure reduction, continuous monitoring of pressure and maintenance of PRV should be taken.

4. Effect of Meter Replacement

Kadobogo

- On-site Meter Test : Sep. 2017- Dec. 2017 (4 months)
- Meter Replacement: mainly Dec. 2017- Apr. 2018 (5 months)

Ruyenzi

- On-site Meter Test : Sep. 2018 - Nov. 2018 (3 months)
- Meter Replacement : Dec. 2018 - Jan. 2019 (2 months)

Result of On-site Meter Test

Kadobogo

Meter Error Tested					Defected	Total Surveyed
Intolerable			Tolerable	Total		
<-5%	5%<	Sub Total				
149	90	239	845	1,084	88	1,172
12%	8%	20%	72%	92%	8%	100%

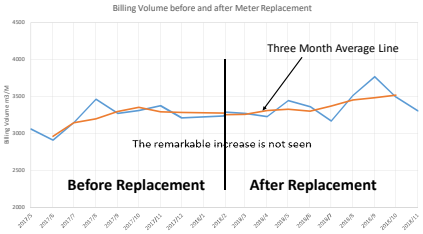
Ruyenzi

Meter Error Tested					Defected	Total Surveyed
Intolerable			Tolerable	Total		
<-5%	5%<	Sub Total				
46	40	86	321	407	6	413
11%	10%	21%	78%	99%	1%	100%

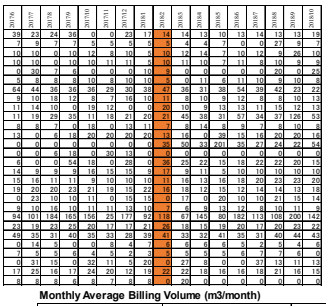
Note: Big customer whoses billing is more than 20m3/month in June, July & August, 2018

Effect of Meter Replacement

Adjusted the replaced month to same Feb. 2018



Kadobogo



This table shows a part of calculation sheet.

Monthly Average Billing Volume (m3/month)

Before Replacement	After Replacement	Increase Volume	Increase Ratio
3,314	3,334	20	0.60%

Meter Test Result

- ✓**The meter setting coverage rate of WASAC is high.**
- ✓**However the meter test and meter replacement were carried out with expending much worker and time, the NRW reduction effects was relatively small.**
- ✓**When there is the meter error of the plus side, it becomes the opposite effect for NRW reduction.**
- ✓**The replacement of the meter should be intended to maintain equitable service of the billing collection for the customer.**

Meter to be Replaced

- ✓**The meter which should be replaced or repaired are**
  - **Defected meter**
  - **Blocked meter**
  - **Aged meter**
- ✓**About the following meter should be tested and it should be replaced if there is an error more than ±5%.**
  - **Meter abnormality is found by the analysis of billing volume.**
  - **When the customer make a complain about a billing amount.**

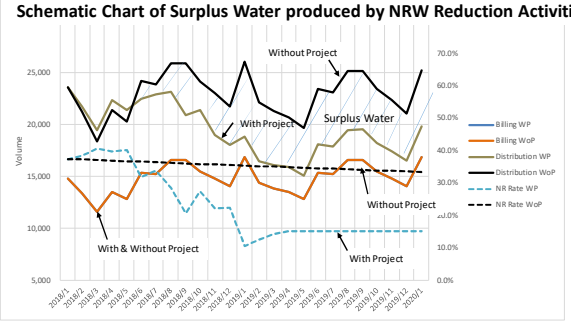
5. Cost Benefit Analysis

Conditions of the Analysis

- ✓ Cost, Benefit: With Project – Without Project
- ✓ Evaluation Index of the Project Effect
  1. NPV: Net Present Value
  2. B/C: Cost Benefit Ratio (CBR)
- ✓ Discount Rate for the NPV calculation = 6.0%
  1. CPI Rwanda = 5.00% (average for the past 10 years)
  2. Interest Rate= 6.53%(ditto)
  3. Inflation= 3.82% (ditto)
- ✓ Evaluation Period : every 1 year

- ✓Project Effect
  1. Water Charge of Selling of Surplus Water
     Water charge unit price: Average of 2018
     Kacyiru Branch : 567 RWF
     Nyarugenge Branch: 592 RWF
  2. Reduction of Production Cost
     Unit cost of production Nzove : 319 RWF

Schematic Chart of Surplus Water produced by NRW Reduction Activities



Without Meter Replacement

Project Effect Case 1-1
Selling of Surplus Water made by NRW Reduction Activities

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	9,792,908	37,521,482	-27,728,574	0.3
1	2019	48,484,569	37,306,840	11,177,728	1.3
2	2020	84,986,136	37,104,349	47,881,788	2.3
3	2021	119,421,577	36,913,318	82,508,259	3.2
4	2022	151,907,842	36,733,101	115,174,741	4.1
5	2023	182,555,262	36,563,085	145,992,177	5.0
10	2028	311,653,343	35,846,915	275,806,428	8.7

Cost Recovery Year

Project Effect Case 1-2
Saving of Production Cost by Deducting Surplus Water

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	5,509,590	37,521,482	-32,011,892	0.1
1	2019	27,277,914	37,306,840	-10,028,926	0.7
2	2020	47,814,070	37,104,349	10,709,721	1.3
3	2021	67,187,801	36,913,318	30,274,482	1.8
4	2022	85,464,906	36,733,101	48,731,805	2.3
5	2023	102,707,458	36,563,085	66,144,373	2.8
10	2028	175,339,359	35,846,915	139,492,444	4.9

With Meter Replacement

Project Effect Case 2-1
Selling of Surplus Water made by NRW Reduction Activities

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	9,792,908	60,572,920	-50,780,012	0.2
1	2019	48,484,569	60,358,278	-11,873,710	0.8
2	2020	84,986,136	60,155,787	24,830,350	1.4
3	2021	119,421,577	59,964,756	59,456,821	2.0
4	2022	151,907,842	59,784,539	92,123,303	2.5
5	2023	182,555,262	59,614,523	122,940,739	3.1
10	2028	311,653,343	58,898,353	252,754,990	5.3

Project Effect Case 2-2
Saving of Production Cost by Deducting Surplus Water

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	5,509,590	60,572,920	-55,063,330	0.1
1	2019	27,277,914	60,358,278	-33,080,364	0.5
2	2020	47,814,070	60,155,787	-12,341,717	0.8
3	2021	67,187,801	59,964,756	7,223,044	1.1
4	2022	85,464,906	59,784,539	25,680,367	1.4
5	2023	102,707,458	59,614,523	43,092,935	1.7
10	2028	175,339,359	58,898,353	116,441,006	3.0

Cost Recovery Period of Individual Activity

Kadobogo

Activity	Area	Cost Recovery Month			Qmnf Effect
		Month	NPV (RWF)	B/C	m3/h
Pipe Replacement	PM1	8th	1,186,196	1.2	2.28
PRV Setup	PM2	6th	258,324	1.3	0.43
	PM3	2nd	1,177,220	1.7	3.64

Ruyenzi

Activity	Area	Cost Recovery Month			Qmnf Effect
		Month	NPV (RWF)	B/C	m3/h
PRV Setup	PRV1	1st	342,168	1.2	5.98
	PRV2	10th	308,829	1.1	1.14
	PRV3	3rd	373,155	1.4	1.06

Result of Cost and Benefit Analysis

It was proved that the cost of activity such as high pressure reduction, pipe replacement and leakage repair were recovered in short period, and produce benefit expansion.

- ✓ Selling surplus water : from 1st year after project
- ✓ Saving production cost : from 2rd year after project

6. Activity with High Priority for NRW Reduction

Result of the High Priority Activity

- High Pressure Management by PRV
- Replacement of Substandard Service and Distribution Pipe

→ ✓High NRW Reduction Effect
✓Preventive and Minimize Effect to Leakage

- Customer Meter Routine Management

→ ✓Provision of Fair Service for the Customer
✓Maintain meters in proper condition

Murakoze Cyane!!

1.9 Cost and Benefit

Without Meter Replacement

Project Effect Case 1-1

Selling of Surplus Water made by NRW Reduction Activities

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	9,792,908	37,521,482	-27,728,574	0.3
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5	2023	182,555,262	36,563,085	145,992,177	5.0
10	2028	311,653,343	35,846,915	275,806,428	8.7

Project Effect Case 1-2

Saving of Production Cost by Deducting Surplus Water

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	5,509,590	37,521,482	-32,011,892	0.1
1	2019	27,277,914	37,306,840	-10,028,926	0.7
2	2020	47,814,070	37,104,349	10,709,721	1.3
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5	2023	102,707,458	36,563,085	66,144,373	2.8
10	2028	175,339,359	35,846,915	139,492,444	4.9

With Meter Replacement

Project Effect Case 2-1

Selling of Surplus Water made by NRW Reduction Activities

Year		Effect of the Project (RWF)			
		Benefit	Cost	NPV	B/C
Project	2018	9,792,908	60,572,920	-50,780,012	0.2
1	2019	48,484,569	60,358,278	-11,873,710	0.8
2	2020	84,986,136	60,155,787	24,830,350	1.4
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10	2028	311,653,343	58,898,353	252,754,990	5.3

Project Effect Case 2-2

Saving of Production Cost by Deducting Surplus Water

Year		Effect of the Project (RWF)			
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COST BENEFITS FOR KADOBOGO PILOT AREA

		WASAC activity				Project Activity				WASAC COST			TOTAL WASAC	PROJECT COST			TOTAL JICA	TOTAL COST
		Emergency Action				Premeditated Action												
		Accident, Request of Customer				Planning based on the analysis of monitoring												
Activity	Day	Qty	Qty	Qty	Qty	Qty	Qty	Qty	Qty	PM1	PM2	PM3		PM1	PM2	PM3		
		PM1	PM2	PM3	Total	PM1	PM2	PM3	Total									
1. Preparation Work																		
1.1 DMA Creation																		
Preparation of the map (GIS, Google map)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Pipe network map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
POC list and location map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Design of DMA and Sub-zone		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Pressure survey for Isolation		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Pipe replacement (Area adjustment)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Finalization of zone area		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Finalization of POC list in DMA and Update of the list (New Connection)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**
Survey of the existing facilities in DMA (Valve, PRV, Pipe, etc.)													0	10,000	10,000	10,000	30,000	**30,000**
Isolation valve installation								1					0		161,720		161,720	**161,720**
Valve installation for step test								1					0		1,637,817		1,637,817	**1,637,817**
1.2 Installation of Inlet and Outlet Facility																		
Inlet Facility (Chamber,		-	-	-	-	1	1	1	3				0	4,986,355	5,472,105	4,962,920	15,421,380	**15,421,380**
Outlet Facility													0				0	**0**
Sub-Total													0				17,490,917	**17,490,917**
2. Activity for Commercial Loss reduction																		
2.1 Customer data analysis (Billing)																		
Analysis the Data inside the pilot araea													0	30,600	2,100	27,300	60,000	**60,000**
2.2 Customer Meter Survey/ POC Survey																		
Survey by visit all customers													0	652,800	44,800	582,400	1,280,000	**1,280,000**
2.3 Customer Questionnaire Survey																		
Questinnaire													0	150,000	150,000	150,000	450,000	**450,000**
Analysis													0	70,000	30,000	60,000	160,000	**160,000**
2.4 On-site Meter Test																		
Identified										0	0	0	0	652,800	44,800	582,400	1,280,000	**1,280,000**
Test meter										0	0	0	0	2,312,315	157,984	2,089,701	4,560,000	**4,560,000**
2.5 Meter Replacement																	0	
Meter replaced (Site work)										0	0	0	0	2,904,636	187,947	2,067,417	5,160,000	**5,160,000**
Customer meter procurement											0		0		12,051,438		12,051,438	**12,051,438**
2.6 Inspection of illegal connection/use																		
Inspection work on site visit										0	0	0	0	408,000	28,000	364,000	800,000	**800,000**
Sub-Total													0				25,801,438	**25,801,438**
3. Activity for Physical Loss reduction		PM1	PM2	PM3	Total	PM1	PM2	PM3	Total									
3.1 Leakage Survey and Repair																		
1) Analysis of Leakage repair record													0	190,000	190,000	190,000	570,000	**570,000**
2) Qmnf measurement & Step Test		-	-	-	-		20		20				0		4,200,000		4,200,000	**4,200,000**
3) Modified Step Test & Leak detection		-	-	-	-	11	20	18	49				0	253,000	460,000	414,000	1,127,000	**1,127,000**
4) Leakage Repair (Include Preliminary work before repairing)																		
3000+22440	2017/6					-	-	-	-	0	0	0	0				0	**0**
	2017/7					-	-	-	-	0	0	0	0				0	**0**
	2017/8	1	1	4	6	-	-	-	-	25,440	25,440	101,760	152,640				0	**152,640**
	2017/9	4	4	5	13	-	-	-	-	101,760	101,760	127,200	330,720				0	**330,720**
	2017/10	10	1	3	14	-	-	-	-	254,400	25,440	76,320	356,160				0	**356,160**
	2017/11	13	4	3	20	-	-	-	-	330,720	101,760	76,320	508,800				0	**508,800**
	2017/12	6	2	1	9	-	-	-	-	152,640	50,880	25,440	228,960				0	**228,960**
	2018/1	5	3	4	12	-	-	-	-	127,200	76,320	101,760	305,280				0	**305,280**
	2018/2	6	1	0	7	-	-	-	-	152,640	25,440	0	178,080				0	**178,080**
	2018/3	3	1	3	7	-	-	4	4	76,320	25,440	76,320	178,080			101,760	101,760	**279,840**
	2018/4	4	4	3	11	1	1	4	6	101,760	101,760	76,320	279,840	25,440	25,440	101,760	152,640	**432,480**
	2018/5	2	1	2	5	-	-	-	-	50,880	25,440	50,880	127,200				0	**127,200**
	2018/6	2	1	2	5	-	1	-	1	50,880	25,440	50,880	127,200		25,440		25,440	**152,640**
	2018/7	2	0	3	5	-	-	-	-	50,880	0	76,320	127,200				0	**127,200**
	2018/8	7	0	0	7	9	2		11	178,080	0	0	178,080	228,960	50,880		279,840	**457,920**
	2018/9	5	0	1	6	-	-	-	-	127,200	0	25,440	152,640				0	**152,640**
	2018/10	7	0	0	7	-	-	-	-	178,080	0	0	178,080				0	**178,080**
	2018/11	6	0	0	6	-	-	-	-	152,640	0	0	152,640				0	**152,640**
	2018/12	5	0	0	5	-	-	-	-	127,200	0	0	127,200				0	**127,200**
	2019/1	5	0	3	8	-	-	-	-	127,200	0	76,320	203,520				0	**203,520**
	2019/2	3	0	1	4	-	-	-	-	76,320	0	25,440	101,760				0	**101,760**
	2019/3				na	-	-	-	-	0	0	0	0				0	**0**
	2019/4				na	-	-	-	-	0	0	0	0				0	**0**
	2019/5				na	-	-	-	-	0	0	0	0				0	**0**
3.2 Pressure Control		-	-	-	-	Not year	2018/5/23	2018/9/18										
1) Pressure survey													0				0	**0**
2) Planning of PRV installation point								1	1				0	0	268,999	268,000	536,999	**536,999**
3) PRV Installation								1	1				0	0	348,852	1,944,767	2,293,619	**2,293,619**
Sub-Total													3,994,080				9,287,298	**13,281,378**
4. Pipe Replacement						2019/2/28												
PM 1		PPR															0	**0**
Procurement of materials						1			1				0	4,010,100			4,010,100	**4,010,100**
Excavation & Backfilling						1			1				0	1,100,000			1,100,000	**1,100,000**
Installation						1			1				0	1,600,000			1,600,000	**1,600,000**
PM 2		PVC, PN50, L200m				2018/6/28							0				0	**0**
Pipe, Installation							1		1				0		473,167		473,167	**473,167**
Man powers							1		1				0		90,000		90,000	**90,000**
Sub-Total													0				7,273,267	**7,273,267**
5. Monitoring/Evaluation													0				0	**0**
NRW Rate Calculation		-	-	-	-	24	24	24	72				0	240,000	240,000	240,000	720,000	**720,000**
Sub-Total													0				720,000	**720,000**
TOTAL													**3,994,080**				**60,572,920**	**64,567,000**
																	Without Meter Work	**41,515,562**

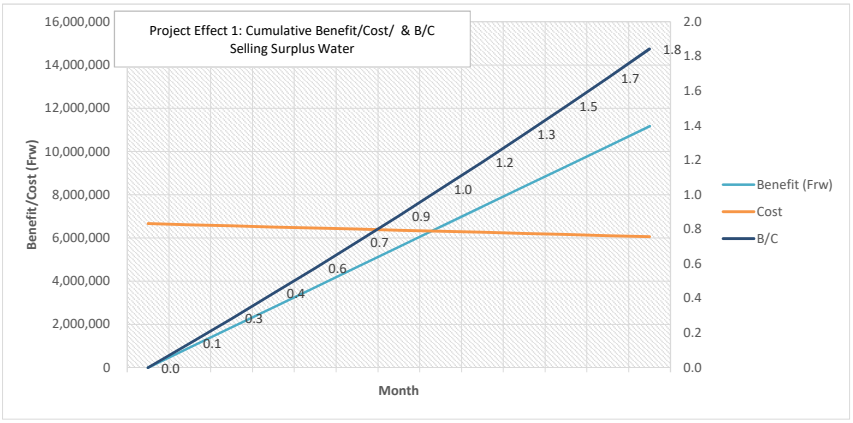
Kadobogo Pilot Area
Pipe Replacement in PM1

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Replacement	0	6,710,100	50,000	6,660,100	0	6,660,100	-6,660,100	0.0
1	930,787	0	50,000	-50,000	930,787	6,610,100	-5,679,313	0.1
2	930,787	0	50,000	-50,000	1,861,574	6,560,100	-4,698,526	0.3
3	930,787	0	50,000	-50,000	2,792,361	6,510,100	-3,717,739	0.4
4	930,787	0	50,000	-50,000	3,723,148	6,460,100	-2,736,952	0.6
5	930,787	0	50,000	-50,000	4,653,935	6,410,100	-1,756,165	0.7
6	930,787	0	50,000	-50,000	5,584,722	6,360,100	-775,378	0.9
7	930,787	0	50,000	-50,000	6,515,509	6,310,100	205,409	1.0
8	930,787	0	50,000	-50,000	7,446,296	6,260,100	1,186,196	1.2
9	930,787	0	50,000	-50,000	8,377,083	6,210,100	2,166,983	1.3
10	930,787	0	50,000	-50,000	9,307,870	6,160,100	3,147,770	1.5
11	930,787	0	50,000	-50,000	10,238,657	6,110,100	4,128,557	1.7
12	930,787	0	50,000	-50,000	11,169,444	6,060,100	5,109,344	1.8

Repair 1 places/month: Without Project 50,000

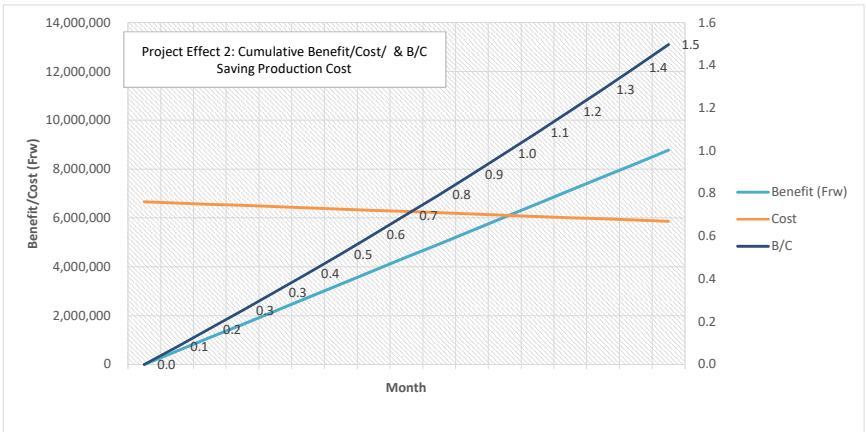
Replacement Cost		6,710,100
Production Cost	Frw/m3	334
Water Price	Frw/m3	567
Qmnf(2019/2/6)	m3/h	5.38
Qmnf(2019/3/27)	m3/h	3.10
Surplus Qmnf	m3/h	2.28
Surplus Qmnf	m3/month	1,642
Selling Water	Frw/month	930,787
Production Cost Reduction	Frw/month	548,294



Project Effect 2: Saving of Production Cost by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Replacement	0	6,710,100	50,000	6,660,100	0	6,660,100	-6,660,100	0.0
1	548,294	0	50,000	-50,000	548,294	6,610,100	-6,061,806	0.1
2	548,294	0	50,000	-50,000	1,096,588	6,560,100	-5,463,512	0.2
3	548,294	0	50,000	-50,000	1,644,882	6,510,100	-4,865,218	0.3
4	548,294	0	50,000	-50,000	2,193,176	6,460,100	-4,266,924	0.3
5	548,294	0	50,000	-50,000	2,741,470	6,410,100	-3,668,630	0.4
6	548,294	0	50,000	-50,000	3,289,764	6,360,100	-3,070,336	0.5
7	548,294	0	50,000	-50,000	3,838,058	6,310,100	-2,472,042	0.6
8	548,294	0	50,000	-50,000	4,386,352	6,260,100	-1,873,748	0.7
9	548,294	0	50,000	-50,000	4,934,646	6,210,100	-1,275,454	0.8
10	548,294	0	50,000	-50,000	5,482,940	6,160,100	-677,160	0.9
11	548,294	0	50,000	-50,000	6,031,234	6,110,100	-78,866	1.0
12	548,294	0	50,000	-50,000	6,579,528	6,060,100	519,428	1.1
13	548,294	0	50,000	-50,000	7,127,822	6,010,100	1,117,722	1.2
14	548,294	0	50,000	-50,000	7,676,116	5,960,100	1,716,016	1.3
15	548,294	0	50,000	-50,000	8,224,410	5,910,100	2,314,310	1.4
16	548,294	0	50,000	-50,000	8,772,704	5,860,100	2,912,604	1.5

Repair 1 places/month: Without Project 50,000



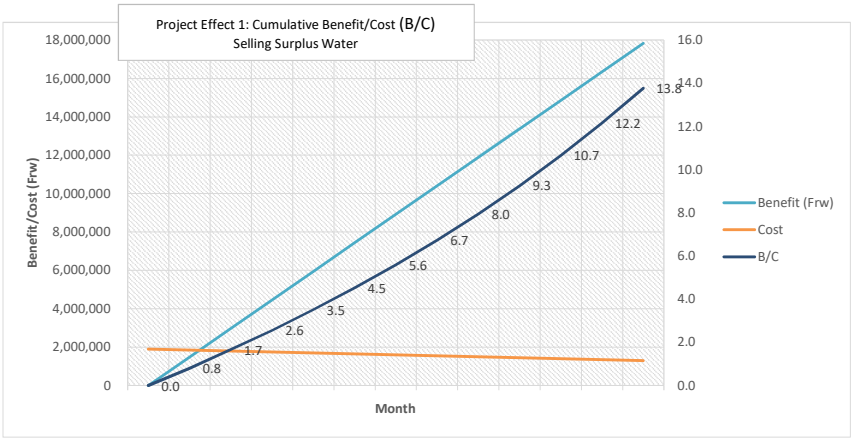
Kadobogo Pilot Area
PRV PM3

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	1,944,767	50,000	1,894,767	0	1,894,767	-1,894,767	0.0
1	1,485,994	0	50,000	-50,000	1,485,994	1,844,767	-358,773	0.8
2	1,485,994	0	50,000	-50,000	2,971,987	1,794,767	1,177,220	1.7
3	1,485,994	0	50,000	-50,000	4,457,981	1,744,767	2,713,214	2.6
4	1,485,994	0	50,000	-50,000	5,943,974	1,694,767	4,249,207	3.5
5	1,485,994	0	50,000	-50,000	7,429,968	1,644,767	5,785,201	4.5
6	1,485,994	0	50,000	-50,000	8,915,962	1,594,767	7,321,195	5.6
7	1,485,994	0	50,000	-50,000	10,401,955	1,544,767	8,857,188	6.7
8	1,485,994	0	50,000	-50,000	11,887,949	1,494,767	10,393,182	8.0
9	1,485,994	0	50,000	-50,000	13,373,942	1,444,767	11,929,175	9.3
10	1,485,994	0	50,000	-50,000	14,859,936	1,394,767	13,465,169	10.7
11	1,485,994	0	50,000	-50,000	16,345,930	1,344,767	15,001,163	12.2
12	1,485,994	0	50,000	-50,000	17,831,923	1,294,767	16,537,156	13.8

Repair 1 places/month: Without Project 50,000

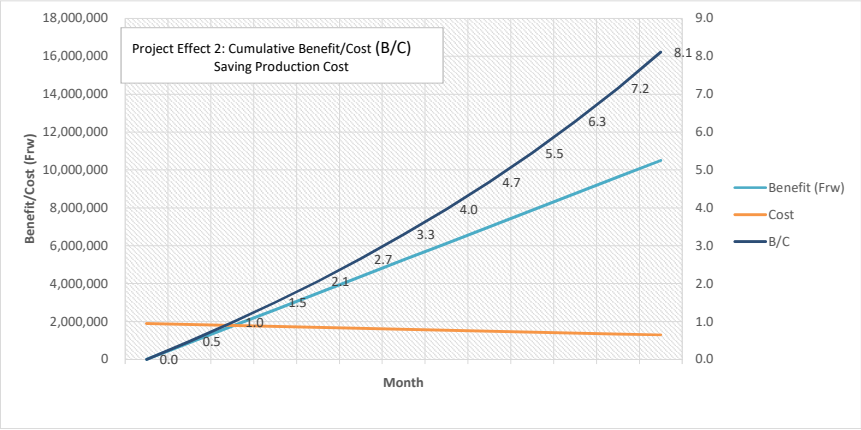
Installation Cost		1,944,767
Production Cost	Frw/m3	334.00
Water Price	Frw/m3	567.00
Effect Qmnf	m3/h	3.64
Effect Qmnf	m3/month	2,621
Selling Water	Frw/month	1,485,994
Production Cost Reduction	Frw/month	875,347



Project Effect 2: Saving of Production Cost by NRW Reduction Activity

Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Effect of the Activity (Cumulative)			
	WP	WP	WoP	Balance	Benefit (Frw)	Cost	NPV	B/C
Installation	0	1,944,767	50,000	1,894,767	0	1,894,767	-1,894,767	0.0
1	875,347	0	50,000	-50,000	875,347	1,844,767	-969,420	0.5
2	875,347	0	50,000	-50,000	1,750,694	1,794,767	-44,073	1.0
3	875,347	0	50,000	-50,000	2,626,042	1,744,767	881,275	1.5
4	875,347	0	50,000	-50,000	3,501,389	1,694,767	1,806,622	2.1
5	875,347	0	50,000	-50,000	4,376,736	1,644,767	2,731,969	2.7
6	875,347	0	50,000	-50,000	5,252,083	1,594,767	3,657,316	3.3
7	875,347	0	50,000	-50,000	6,127,430	1,544,767	4,582,663	4.0
8	875,347	0	50,000	-50,000	7,002,778	1,494,767	5,508,011	4.7
9	875,347	0	50,000	-50,000	7,878,125	1,444,767	6,433,358	5.5
10	875,347	0	50,000	-50,000	8,753,472	1,394,767	7,358,705	6.3
11	875,347	0	50,000	-50,000	9,628,819	1,344,767	8,284,052	7.2
12	875,347	0	50,000	-50,000	10,504,166	1,294,767	9,209,399	8.1

Repair 1 places/month: Without Project 50,000



2.Workflow of NRW Reduction

2.1 Workflow of NRW Reduction

Workflow of NRW Reduction

: Recommendation Based on Lessons of Kadobo go Pilot Project

Lessons Learned from the Project

Kadobogo

I. POC: limited access to the customers
II. High pressure and low quality materials: frequent leak after repair
III. Meter calibration: took five months
IV. Meter replacement: water bills not prepared normally
V. Leak detection: leak sound hardly detectable
VI. Team organization: limited number of staff/engineers

Ruyenzi

I. POC to be confirmed early and stickers on the gate for access
II. PRV to be installed or pipelines to be replaced
III. Prioritized customers and simplified procedures
IV. Bill adjustment
V. Qmnf+Modified step test by portable flow meters
VI. Two teams for physical and commercial loss reduction

Contents of Survey Manuals and Procedures (tentative)

- Main text
- Diagnostic flowchart (refer to page 4)
- Appendix-Workflow (refer to page 5 to 7)
- Appendix-Methodology and procedures (refer to page 8)

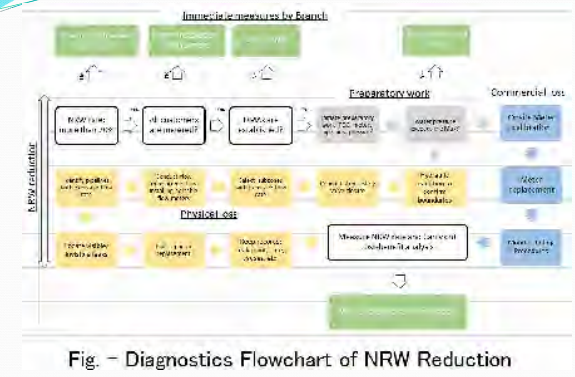
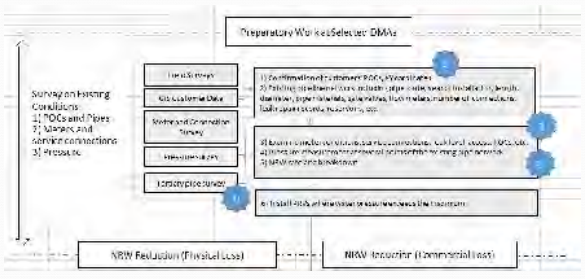
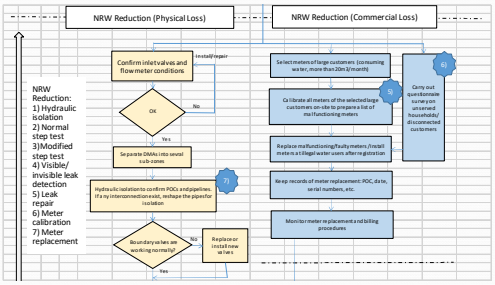


Fig. – Diagnostics Flowchart of NRW Reduction

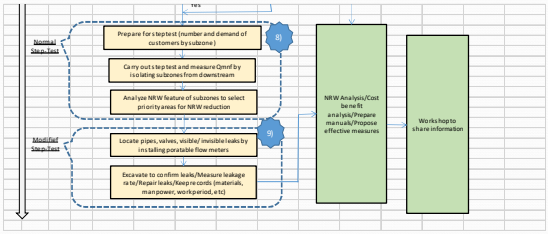
Workflow (1) : Preparatory Work



Workflow (2): Physical & Commercial Loss Reduction

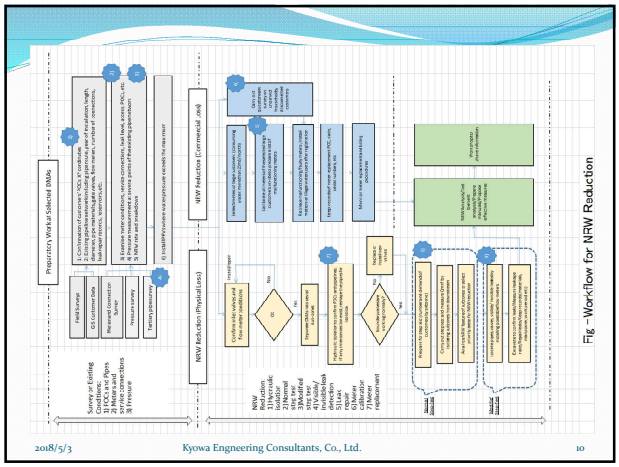


Workflow (3): Physical & Commercial Loss Reduction



Sample procedures

Reference



Thanks for attention!

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

WATER AND SANITATION CORPORATION (WASAC)

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

Completion report of the Pilot Project 2 Ruyenzi Area

FEBRUARY 2020

KYOWA ENGINEERING CONSULTANTS CO., LTD.

YOKOHAMA WATER CO., LTD.

KOKUSAI KOGYO CO., LTD.

Contents

Chapter 1. Outline of Pilot Project

1.1 Purposes of Pilot Project

The purposes of the Pilot Project are 1) to implement various activities for the reduction of non-revenue water (NRW) and verify their effectiveness and 2) to identify the most effective NRW reduction method that produces immediate effects while implementing the activities and include it in the Five-year Strategic Plan for Non-revenue Water Reduction.

1.2 Activities Implemented in Pilot Project

The pilot project was implemented in two areas in accordance with the PDM of the Project for Strengthening Non-revenue Water Control in Kigali City Water.

The activities in Area 1 began in June 2017 after a preparatory period and completed in September 2019. Based on the knowledge and lessons learned from the activities, those that were not included in the original PDM, *i.e.*, high pressure control and replacement of distribution and service pipes, were included in the pilot project.

The NRW rate in Ruyenzi is still far higher than the ambitious target of 25 % of Pilot Project 2 because of the high water pressure caused by the water distribution through a pipe that bypasses a reservoir. The project is being implemented with introduction of the water pressure control in the night and water rationing taken into consideration.

This report summarises the achievement of the activities in Pilot Project 2.

1.3 Outcome of Pilot Project

The lessons learned and recommendations derived from the Pilot Project on NRW reduction activities are described in Chapter 3, as outcome of the project.

The method that enables NRW reduction in a short time is summarised below. It was revealed that water leakage from distribution and service pipe was the major cause of NRW because it accounted for approx. 80% of NRW. It was also revealed that the leaks were caused by the high pressure used for water distribution and poor quality of pipe materials. Therefore, the prioritized implementation of the activities mentioned below, as activities for NRW reduction, is recommended.

1. **Activities to reduce water leakage**

   A. Water pressure control (reduction of the high pressure)

      Identify areas where water pressure is high and take corrective measures against the high pressure. Where it is not possible to take a measure that permanently reduces high pressure, including rehabilitation of a water distribution system, the installation of PRVs is the quickest and effective

temporary measure. Installed PRVs must be maintained in good condition.

B. Installation of new pipes that comply with the standards

Use pipe materials that comply with the quality standards of WASAC and install them appropriately when installing new pipes.

2. Measures against existing water leaks

A. Replacement of leaky pipes and old and dilapidated pipes

Identify leaky pipes, those that leak even after repair and old and dilapidated pipes and replace them with pipes that comply with the standards.

B. Water leak survey and repair

Repair a pipe at a place where a water leak has been reported quickly as part of the regular work. Conduct a systematic leak survey in an area in which many water leaks have been detected to locate leaking points. Create as many DMAs as possible and monitor volume and rate of NRW in each of them. In an area where water leaks occur frequently, it is possible to locate leaking points by plotting points of leaks in the past on a map. Measure minimum night flow in such an area and estimate the frequency and scales of leaks from the measurements. Conduct the water leak detection survey in areas where NRW volume is large.

3. Accurate measurement of water consumption to be billed

A. Maintenance of customer meters

Repair/replace defective meters (including malfunctioning ones) found in the meter reading immediately to ensure the impartiality of customer meter measurement. Conduct the accuracy test of a meter when the cost-benefit analysis of the billed water consumption has revealed abnormality in meter readings and replace a meter that has a measurement error outside the allowable range.

B. Accurate measurement of water consumption to be billed

Read customer meters accurately. When a meter reader fails to read a meter of a customer (because of such reasons as the absence of the customer or breakdown of a meter), charge such a customer for water consumption estimated in accordance with the rule of WASAC with consent of the customer. When a meter has been replaced, add the water consumption measured by the replaced meter to that measured by the new meter and use their sum in the billing.

Identify a cause of no billed water consumption, whether water has not been used (disconnection, not in use, not main, shifted) or water consumption has not been measured (a meter blocked, closed, stolen or vandalised) and correct the cause in the case where water consumption has not been measured.

Chapter 2. Contents and Outcome of Pilot Project Activities

2.1 Formation of Action Team

The counterparts from WASAC were officially appointed by the CEO and Action Team were formed in August 2016.

2.2 Selection and Outline of Project Areas

Two pilot areas (Area 1: Kadobogo, Kacyiru Branch, and Area 2: Ruyenzi, Nyarugenge Branch) were selected from the proposed candidate sites 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.

(1) Selection of pilot project areas

Kadobogo and Ruyenzi were selected as Pilot Areas 1 and 2, respectively, at the same time

Table 2.2.1 Name of Pilot area and administrative area

Pilot Area	Cell	Sector	District	WASAC Branch	Order of implementation
Area 2	Ruyenzi	Runda	Kamonyi	Nyarugenge	Second

The criteria used for the area selection were as follows:

a. An area that can be hydraulically isolated,
b. Fewest possible inflow and outflow points and three or less subzones,
c. 1,000 or so service connections,
d. Continuous water supply for 24 hours a day and seven days a week, and
e. Availability of a distribution network drawing.

Based on the methods used in Pilot Area 1 and the lessons learned through the use of the methods, a POC position map of Pilot Area 2 required for the meter accuracy survey was prepared and the boundaries of subzones in Pilot Area 2 required for hydraulic isolation were defined. Pilot Area 2 was divided into three subzones (RY 1, RY2, and RY3) along the defined boundaries.

Notes on selection of pilot project areas

Because water outage made it very difficult to conduct various surveys, including flow measurement, pressure measurement and meter calibration, 24 hours/7days water supply was selected as a selection criterion. However, all the four branches rationed water supply by day of the week because of the shortage of water supply and suspended water supply constantly and frequently for leakage repair.

Roads branching off from main streets and entering project sites are unpaved, meandering and uneven.

Their widths vary. All of them are sloping and none of them is flat. Therefore, it is not possible to locate where water pipelines are installed. Some of them run through premises of private houses. The earth covering over them is not constant: Pipelines are partially exposed at some places and buried very deep in the ground at others. Resin pipes are mostly used for the water distribution. The number of gate valves installed at the branching points of distribution pipes is extremely small. The number of valves to control water flow and that of the places at which sensors of leakage survey instruments can be installed are also small. For these reasons, the difficulty in the leakage detection was expected at all the sites.

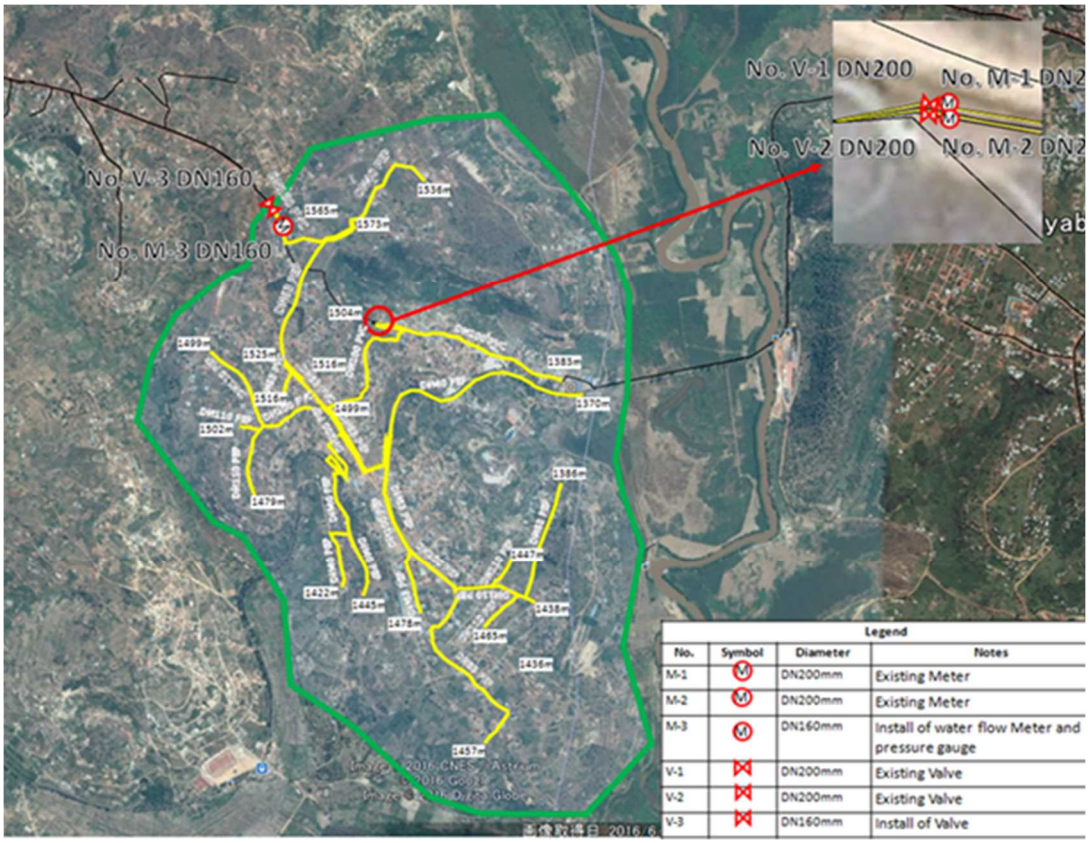


Fig. 2.2.1 Pilot Area 2 (Ruyenzi)

(2) Collection of basic information

The table below shows the basic data of the water supply service in the two pilot areas. The population in each area was estimated from the 2012 Census data.

Table 2.2.2. Basic data of the pilot areas (as of October 2017)

Pilot Area	Area1 Kadobogo	Area 2 Ruyenzi
Area	100.4ha	648.2ha
Population	15,329	32,467
Served Population (connections x 5)	4,940	5,925

Service Coverage Ratio (%)	32	18
Number of Connections	938	885
Domestic	906	854
Public taps	1	6
Collectivity	2	3
Commercial	27	18
Industry	0	0
Government	2	4
Monthly Water Consumption (m3/month)	13,157	12,259
Average Consumption per Capita (L/day)	86	67
Number of Illegal Connections	19	14
Number of Meter Problems (including screen and index status)	98	50
Percentage of Illegal and Meter Problems	12%	7%

(3) Creation of POC list and POC map

The on-site accuracy test of customer meters in Pilot Area 1 revealed that the existing POC (customer number) list and map had many errors: Some of the existing customers were not on the list or map, while some customers on the list and map could not be found. Therefore, a considerable time was used for the field verification of POCs for the correction of the list and map and re-calculation of NRW rates.

Based on this lesson learned in Area 1, a field survey was conducted for the confirmation of POCs and the recording of their positions with a portable GPS receiver in Area 2 and a new POC list of the area was created. The GIS Team created a POC map of the area (See Fig. 2.2.2) from the POC list upon request of the Project. At the time of hydraulic isolation of the distribution network, supplementary field verification of the POCs was conducted in areas near the isolation boundaries.

POC numbers are displayed on different places at different customers. As the numbers are written with a marker by hand, some of them have been faded. These problems have affected the efficiency of meter reading and meter maintenance/inspection. The efficiency may improve with experience if the same CFOs continue to read, maintain and inspect the same meters. However, (as many CFOs are non-permanent employees,) the replacement of CFOs has often reduced the efficiency. Therefore, the Project Team recommended affixing of POC number stickers on the gate door of each customer and created sample stickers.

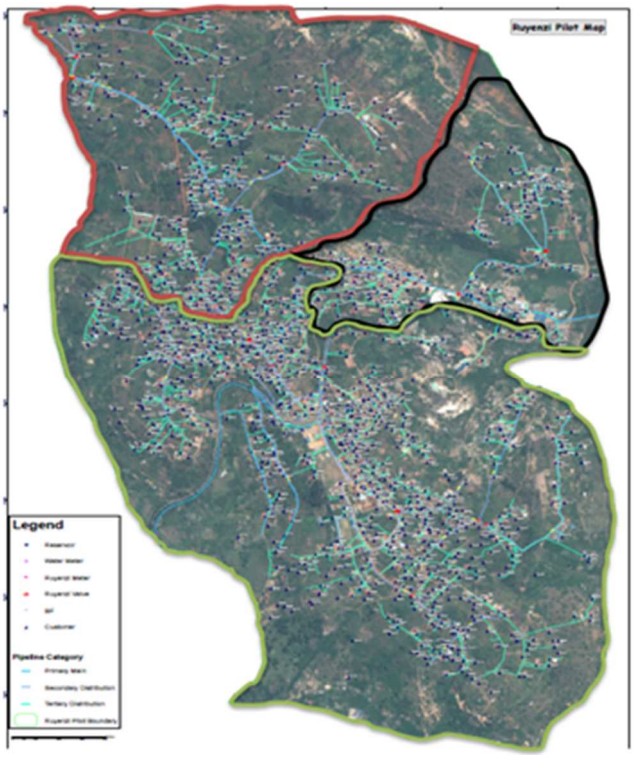


Figure 2.2.2. POC map

Figure 2.2.3. Sample POC number sticker

(4) Pilot Area 2

Topography

Pilot Area 2 is located on a ridge of a hill that drops from Gihara in Runda Sector toward the Nyabugogo River. This river, which is the source of water of the Nzove Purification Station, marks the eastern border of Pilot Area 2. Steep slopes occupy the area between the ridge and the river. The elevation of the pilot area is between 1,380 m and 1,570 m, *i.e.*, there is an elevation difference of 190 m in the area. The area has an area of approx. 5.5 km^2 and the total length of its boundary is 12 km. The highest point in the area (at EL 1,570 m) is at its northwestern edge. A chamber for flow meter (PM4) was constructed at this point in this project for the measurement of the volume of piped water flowing into this area. An asphalt-paved trunk road that runs from central Kigali to western Rwanda (and to neighboring countries, Burundi and the Democratic Republic of Congo) runs from east to west in the middle of this area. Another main road is on the hill ridge, which runs in the northwest-southeast direction. The intersection of the two roads is at the center of the area. The average and maximum gradients of the trunk road in the section between a bridge on the Nyabugogo River on the west to the above-mentioned intersection are 7 % and 14 %, respectively. Heavily loaded trucks crawl up the slopes on this section of the road.

Distribution of houses

While a relatively high concentration of houses is found on the ridge, they are found everywhere in Area 2 along the roads branching off from the main roads. Many new houses are being constructed in this recently developed housing area. As of the end of April 2018, 1,640 customers had water service contracts with WASAC. However, the service coverage of WASAC is less than 50 %.

Water distribution system

The Nzove Purification Station is the source of piped water in Area 2. The water purified at the station is pumped up to the Ntora Distribution Reservoir through a delivery pipe. Part of the water is diverted to the Ruyenzi 1 Distribution Reservoir (400 m^3, EL 1,503 m) in the pilot area through a pipe that branches off from the delivery pipe.

Part of the water delivered to the Ruyenzi 1 Distribution Reservoir is pumped another 4.2 km from its pumping station to the Gihara Distribution Reservoir (400 m^3, EL 1,735 m), from which water is distributed in the Gihara Area. Part of the water in the Gihara Distribution Reservoir is delivered back to the Ruyenzi 2 Distribution Reservoir (50 m^3, EL 1,570 m) in the Area 2 by gravity through a water delivery pipe. A water distribution pipe branches off from this delivery pipe. Therefore, a chamber for flow rate measurement was installed at the point where the delivery pipe from the Gihara Distribution Reservoir entered the pilot area (PM4), so that the volume of water flowing from the Gihara Distribution Reservoir into the Pilot Area 2 could be measured. This location of PM4 means that the measurement taken at PM4 includes the water distributed from the Ruyenzi 2 Distribution Reservoir. The gravity flow is used for the water delivery to the Ruyenzi 2 Distribution Reservoir and distribution from the reservoir to the high elevation zones in its service area (Nyabitare and higher part of Nyagacaca 1).

The water in the Ruyenzi 1 Distribution Reservoir is distributed to Kamhanda by gravity. The water pumped from Nzove is distributed to Rugazi, the lower part of Nyagacaca 1 and Nyagacaca 2 through a distribution pipe that branches off from the Nzove-Ruyenzi 1 delivery pipe near the reservoir and bypasses the reservoir (the bypass). A delivery pipe is installed between the Pilot Area and Kigese (EL = 1,540 m and above), located at approx. 7 km away from the Pilot Area. The water pumped from Nzove is also delivered to Kigese through the bypass and the delivery pipe. The excess pressure the water pumped up from the Nzove Purification Station has is used for this water delivery. To measure the volume of water outflow from the pilot area to Kigese, a flow meter is installed on the delivery pipe at the boundary between Ruyenzi and Kigese. Flow meters are installed on both the pipe for the gravity flow distribution and that for the pumped distribution from the Ruyenzi 1 Distribution Reservoir. The figure below (Fig. 2.2.4) shows a schematic map of the water delivery and distribution network in Ruyenzi.

Table 2.2.3. Demarcation of subzones by water distribution block

Subzone	Description of water source and water distribution in subzone
RY1	An area to which water is distributed through a (200 mm) bypass pipe that directly connects the delivery pipe to the Ruyenzi Distribution Reservoir and the (200 mm) outflow pipe from it: (Part of Nyagacaca 1, Nyagacaca 2 and Rugazi)
RY2	Gravity flow distribution area of the Ruyenzi Distribution Reservoir (Kamhanda)
RY3	The distribution area to which water pumped from the Ruyenzi Distribution Reservoir to Gihara Distribution Reservoir is distributed through a (PVC 160 mm) distribution pipe from the Gihara Distribution Reservoir: A flow meter, PM4, was installed at the location where the delivery pipe entered this subzone.

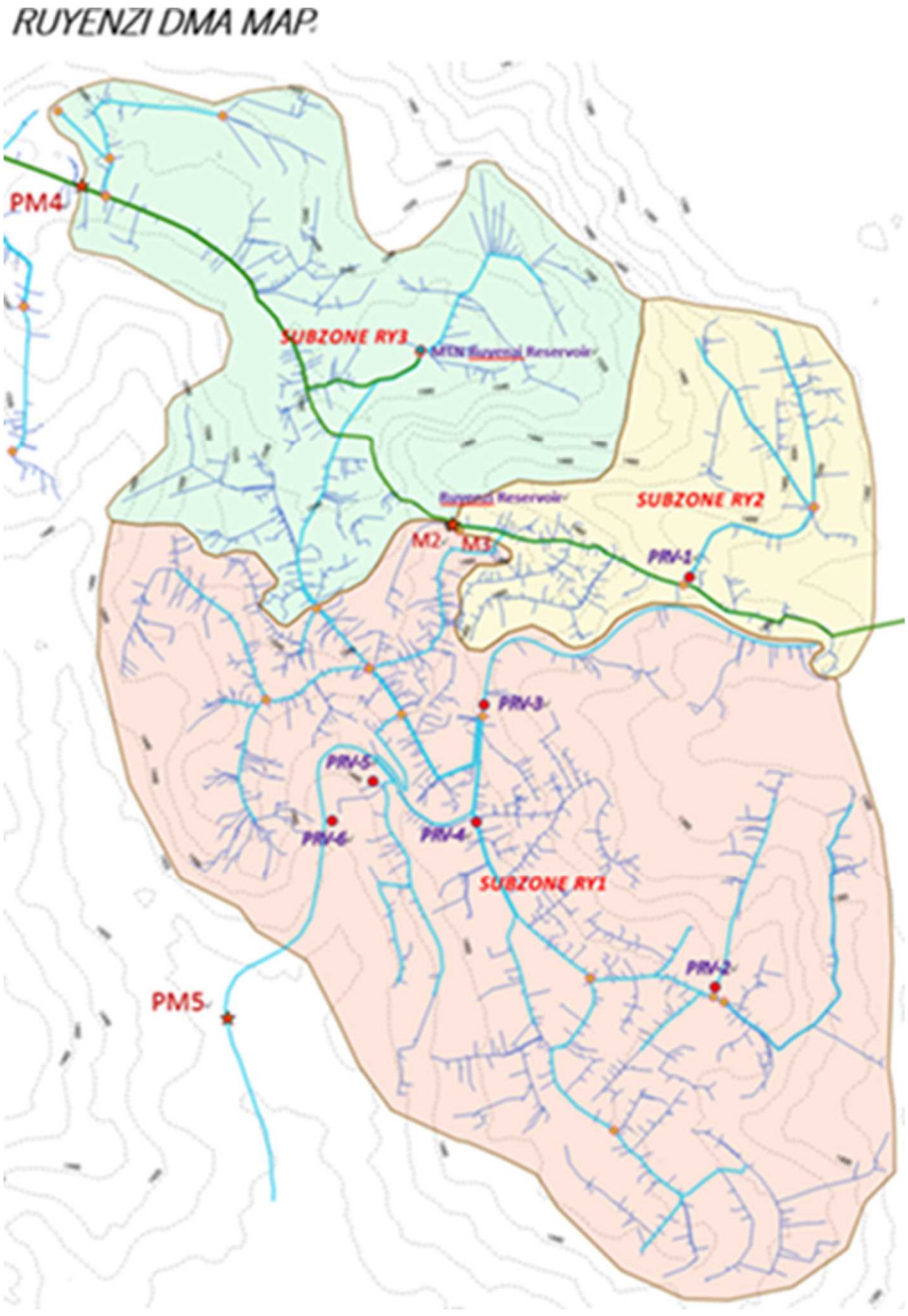


Fig. 2.2.4. Schematic map of water delivery and distribution network in Ruyenzi

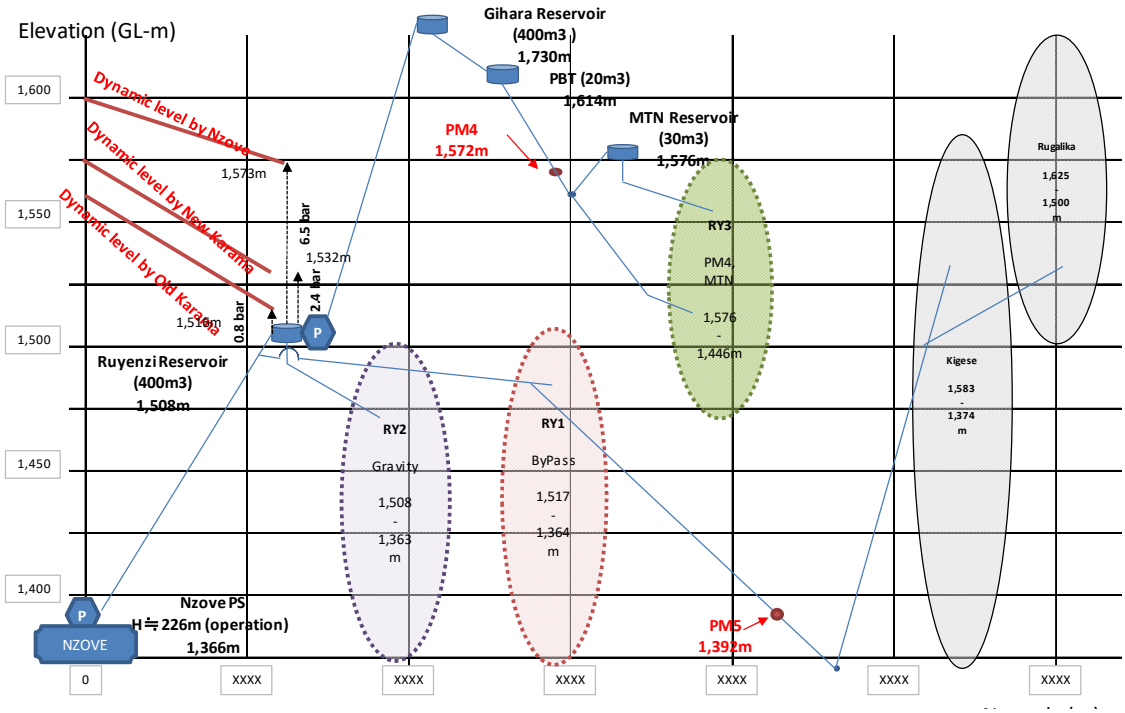
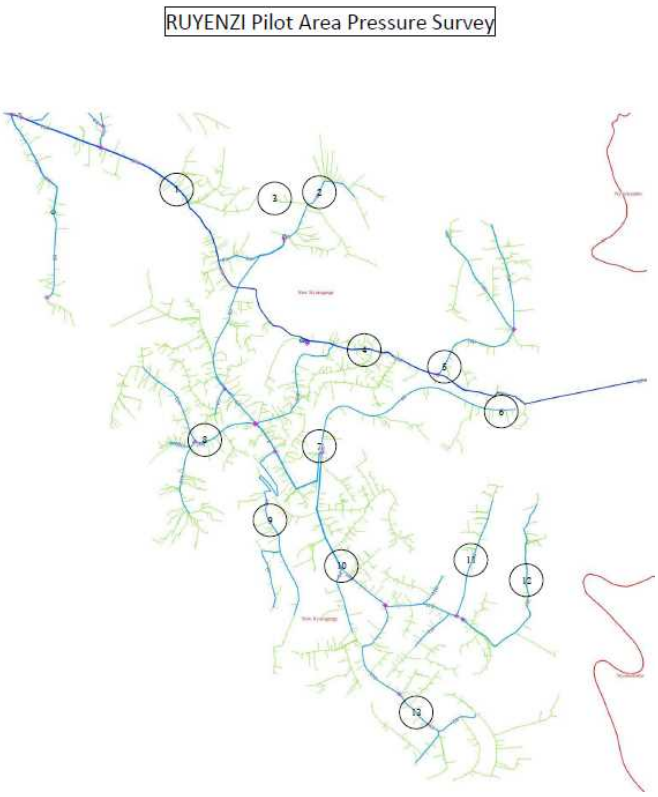


Fig. 2.2.5. Schematic diagram of elevations of water supply facilities and distribution areas

(5) Water Pressure Data

Water pressure was measured at the 14 points in different distribution networks and at different elevations in the Ruyenzi Area with assistance from plumbers of New NYARUGENGE. The measuring points and the result of the measurement are shown below (Fig. 2.2.6). High water pressure was observed in low elevation areas.



RUYENZI Pilot Area pressure survey

Point No.	Date/Time	Pressure(bar)	Altitude(m)	Serial No.
1	Apr. 25, 2017	1.5 – 2.0	1536	D12UA5H4520
2	Apr. 25, 2017	1.0	1533	D12UA138328
3	Apr. 25, 2017	2.0	1555	D14UA125925
4	Apr. 25, 2017	7.5	1455	D12CA062578
5	Apr. 25, 2017	10.5 – 11.0	1384	D12CA056849
6	Apr. 25, 2017	16.0	1365	D12UA542674
7	Apr. 25, 2017	5.5	1376	D12CA055725
8	Apr. 25, 2017	3.5	1492	D11UA086814
9	Apr. 25, 2017	4.0	1460	93850646
10	Apr. 25, 2017	1.0	1482	D11UA092732
11	Apr. 25, 2017	10.0	1393	I11BA388904
12	Apr. 25, 2017	1.0	1441	D14UA108518
13	Apr. 25, 2017	3.5	1462	D12UA573180

Fig. 2.2.6. Water pressure measuring points and measurement result

2.3 Plan and Schedule of Project Implementation

Based on a lesson learned in Pilot Area 1, it was decided to take a measure to reduce high water pressure (installation of PRVs) first in Pilot Area 2, followed by activities to reduce commercial losses and, then, those to reduce physical losses.

After having 1) elucidated the overview of the area, 2) completed hydraulic isolation of the area and 3) set the baseline NRW rates, 1) a comprehensive survey of customers, 2) questionnaire survey of zero-consumption and disconnected customers, 3) on-site accuracy test of customer meters, 7) installation of pressure reducing valves (PRVs), 4) replacement of customer meters, 5) quantification of water leaks (Qmnf measurement and step test), 6) detection and repair of leaks and 7) installation of additional PRVs were implemented in this order.

See Attachment 2.3 for the original schedule and achievement of the action plan of the pilot project.

The pilot project activities were delayed for various causes. The following are lessons concerning the delay for future projects.

- The heavy rainfall in May 2018 caused flooding of the Nyabugogo River, which damaged the water supply pipe from Nzove Purification Plant to Pilot Area 2. Because of the damage, water supply to the area was suspended. Until the restoration of the pipe was finally completed on June 23, because the water supply from the alternative water source was not stable, water rationing was frequently put in place. The

frequent water rationing affected the implementation of various project activities.

- Staff members of WASAC can participated in the project activities for limited time because they have their daily duties to perform. Because of the time limitation, it was not possible to prepare a work plan as planned.
- The POC list and POC location maps are important information and are essential for the day-to-day work carried out by WASAC, such as meter reading, meter surveys, surveys of water leaks, etc., and accurate information is necessary. However, POC numbers of some customers are marked on places other than gate doors and other designation places. Indeed, they are marked on various places, including gate doors, gate posts, window frames, house doors, electricity meters and water meters. In addition, quite a few of them have become illegible because rain has faded these numbers hand-written with a marker. Therefore, it was very difficult to locate customers by POC numbers on site and, consequently, it took a long time to create a POC list.
- Because many distribution pipes were not found at the places indicated by GPS, it took a long time to confirm the types and locations of pipes on site.
- Although the rationing schedule gave the days of the week of the scheduled water suspension, additional suspension often took place on any day without prior notice for the repair of water leaks from distribution and service pipes. Flow rate and water pressure could not be measured if such unscheduled suspension took place. A date and time of unscheduled suspension was rarely announced in advance and such suspension was usually realized at the stage of installation of the measuring devices, measurement or analysis of measurement data. The suspension of the operation of the purification station that supplied piped water to the area and pumping stations also suspended water supply. When such unscheduled suspension took place, the time and labor spent on the measurement was wasted and the measurement had to be rescheduled for a new date.

2.4 Hydraulic Isolation of Pilot Areas and Installation of Water Flow Meters and Pressure Gauges

The completion surveys for the equipment procurement and construction of chambers that were outsourced locally for installation of flow rate meters and pressure meters at the inlets to Pilot Areas 1 and 2 were are carried out on May 24 and May 25, 2017, respectively. Thereafter on May 31, installation of the measuring equipment was completed (See Project Work Progress Report (Part 3) for reference). PM4 was the only inflow point in Ruyenzi where a chamber was constructed and the measuring equipment was installed in it.

1) Survey of Boundary of Hydraulic Isolation

The hydraulic isolation should have been the first activity in the Pilot Project. However, in Pilot Area 1, as

the accuracy test of customer meters was implemented before the isolation, meters in the isolated area were erroneously identified and meters outside the isolated area were tested.

Therefore, it was decided to implement the hydraulic isolation first and complete the creation of a POC list of the area in an early stage of the pilot project in Area 2. The boundary of the pilot area and those among the three subzones of the area (RY1, RY2 and RY3), which had been created based on the shape of the distribution network, were verified in December 2017.

The positional coordinate data of customer POCs were collected with mobile GPS 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 were confirmed on the POC positional maps to finalize the boundaries of the areas and subzones. The POC lists and POC positional maps were revised during this confirmation work.

The hydraulic isolation at the boundary of the pilot area or that of each of its subzones was confirmed by checking water flow from customers' water taps while water supply to the isolated area or subzone was suspended. If the isolation had been established, water should flow out from taps on the side of the boundary to which piped water is distributed, while water should not flow out from the tap on the side to which supply of piped water is suspended. See POC Survey Manual and Hydraulic Isolation Manual for the details of the work procedures used in the POC survey and hydraulic isolation.

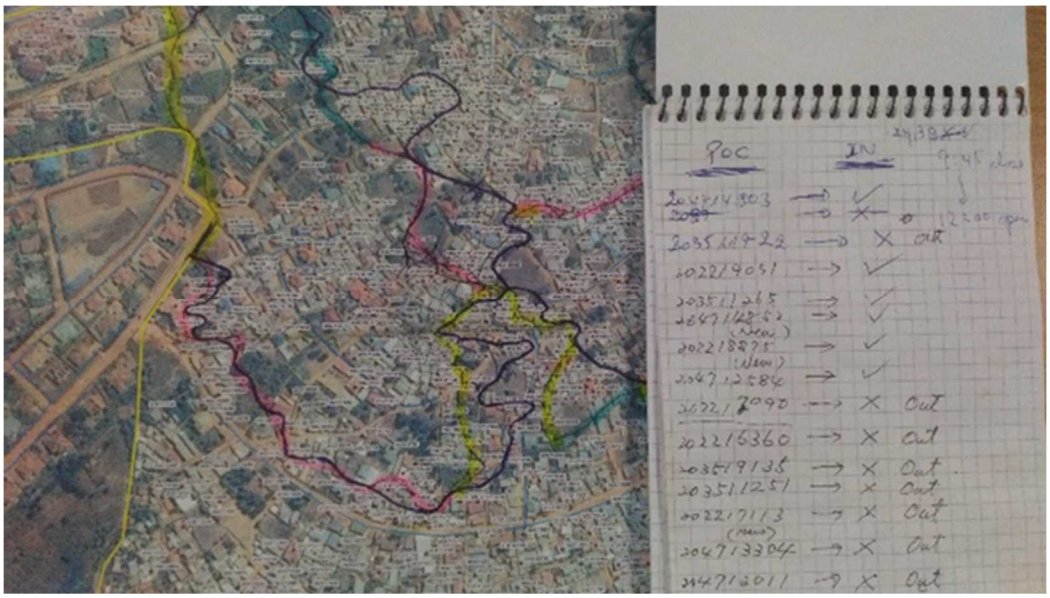


Figure 2.4.1. POC map (with subzone boundaries) and logbook

2) Survey of Gate Valves in Pilot Area

A survey was conducted to confirm the locations and working status of gate valves, which were required in the step test for leak detection. In the survey, valves directly buried in the ground without valve chambers,

defective ones and those installed at wrong places were found.

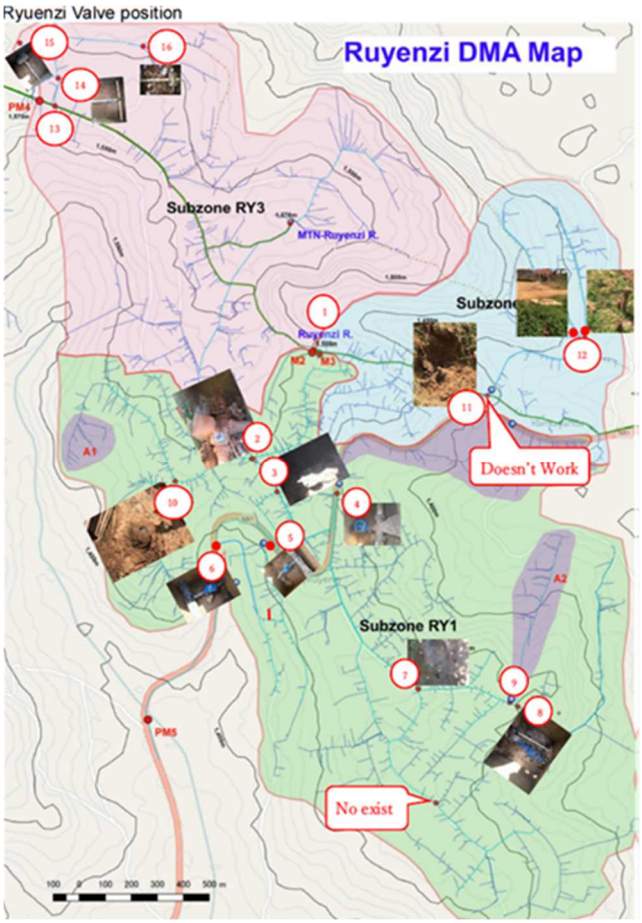


Figure 2.4.2. Locations and working status of gate valves

2.5 Baseline NRW rate setting

Table 2.5.1 Pilot project baseline

Pilot area	Area 1	Area 2
Calculation months	Average value of June and July 2017	Average value of March and April 2018
Non-revenue water percentage	37.3%	68.4%
Target value	20%	25%

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 flow meter was installed on the pipeline to measure the flow rate in it. The installation of the new meter in March 2018 has enabled the calculation of NRW rate in Pilot Area 2 since then. Therefore, the average of the NRW rates in March and April 2018 of 68.4 % (March: 64.4%, April: 72.4%) was set as the baseline value of NRW rate. The SC meeting held in August 2018 adopted an NRW rate of 25 % as the target value for the NRW reduction.

The total volume of water inflow into the pilot area was calculated by subtracting the volume of water that flowed out of RY1 to the Kigese Area, outside the pilot area, from the sum of the volume of water distributed from the Ruyenzi Distribution Reservoir to RY1 and RY2 and the volume of water inflow into RY1 measured with PM4.

Table 2.5.2. Calculation of NRW rates

DMA Number		Jan*	Feb*	Mar	Apr	May	Jun
Billed water		21,574	17,441	19,486	17,540	13,742	16,495
	RY1	14,084	11,762	12,849	11,845	8,906	10,705
	RY2	2,900	2,097	2,666	2,543	1,869	2,620
	RY3	4,590	3,582	3,971	3,152	2,967	3,170
Input Volume		55,992	53,704	54,812	63,327	35,349	39,895
	RY1	34,610	33,840	38,085	45,469	22,422	22,168
	RY2	12,580	11,560	7,480	8,790	6,240	9,910
	RY3	8,802	8,304	9,247	9,068	6,687	7,817
NRW		34,418	36,263	35,326	45,787	21,607	23,400
	RY1	20,526	22,078	25,236	33,624	13,516	11,463
	RY2	9,680	9,463	4,814	6,247	4,371	7,290
	RY3	4,212	4,722	5,276	5,916	3,720	4,647
NRW ratio		61.5%	67.5%	64.4%	72.3%	61.1%	58.7%
	RY1	59.3%	65.2%	66.3%	73.9%	60.3%	51.7%
	RY2	76.9%	81.9%	64.4%	71.1%	70.0%	73.6%
	RY3	47.9%	56.9%	57.1%	65.2%	55.6%	59.4%

Water Transmitted		Jan*	Feb*	Mar	Apr	May	Jun
Gihara Res.	Total	24,020	24,070	24,019	21,785	11,940	8,530
	Area	15,218	15,766	14,772	12,717	5,253	713
Gisegi&Bisheny		NA	NA	4,496	2,386	2,148	4,372

Note: Water transmitted to Bisheny area in January and February from RY1are not considered in the values of input volume and NRW of the same months.

2.6 Activities for Reducing Apparent Losses

Apparent losses usually 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.

All 1,705 customer water meters in Ruyenzi 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 m3 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 consumed no water 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 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.

2.6.1 Visual Inspection of Customer Meters and Simple Leakage Survey

A comprehensive survey of the customer meters began on June 4, 2018. A simple leakage survey with an automatic acoustic leak detector was also conducted at customers' water taps in the survey.

The total number of POCs in the POC list created from GIS data of their locations before the survey was 1,623. However, because of the existence of new customers and customers who were not listed due to the lack of GIS positional data, the total number of the surveyed customers was 1,705.

Table 2.6.1. Number of surveyed customers

Original POC	Missed POC	New POC	Total Numbers of surveyed POC
1,623	21	103	1,705（RY1：1,046, RY2:242, RY3：417）

The ratio of the number of installed meters to the total number of customers was very high (99.8 %). Six percent (6 %) of the meters had been disconnected and 91 % of them were working. Both the installation and working rates were very high. Approximately 3 % of the surveyed meters were defective and required to be replaced. The causes of the defects were clogging (47 %), mechanical failure (23 %), unreadable indicator (4%) and defective shut-off valve, etc. (26 %). Seventy-four percent (74 %) of the defects had been caused by problems on meters. Ninety-four percent (94 %) and 1 % of the surveyed meters were for domestic and public use, respectively. (See Table 2.6.2 and Attachment 2.6).

Table 2.6.2. Results of Visual Inspection of Customer Meters

Classification	Quantity	Breakdown 1 (of surveyed POCs)	Breakdown 2 (of surveyed meters)	Breakdown 3 (of defective meters)
1. Listed POCs	1,705	100%		
2.Number of installed meters	1,702	99.8%	100%	
Working	1,548		91%	
Disconnection	107		6%	
Defective (to be replaced)	47		3%	100%
Clogging	22			47%
Mechanical failure	11			23%
Unreadable indicator	2			4%
Defective shut-off valve	12			26%
3. Use				
Domestic	1,601	94%		
Public	17	1%		
Commercial	50	3%		
Others	37	2%		
4. Meters installed in garden	793		46%	
5.Meters in meter boxes	355		21%	
6. Rented houses	184	11%		

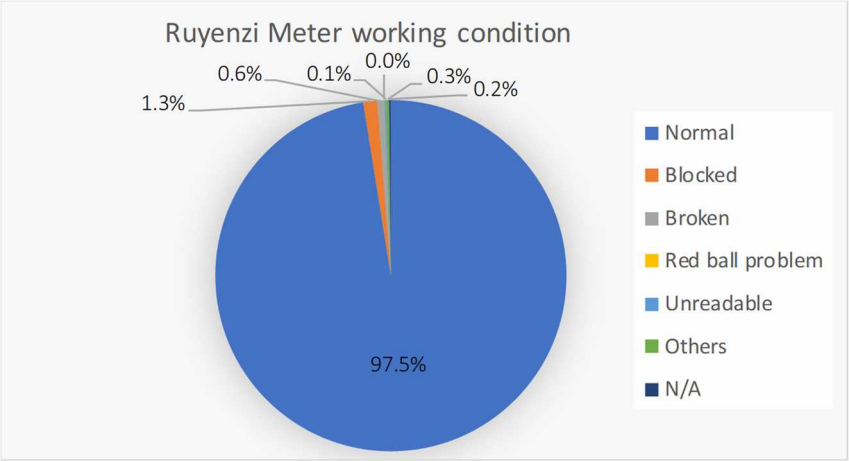


Figure. 2.6.1. Working status of meters revealed in the Visual Inspection

A leakage survey with simple water leak detector was conducted at all POCs with the comprehensive visual survey. The leakage survey identified nine level-3 POCs (possible leakage on service pipe) in the entire Ruyenzi Area.

Table 2.6.3. Numbers of meters required to be replaced and service pipes with possible leakage

Subzone	Meter to be replaced	Possible Leakage on Service pipe
RY1	20	5
RY2	17	2
RY3	10	2
TOTAL	47	9

2.6.2 Accuracy Test of Customer Meters (Large customers)

(1) Survey Result

The on-site meter error measurement was implemented at only 413 points of large consumers (consumers who consumed 20 m3/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).

Table 2.6.4. Number of meters whose accuracy was tested

Pilot area	Area 2
Number of customers surveyed	1,705
Number of meters surveyed	413 (large customers)
Meter replacements	139

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 unlike in Ruyenzi, 28 % of the meters required replacement. The figures obtained in the two areas indicate that 20 to 30 % of water meters are either inaccurate or defective.

Table 2.6.5 Result of the meter accuracy survey

Meter error	-5 % or below	Between -5 % and +5 %	+5 % or above	Defective	total
Large consumer	46	321	40	6	413
	11%	78%	10%	1%	100%

Table 2.6.6 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 were 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) Effectiveness of meter replacement

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. (See Attachment 2.6.)

Table 2.6.7 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 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. (Note that water consumption of each consumer was assumed to be the same before and after the replacement.). 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. (Meter replacement could reduce the profit.)

Regarding improvement in the quantity of non-revenue water as a result of meter replacement, the total amount of meter error before and after meter replacement and the total amount of water invoiced were compared, but the meters had errors on both the plus side and on the minus side, so it is judged that there was almost no non-revenue water improvement effect.

Explanation of how to record meter replacement

On-site meter error measurement

Measurement flow rate

In the beginning, a flow rate to be used in the test was set at 1,000 L/h, as described in the instructions of the measuring instrument. However, because this rate was too high compared with the water consumption of customers in the project area, the flow rate setting was changed. The test was conducted for one minute at a high flow rate of 800 – 1,000 L/h and for three minutes at a low flow rate of 100 – 300 L/h. The final decision on the meter replacement was supposed to be made based on the result of the accuracy test on the test bench in the laboratory of the Meter Unit of WASAC. However, as this laboratory test was found to be time-consuming, the decision on the replacement was to be made based only on the readings of a portable test meter on site, in the end.

However, it took a very long time to test a meter of each customer in the test conducted in Kadobogo and the test inconvenienced customers because a lot of water was wasted in the test. To conduct the test efficiently without inconveniencing customers in Pilot Area 2 (Ruyenzi), the measurement method described below was adopted in April 2018.

① Use 600 L/h, the average water consumption of the customers, as the flow rate for the test. (The average water consumption was obtained from the on-site measurements of water consumption of customers at three locations.)

② The duration of the measurement shall be two minutes to reduce the cost of water consumption of customers and to ensure the accuracy of the measurements.

③ The measurement results shall not be corrected for instrumental error of a test meter.

④ The allowable range of the instrumental error shall be ±5 %.

⑤ Conduct the accuracy test at large-scale customers.

⑥ Conduct the surveys of water meters and service pipes of all customers prior to the accuracy test to identify defective meters and confirm the scale of water leakage with a detector and operating conditions of water pipes.

Problems found and lessons learned in meter survey

The following problems were encountered in the meter survey:

- Because of the errors and omissions on the POC map, it sometimes took time to find POCs of interest. It is necessary to continue updating POC numbers in the GIS and CSM (Customer Service Management) system and synchronized the updating of two data sets.
- It was necessary to visit the same POCs repeatedly because there is no one at home at many POCs.
- It took time to have meter boxes locked by landlords unlocked.
- The water pressure at some POCs was too low to be measured with a test meter.

(3) Strategies for meter replacement

The above-mentioned meter survey revealed the following;

- 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.
- The replacement may have negative effect because some meters have positive errors.

The above-mentioned findings suggest the appropriateness of the following meter management strategies.

- The purpose of the ordinary meter replacement is 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.

2.6.3 Survey of Disconnected and Zero-consumption Customers

Disconnected and zero-consumption customers identified in the comprehensive survey of the customers were interviewed. A customer with zero water consumption in the last three months (May – July 2018) was considered a zero-consumption customer.

The purpose of this survey was to elucidate water use by the disconnected and zero-consumption customers and confirm whether they might be using piped water illegally. Therefore, the interviewers checked the taps installed in the premises of these customers while asking questions to them. The final version of the questionnaires (for disconnected and zero-consumption customers) used in Ruyenzi was created by revising those created in the Pilot Project in Kadobogo to make them appropriate for the use in Ruyenzi. See Attachment 2.6 for the result of this survey.

The survey revealed that many of these customers complained about the disconnection and that some owners of houses used ambiguity in the lease contracts to restrict water supply to the houses they rented unilaterally. WASAC should take deliberate measures to improve its customer service during the revision of water fees and collection system in February 2019.

2.6.4 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 no 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 was discovered in Ruyenzi. However, two to three cases of illegal consumption with unauthorized opening of disconnected water taps and intentional removal of meters were uncovered in Ruyenzi, respectively. As the numbers of these cases

are very small compared with the total numbers of customers, the losses caused by the illegal consumption was estimated at less than 0.5 % of the total amounts of water distributed.

(2) Estimation errors where it is impossible to read meters

1) Estimation from the consumption data of June – August 2017

WASAC is supposed to read the meters at 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.

Inaccurate meter reading is suspected because of the existence of customers that have been billed for the same amount of water consumption continuously. The tables below show the number of the customers billed for the same amount of water consumption for three consecutive months in each subzone of Ruyenzi. The numbers of such customers accounted for 12.9 % of customers (214 out of 1,655 customers) in Ruyenzi (in May to July 2018), (reference:10.6 % of customers (142 out of 1,342 customers) in Kadobogo (in June to August 2017)). The staff members in charge of billing at the branches 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 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 billed water consumption in Ruyenzi as of July 2018 (reference: 4.3 % in Kadobogo as of August 2017), where steep topography was found.

Table 2.6.8 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

Note) The amount of NRW was estimated at 800 m3 (= 167 customers x 50 % (an estimate based on the result of the interview survey) x 12.6 m3/m (average monthly water consumption per customer)), which corresponded to 6.4 % of the total amount of water distributed of 16,410 m3.

The tables below show the numbers of customers with the same billed water consumption for the three consecutive months (January to March 2019) obtained for the analysis of the latest meter readings. The number of such customers in Ruyenzi was reduced from 214 in the previous count 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 accounts for 4 to 5 % of NRW.

As it is difficult to calculate the amount of NRW accurately unless water meters are read correctly, Billing Department needs to take the lead in taking such a measure as reviewing the standards for meter reading at extremely inaccessible places and increasing the number of meter readers as soon as possible.

Table 2.6.9 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
Total	104	21	40	165 (9.5%)
Non-zero billed water consumption	20	6	4	30
Zero billed water consumption	84	15	36	135

2) Estimation from the consumption data of May 2018 – April 2017

Water consumption of the customers in the pilot area who had a month of no billed water consumption in a year period between May 2018 and April 2019 was analysed to estimate the maximum increase in NRW rate that could be caused by zero billed water consumption. In this analysis, such a customer was assumed to have consumed water in a volume equivalent to the average monthly consumption in the other billed months in the unbilled month and the actual total billed water consumption and the total water consumption that should have been billed were compared to estimate the volume of NRW caused by zero billed water consumption. Even if a customer actually did not consume water in the unbilled month, the customer was assumed to have consumed the said volume of water in the estimation. The following are the possible causes of no billed water consumption.

When the cause was NRW;

- Even though a customer consumed water, water consumption was not measured because of meter failure. (Block)
- Water is stolen. (Stolen)
- The meter has been illegally altered. (Vamdalism)。
- Water consumption of a customer is not measured and, therefore, a customer is not billed. (Close: inaccessible、Zooming)。
- Although water consumption is measured, the customer is not billed. (Negligence)

When the cause was not NRW;

- A customer did not consume water in a particular month because the customer was away from home (Not in use). The customer consumed water in the other months.
- Water supply was forcibly suspended. (Disconnection)

- Cancellation of service contract, a customer outside the pilot area, relocation of a meter (Cancel, Not main, Shifted)

Table 2.6.10 Estimated NRW rate caused by zero billed water consumption (Ruyenzi)

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

The calculation shown in the table above indicates that the rate of NRW caused by zero water consumption was 3.6 %. Because the cases in which water was not actually consumed because of the disconnection, etc. were included in the calculation, the actual rate of NRW caused by zero water consumption is estimated at around 3 % or less.

Water consumption by some zero-consumption customers has been zero for a long time because meter readers do not read water meters of such customers every month. Because it is not possible to estimate NRW rate accurately unless the meter reading is performed appropriately, the meter reading needs to be improved urgently and the Billing Department needs to take lead in the improvement. However, it is difficult to improve the meter reading with a simple measure because many POCs in Ruyenzi are on steep slopes, which predominate the area, and meter readers cannot reach these POCs easily. It is necessary to take measures, such as the revision of the work standards of meter readers to make meter reading at difficult-to-access POCs once in three months a minimum requirement.

2.7 Activities to Reduce Physical Losses (Water Leakage)

2.7.1 Pilot Area

The Pilot Area 2 consists of RY1, RY2 and RY 3. RY1 is the area where water is distributed through the pipeline that bypasses the Ruyenzi Distribution Reservoir located at the center of the area. RY2 is the area where water is distributed from the Ruyenzi Reservoir. RY3 is the area where water is distributed from the Gihara Reservoirs, which is located approx. 230 m higher than the Ruyenzi Reservoir. The elevation difference in RY1 is 120 m. The surplus water pressure in the bypassline is 6.5 bars where it diverges from

the pipeline from the Nzove Purification plant to the Ruyenzi Reservoir and this pressure is used for distributing the water pumped from the plant in RY1. Therefore, the water pressure in pipes in low-elevation areas in RY1 is very high (16 bar or above). It is difficult to prevent water leakage from such pressurized pipes with ordinary control methods.

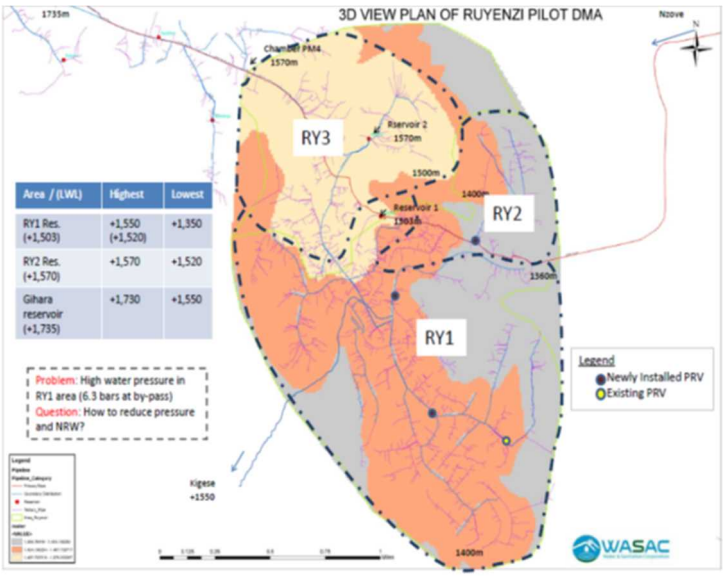


Figure 2.7.1. Schematic map of Pilot Area 2

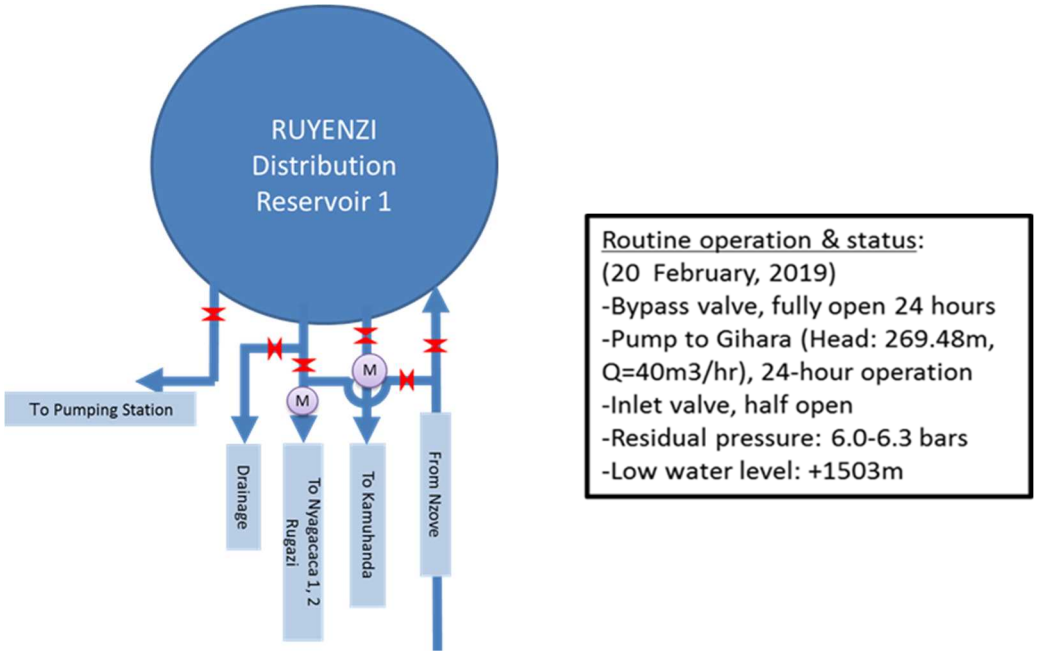


Fig.2.7.2 General Layout of Ruyenzi Reservoir

Flow rate measurements were taken for a week in July, 2018 at the inflow point in each subzone to elucidate the changes in the flow rate and Qmnf. It was necessary to consider the daily water rationing in RY3 and efflux outside Pilot Area 2 from RY1 when implementing the leakage step test.

Surface leakage is discovered daily during various site surveys of this Project (including the meter accuracy surveys, questionnaire surveys and hydraulic isolation) 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.

2.7.2 Water Leakage Survey

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

The measurement of the minimum night flow (Qmnf) conducted on December 3, 2018, revealed large water leakage (28 m3/h) in RY1. It also revealed water leakage of approx. 7 m3/h in RY2. Therefore, an intensive water leakage survey was conducted in RY1 and RY2, where large water leakage had been found, in March.

The large water leakage in RY1 could also be clearly inferred from the map of the locations of past leakage repair.

In pilot area 2 (Ruyenzi), the water leakage surveys commenced from January 2019, the nighttime minimum flow rate (Qmnf) was measured in order to determine the quantity of water leakage, and step tests were implemented in order to narrow down the areas where the water leakage was highest.

In February, step tests were carried out at night during the time of the minimum flow rate in RY1 and RY2. In March, water leak detection and repair were carried out in areas where large water leakage was detected in the step tests (Zones 1-5 and -6 in RY1 and Zones 2-1 and -2 in RY2). A portable ultrasonic flow meter was used in the step tests in the water leakage survey because the distribution network was complex and the number of installed gate valves was small. However, the soil on the roads was compacted hard and, in some cases, there was also rock, so a large amount of labor was spent in the excavation for installation of the flow rate meters. The water leaks at 16 locations detected in the survey were repaired in March and night time step tests were performed in April to evaluate the effect of the repairs. However, because it was very difficult to excavate the ground, no noticeable reduction in water leakage could be seen.

RY1, where the water leakage was markedly large, was the target area of the water leakage survey conducted in July and onwards. In the survey, a step test was conducted on the network of 63 mm PVC distribution pipe to identify priority leakage survey sites. The tests revealed water leaks at 14 sites in a month period from the latter half of July and these leaks were repaired.

A particularly large number of water leaks were found on service pipes of long-time customers.

(2) Step tests in RY1 and RY2

To identify areas with large water leakage, step tests were conducted in RY1 and RY2 in February 2019. The results of the tests are described in the following.

1) RY1 (distribution area of the bypass)

Particularly large water leakages were found in Zones 1-5 and 1-6. The water pressure in Zone 1-5 was regulated by PRV1. Although the valve reduced the primary pressure of 9.0 bars to the secondary pressure of 3.5 bars, the 55 m elevation difference between the valve and the lowest point in the zone generated large differential pressure (9.0 bars), which was considered to have contributed to the large water leakage in this zone. Piped water is directly distributed from the Ruyenzi Distribution Reservoir to Zone 1-6. Because the water pressure at the reservoir in the night was 6.0 bars and the elevation difference in the zone was 35 m, water pressure up to 9.5 bars was applied to the distribution pipe in the zone in the night. Two PRVs, PRV 1 and PRV 3, were installed in RY1 in October 2018. However, water pressure was not regulated by these PRVs in 70 % of the total area of RY1, including Zone 1-6. Therefore, it was considered necessary to take pressure reduction measures that covered the 70 % of the area for the effective NRW reduction. The result of the Qmnf measurement at a point immediately downstream of the Ruyenzi Distribution Reservoir is shown below (Fig. 2.7.3). Because the volume of NRW in RY1 in February was 18.082 m3, water leakage is considered to have accounted for almost 100 % of NRW.

February 13, 2019： 32.4 m3/h (32.4 x 24 x 28 = 21,772 m3/month)

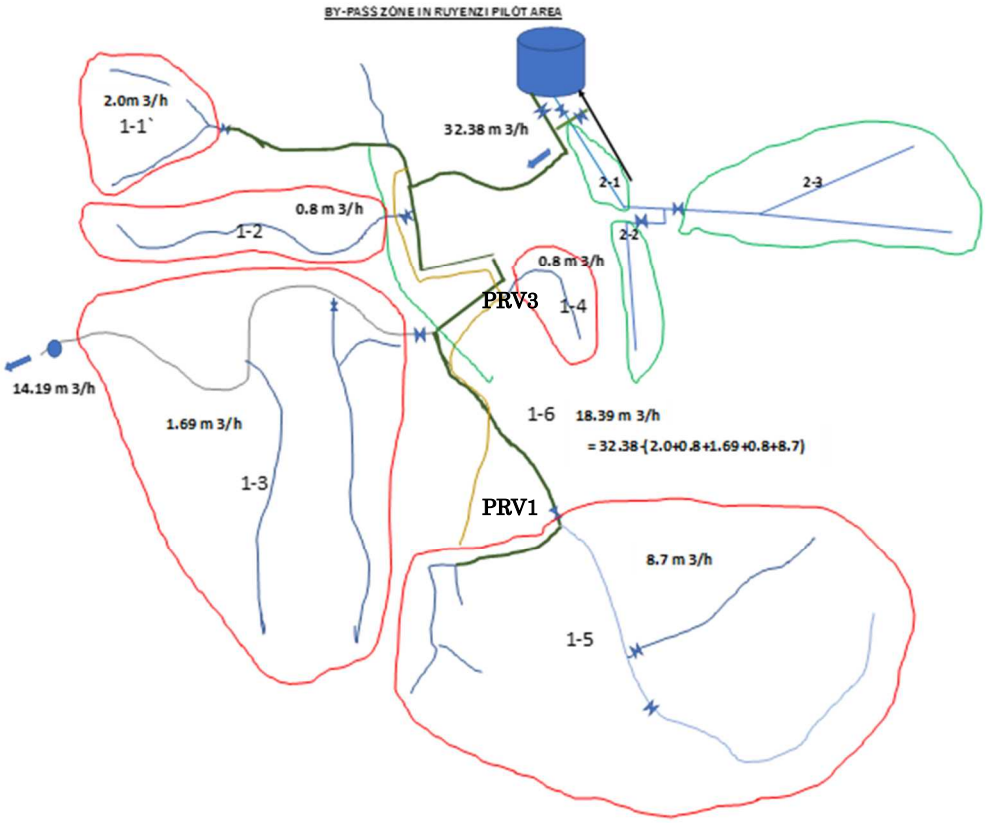


Figure 2.7.3: Result of step test in RY1

2) RY2 (area of gravity flow distribution from the Ruyenzi Distribution Reservoir)

The result of the step test on February 19, 2019, is shown below (Fig. 2.7.4). As NRW in RY2 in February was 3,402 m3/m, water leakage accounted for almost 100 % of NRW.

Qmnf at a point directly downstream of the Ruyenzi Distribution Reservoir: 4.71 m3/h (4.7 x 24 x 28 = 3,158 m3/month)

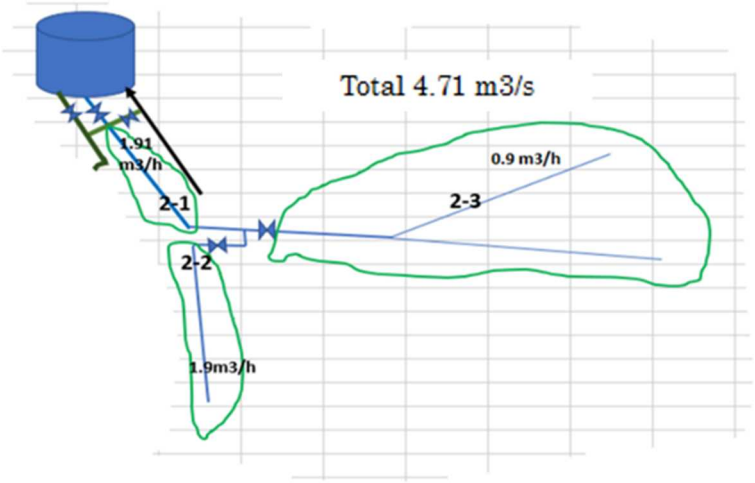


Figure 2.7.4. Result of step test in RY2

The step tests conducted in February 2019 identified RY1 and RY2 as areas with large water leakage and revealed that the water leakage in RY1 was particularly large. The flow rate survey and leak detection and repair were conducted in the zones with large water leakage (Zones 1-5 and-6).

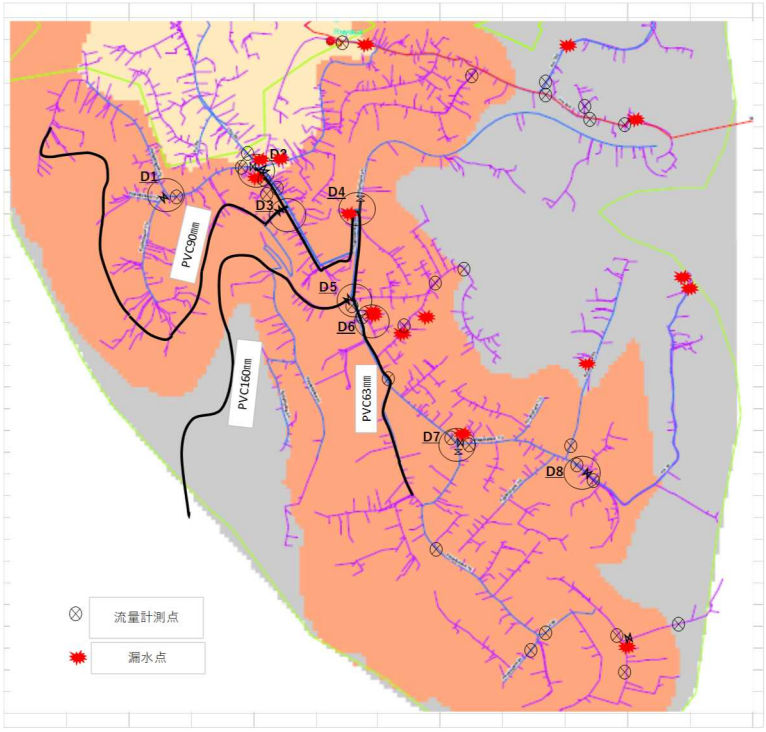


Figure 2.7.5. Leak detection sites (points of flow rate measurement and water leaks)

A large Qmnf value (8.7 m3/h) was observed in Zone 1-5. This zone is in the PRV1 pressure reduction area. Despite the pressure reducing effect of the valve, the water pressure near the end of distribution network was high because of the large elevation difference in the zone. As expected from the high water pressure in the zone, above-ground leaks (2 – 3 m3/h) were detected at four locations near the end of the network.

In Zone 1-6, 63 mm and 50 mm distribution pipes were installed in the north-south direction side by side with a 200 mm PVC distribution pipe. While the 63 mm pipe is used for the water supply to long-time customers, the 200 mm pipe is used for the supply to new customers. Therefore, old and new distribution and service pipes coexist in this zone. The low quality of the old service pipes was not a serious problem when the water pressure was low. It was assumed that many small-scale water leaks had occurred everywhere on the service pipes since the high-pressure water distribution through the bypass began.

Leaking pipes detected at 13 and three locations in RY1 and RY2, respectively, in the leak detection were repaired in March. From the flow measurement data taken on April 25, the Qmnf in RY1 was estimated at around 27 m3/h. As the Qmnf value of February 13 was 32.4 m3/h, the repair reduced Qmnf by around 5.4 m3/h. Meanwhile, the repair of leaking pipes conducted at a total of 14 locations in July and August did not have quantifiable effect as the Qmnf values in July and August were 27 – 37 m3/h and 36 m3/h, respectively.

		
Connection of different types of pipes and distorted central axis	Insufficient protection and distorted central axis	Insufficient protection

(4) Flow rate survey and leakage survey

The purposes of the Qmnf measurement are:

① To quantify water leakage to identify leakage points (implement leakage step test),

② To compare the quantities of water leakage before and after the implementation of leakage reduction activities to measure their effectiveness, and

③ To monitor the quantity of water leakage regularly.

The table below shows the result of the Qmnf measurement. The result of the Qmnf measurement is shown in Attachment 2.7.

Table 2.7.1. Record of Qmnf measurement (Ruyenzi)

Measurement of Flow Rate in Subzones of Ruyenzi (m3/h)

RY1 (Bypass)						RY2 (Gravity)				RY3 (PM4)		
Date of measurement	Bypass pipe (Inflow)	Kigese (Outflow)	Volume of water distributed to RY1 (Balance)	Item	Notes	Date of measurement	Volume of water distributed	Item	Notes	Date of measurement	Minimum volume of water distributed	Notes
Jan. 31-Feb.2, 2018	40～26	-	-	Qmnf	Qmnf changed day by day.							
Jul. 11-18, 2018	30	-	-	Qmnf	Balance was small. Valves might have been closed.	Jul. 11-18, 2018	4.8	Qmnf		Jul. 11-18, 2018	6.0	Flow rate fluctuated abnormally. Qmnf could not be measured.
Dec. 3-4, 2018	30.46	2.51	27.95	Qmnf	Balance was small	Dec. 3-4, 2018	7.5	Qmnf		Dec. 3-4, 2018	13.0	Water consumption in the night was large. Qmnf could not be measured.
Feb. 13, 2019	46.57	14.19	32.38	Qmnf/Step	The volume of outflow to Kigese was large.	Feb. 19, 2019	4.7	Qmnf/Step				
April 25-26, 2019	29.8	-	-	Qmnf/Step	Valves might have been closed.	April. 10, 2019	2.9	Step				
April 29-30, 2019	22.2	-	-	Qmnf/Step	Flow rate in 200 mm pipe (excluding those in 63 mm and 50 mm pipes) was measured.							
May 21, 2019	34.87	-	-	Qmnf/Step								
Jun 27-28, 2019	28	-	-	Qmnf	Rates were almost the same on 27th and 28th	Jun 27-29, 2019	4.5	Qmnf		Jun 26-28, 2019	16.0	Water volume changed unstably. Water was consumed in the night.
July 22-29, 2019	32－40	-	-	Qmnf	-							
Aug 07-08, 2019	38.7	3.1	35.6	Qmnf								
Aug 27-28, 2019	38.3	4.7	33.6	Qmnf	Measurement was almost the same as the previous one.	Aug 27-28, 2019	5.1	Qmnf				
Sept 19-20, 2019	30.1	1.3	28.8	Qmnf						Sept 2-3, 2019	14.0	Water volume changed unstably. Water was consumed in the night.
-	-	-	-	-	-							

PRVs 1 and 3: Operation began on Sept. 28, 2018. Valve settings were adjusted on Nov. 8.
Leakage repairs in 2019 13 locations in RY1 in March,
2, 8 and 4 locations in RY1 on July 24, Aug. 7 and Aug. 20, respectively

PRV2: Operation began on Nov. 16, 2018
Leakage repairs in 2019 3 locations in RY2 in March

PRV5: Operation began on Sept. 23, 2019

The inflow rate fluctuated. Valves (a valve on the delivery pipe from Nzove or valves in the pilot area) might have been operated.

PRV4: Operation began on Aug. 29, 2019

Measurement of the effect of PRV4 by comparing data before and after its operation began

- Reduction in RY1: Reduction by 5.8 m3/h (17 % reduction) from 34.6 m3/h (average of previous measurements) to 28.8 m3/h
- Reduction in the bypass area, including Kigese: Reduction by 8.4 m3/h (22 % reduction) from 38.5 m3/h (average of previous measurements) to 30.1 m3/h

63mm Valve: Operation began on Oct. 3, 2019

2.7.3 Survey of Tertiary Distribution Pipes

Many water leaks occurred on tertiary distribution and service pipes in Pilot Area 2. To quantify how much these leaks increased the volume of NRW, a survey of tertiary distribution pipes was conducted in three areas with different water distribution pressures in the pilot area. See Attachment 2.12, "Methodology and Procedures," for the method used in this survey. The outline of the method is also described in the following.

1) Select three representative tertiary distribution pipes with the water pressure distribution, topography, number of POCs, etc. taken into consideration,
2) Confirm the shapes of distribution networks and the locations of gate valves and POCs and create a POC list,
3) Hydraulically isolate tertiary pipes and re-confirm POCs,
4) Install an ultrasonic flow meter on the inflow pipe and begin data logging with a data logger (continuous measurement at 30-second intervals),
5) Perform comprehensive pre-survey customer meter reading at the beginning of the data logging, (divide the survey team into two or three groups)
6) Perform comprehensive customer meter reading after 24 hours,
7) Measure the minimum flow rate through the inflow pipe with all customer meters closed to measure water leakage,
8) Collate and analyze the data

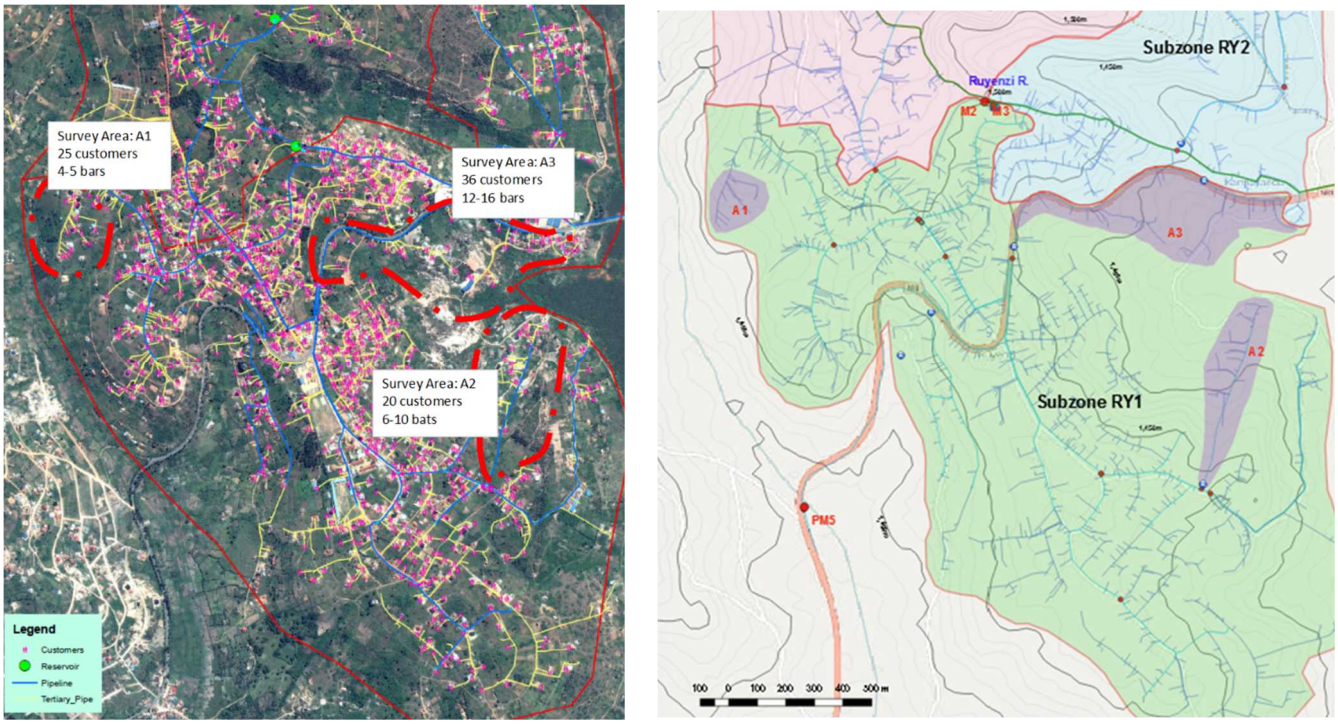


Figure 2.7.6. Areas selected for the survey of tertiary distribution pipes (A1, A2 and A3)

The table below (Table 2.7.2) shows the result of the survey. The table shows that NRW rate in A1, where the water pressure was relatively low (4.0 -5.5 bars), was small (12 %), while the rates in A2 and A3, where the pressure was high (>10 bars), were very high (76 and 81 %, respectively). This observation clearly shows that the NRW rate tends to be high where the water pressure is high. However, the NRW rate in A2 calculated from the result of the measurement described in 2.9.2 (Table 2.9.7) was 58 %.

Table 2.7.2: Result of the survey of tertiary distribution pipes

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

2.8 Activities to Control High Water Pressure

2.8.1 Study on Pressure Control Methods

(1) Excess pressure at the Ruyenzi Distribution Reservoir

High water pressure is working on the distribution pipes in the area where piped water is distributed through the bypass because of the high excess water pressure at the Ruyenzi Distribution Reservoir (approx. 65 m) and the large elevation difference between the reservoir and the lowest point in the distribution area (120 m). Simple calculation from the dynamic water pressure at the reservoir and the elevation difference in the distribution area gives the maximum water pressure of 185 m (65 m + 120 m). The water pressure at the Ruyenzi Distribution Reservoir estimated from the head of the pump at the Nzove Purification Station is also around 65 m.

Nzove-Ntora L=8.8km, Nzove-Ruyenzi L=7.5km

Nzove EL1,369＋Hp220－NtoraEL1,567＝22m (Loss)

22m/8.8km (Distance) = 2.5m/km (Hydraulic gradient)

Nzove EL1,369 + Nzove Hp220－Elevation of Distribution Reservoir1 EL1,503 = 86m

Hydraulic gradient 2.5m/㎞×7.5 ㎞ = 19m、86m－19m = 67m

The water pressure at the reservoir is barely enough to distribute water to the Kigese Area (EL 1,540 m), outside the Pilot Area 2.

Distance 7 ㎞ 3m/㎞×7km＝21m

EL1,503 + 65 - 21 - 1,540 = 7m

(2) Pressure reducing measures

The four plans mentioned below can be used for the water pressure reduction in the pilot area. The best plan is to terminate the water distribution through the bypass. However, this plan will require establishment of a self-contained water distribution system in the Kigese Area. The second plan, a plan to use the bypass exclusively for water delivery will require disconnection of the bypass and distribution pipes and rearrangement of the water distribution network in the pilot area. As a long time and a large amount of money were 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 a general-purpose NRW reduction measure, the installation of PRVs was adopted for the relative ease of its implementation.

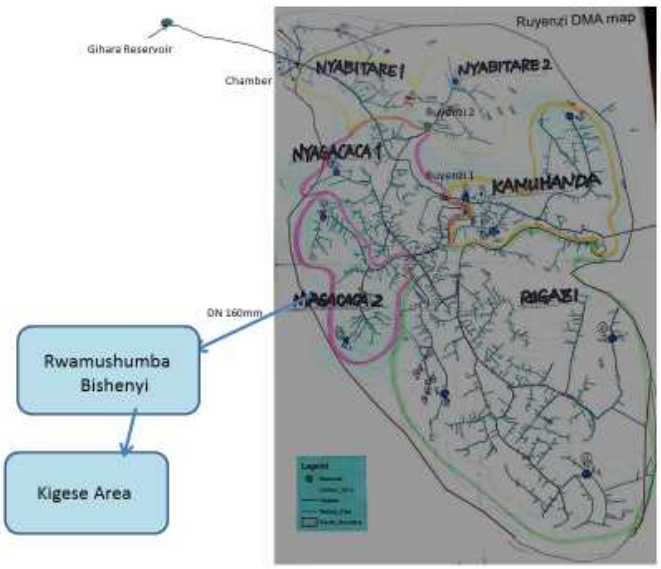


Figure 2.8.1: Map of the existing water distribution network

Table 2.8.1: Candidate plans for the reduction of high water pressure

Plan	Description	Requirement	Implementation period
Plan 1	Complete termination of the use of the bypass	An independent water source is required for water distribution in the Kigese Area	Long
Plan 2	Use of the bypass exclusively for water delivery to Kigese (separation from the water distribution network)	Re-development of the existing water distribution network	Long
Plan 3	Installation of PRVs	Installation of PRVs at multiple locations	Relatively short
Plan 4	Water rationing when the bypass is not used	Water rationing to customers	Short

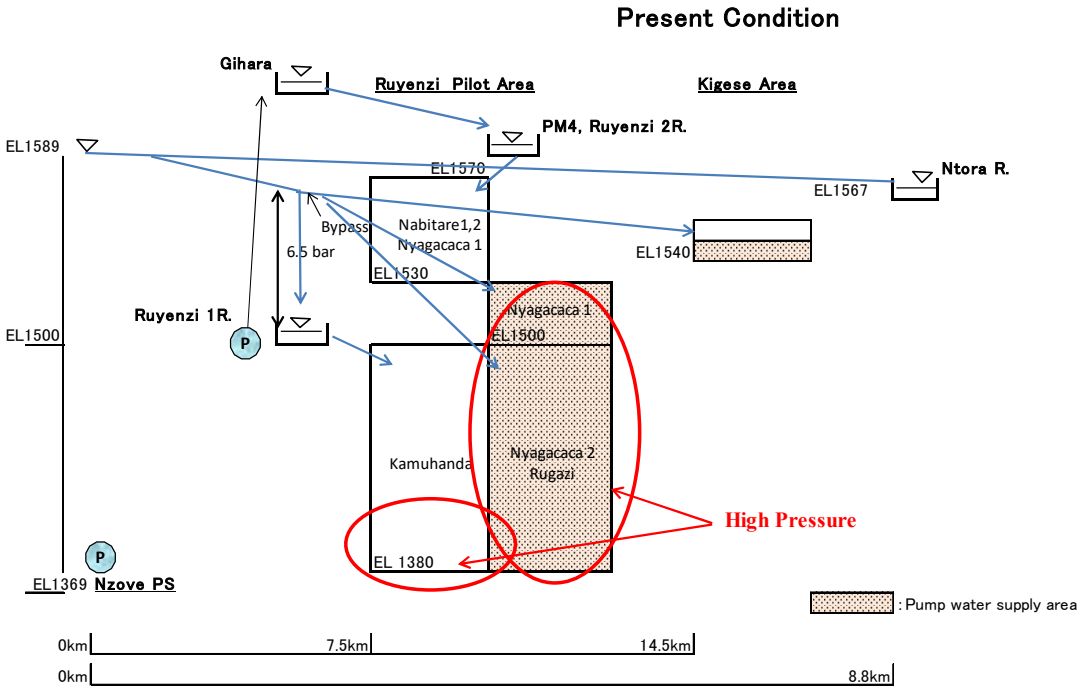


Figure 2.8.2: Schematic diagram of existing water distribution network

1） Plan to terminate the use of the bypass completely (Plan 1)

The disconnection of the bypass will necessitate a new source of water for water distribution in the Kigese Area, outside the pilot area, preparation of a water supply plan of the area and development of required facilities. At present, pressurized water is distributed to a zone at high elevation (the lower part in Nyagacaca 1) in the pilot area through the bypass. If the use of the bypass is terminated, a system to distribute piped water from RY1 to the zone by gravity will have to be developed. The development of such a system will require rearrangement of distribution zones and installation of new distribution pipes. Another measure will be required to distribute piped water to part of Rugazi where the elevation is higher than that of the Ruyenzi 1 Distribution Reservoir.

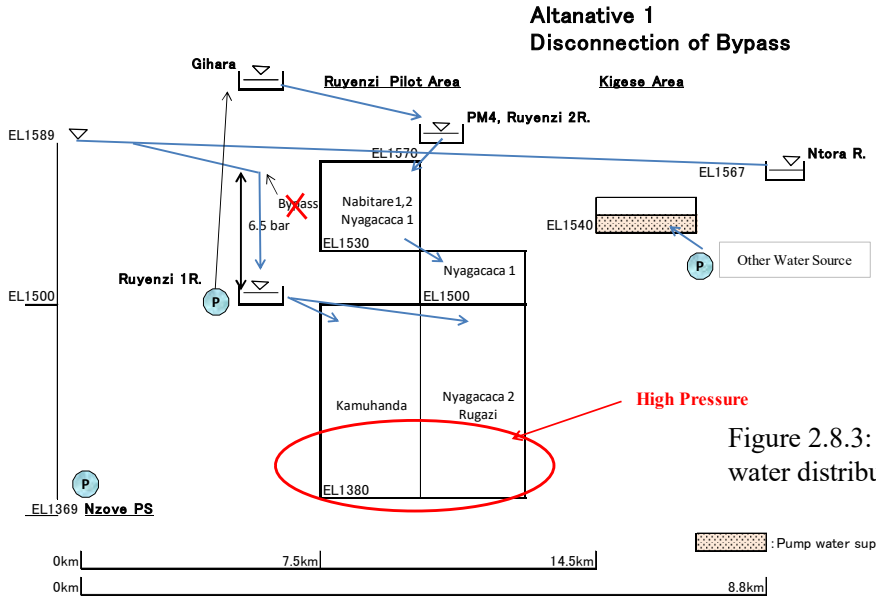


Figure 2.8.3: Schematic diagram of water distribution network of Plan 1

2) Plan to use the bypass exclusively for water delivery to Kigese (Plan 2)

The bypass shall be used exclusively as a water delivery pipe to the Kigese Area and the gravity flow from the Ruyenzi 1 Distribution Reservoir shall be used for the water distribution to the whole area to which water is currently distributed through the bypass. As Plan 1, this plan will require separation of all water distribution pipes to the pilot area from the water delivery pipe and rearrangement of water distribution zones and water distribution network to realize water distribution by gravity from the Ruyenzi 1 Distribution Reservoir.

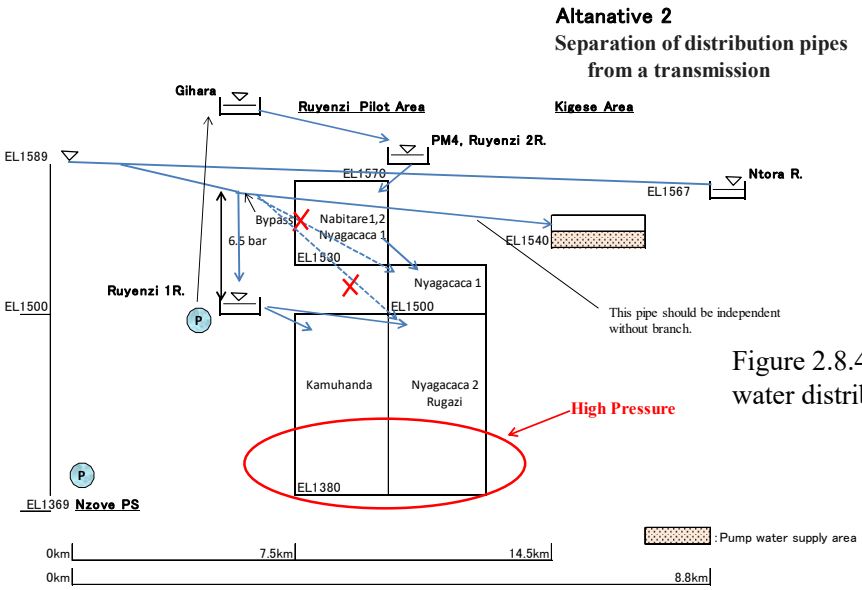


Figure 2.8.4: Schematic diagram of water distribution network of Plan 2

3) Plan to install PRVs – Survey of planned PRV installation sites (Plan 3)

PRVs shall be installed at various locations in the pilot area, while the pressurized water is continuously distributed through the bypass for 24 hours.

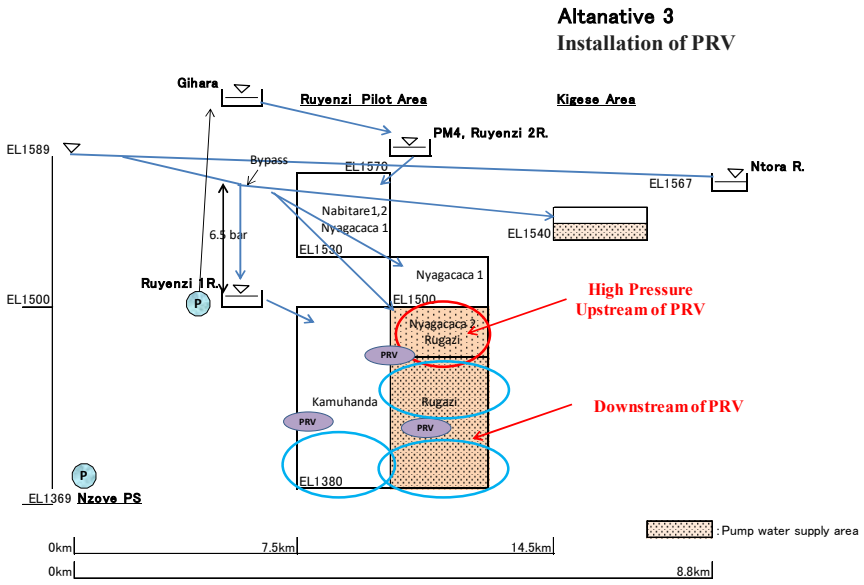


Figure 2.8.5: Schematic diagram of water distribution network of Plan 3

4) Water Rationing (Plan 4)

Water distribution to Kigese, outside the pilot area, shall be rationed. The water rationing will also be used in the pilot area to reduce water leakage in the night when the water pressure in the distribution pipes is the highest. A valve on the bypass will be closed completely to suspend water distribution for a certain period in the night. The distribution network of the distribution area of the bypass in the pilot area cannot be separated from the bypass, water distribution to this area will be rationed in the same way as that to Kigese. Customers in the water rationing area will have to install water storage tanks for domestic use.

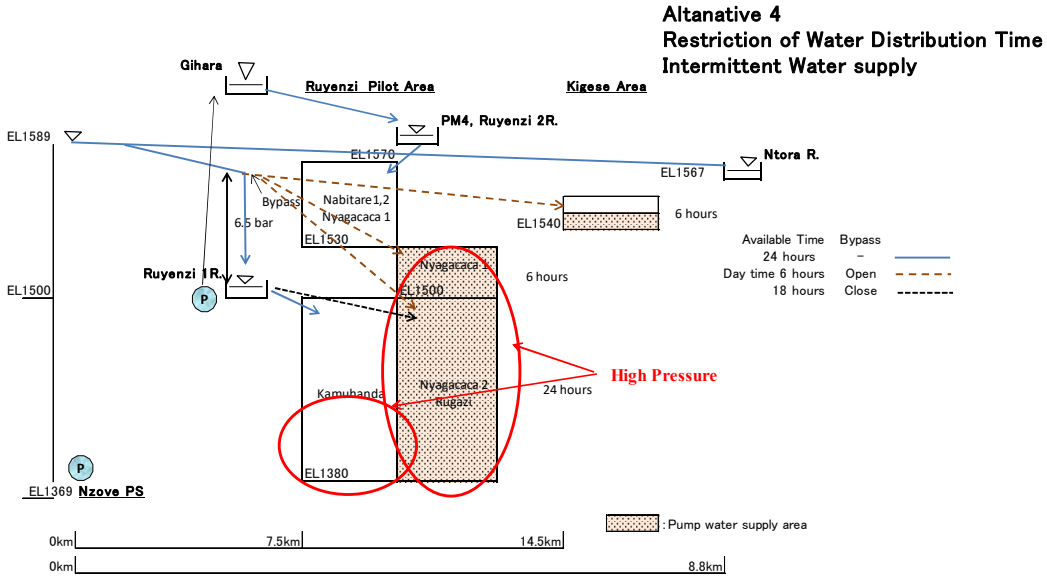


Figure 2.8.6: Schematic diagram of water distribution network of Plan 4

2.8.2 PRV Installation (at 3 locations)

It was decided to implement the measure against high water pressure first and the water leakage survey and repair later in this area based on the lessons learned in Pilot Area 1. The construction of PRV chambers 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. In addition, a water pressure gauge was installed on the bypass.

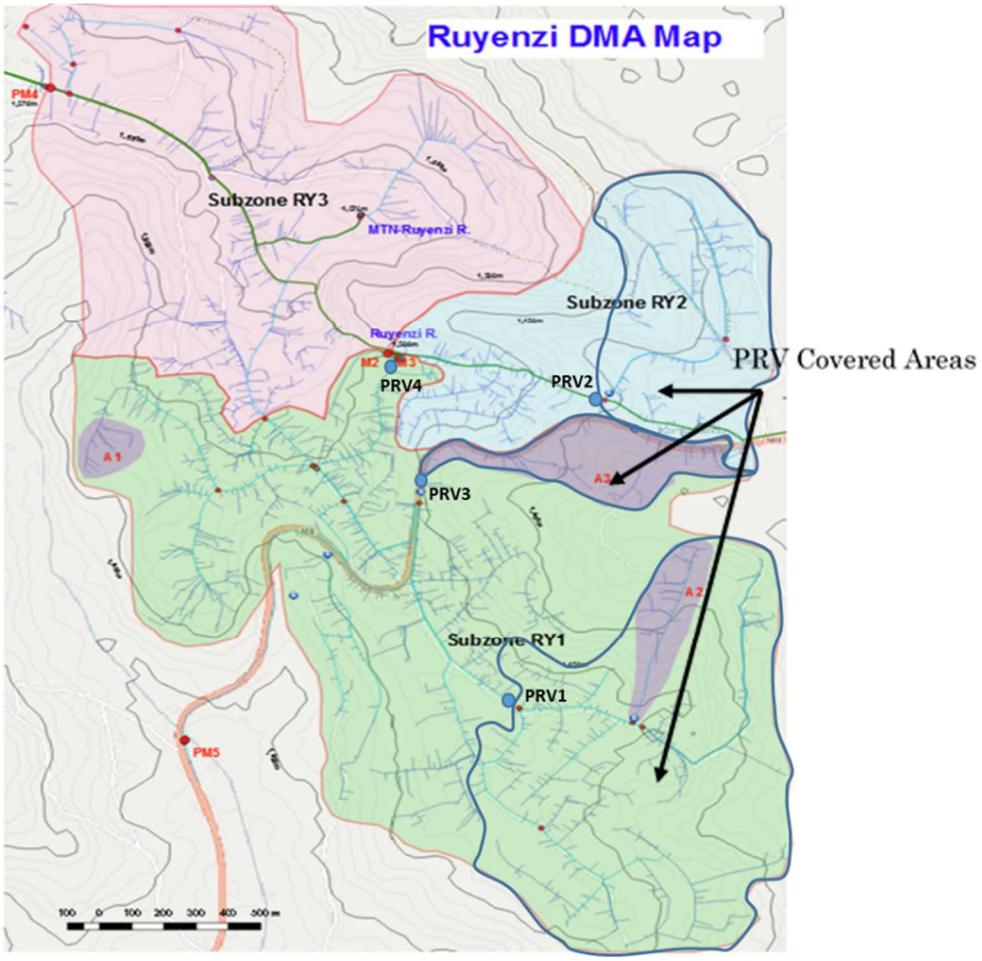


Fig. 2.8.6 Pilot area 2 overview map (Ruyenzi)

1) Subzone RY1

The difference between the water pressure measured at the Ruyenzi Distribution Reservoir and that at the lowest part of the PRV1 pressure reduction area in the night used to be 18.5 bars (1,508 – 1,388 + 65) before the installation of PRV1. However, the installation PRV1 (which reduced the secondary pressure to 3.5 bars) reduced the difference by approx. 6 bars to 12.3 bars (1,476 -1,388 + 35). The installation of PRV3 (which reduced the secondary pressure to 2.0 bars) also reduced the water pressure at PRV3 in the night by approx. 10 bars from 21 bars (1,508 – 1,366 + 65) to 10 bars (1,499 – 1,366 + 20).

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 reduce 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 switching the water distribution areas, and this study has been progressed by WASAC. In order to obtain stable water distribution to the area by switching, it is a precondition that stable water distribution can be obtained from subzone RY3, but the float valves on the pressure reducing water tanks and distribution reservoirs within RY3 have been removed because of breakdown, so it has not been possible to distribute water in accordance with the demand. On January 24, 2019 a float valve was installed on one of these pressure reducing water tanks. The extension of the (PVC, DN50) pipe from RY3 (for approx. 1 km) has been suspended because of the extreme hardness of the ground on the planned pipe installation route and financial problems.

Reference

The Qmnf in the subzone was measured on November 7 - 8, 2018, with the secondary pressure (P2) set at 6.0 bars. As shown in Fig. 2.8.7, Qmnf was measured at 2.6 m3/h.

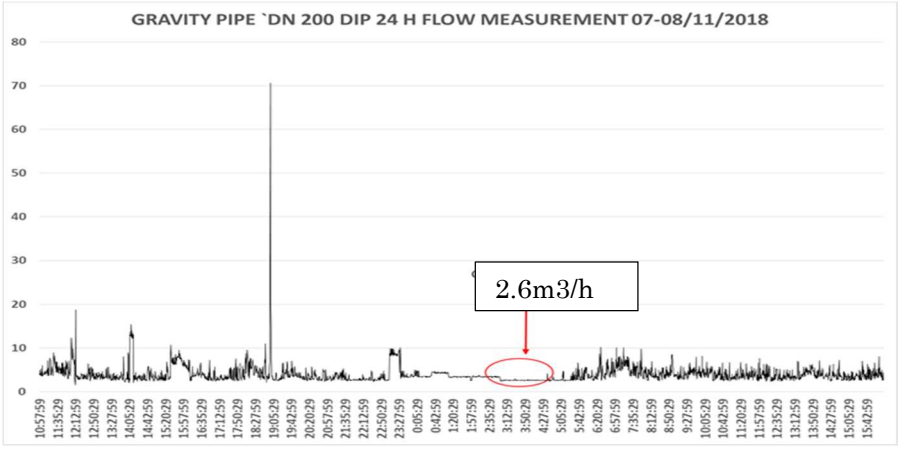


Figure 2.8.7: Measurement of Qmnf at PRV 2 (November 7-8)

Table 2.8.2 shows the result of the water pressure measurement at water taps of customers in RY2. When P2 was set at 5.5. bars, water pressure at customers in the lowest area was high (7.7 bars), while that in the highest area was barely enough to distribute the piped water to the taps (0.2 – 1.0 bar). When P2 was raised by 3 bars to 8.5 bars, the water pressure at the customers at the highest point also rose by approx. 3 bars.

Table 2.8.2. Water pressure measurement in the distribution area (November 13)

Site Pressure Test
Date: 2018/11/13
Ruyenzi

Date	Time	Facility	POC	P1	P2	Area	Location	Elevation
				bar	bar			m
181113	10:20	Tap	240218363	2.0	-	RY3	EL Lowest	1542
181113	10:50	Tap	240215122	0.2-1.0	-	RY2	EL Highest	1460
181113	11:20	Tap	240215051	7.7	-	RY2	EL Lowest	1384
181113	11:30	PRV2	Exist	9.5	5.5			1410
181113	11:40	PRV2	Full Open	9.5	8.5			1410
181113	15:00	Tap	240215122	3.3-3.8	-	RY2	EL Highest	1460
181113	14:40	Tap	240215051	11.0	-	RY2	EL Lowest	1384

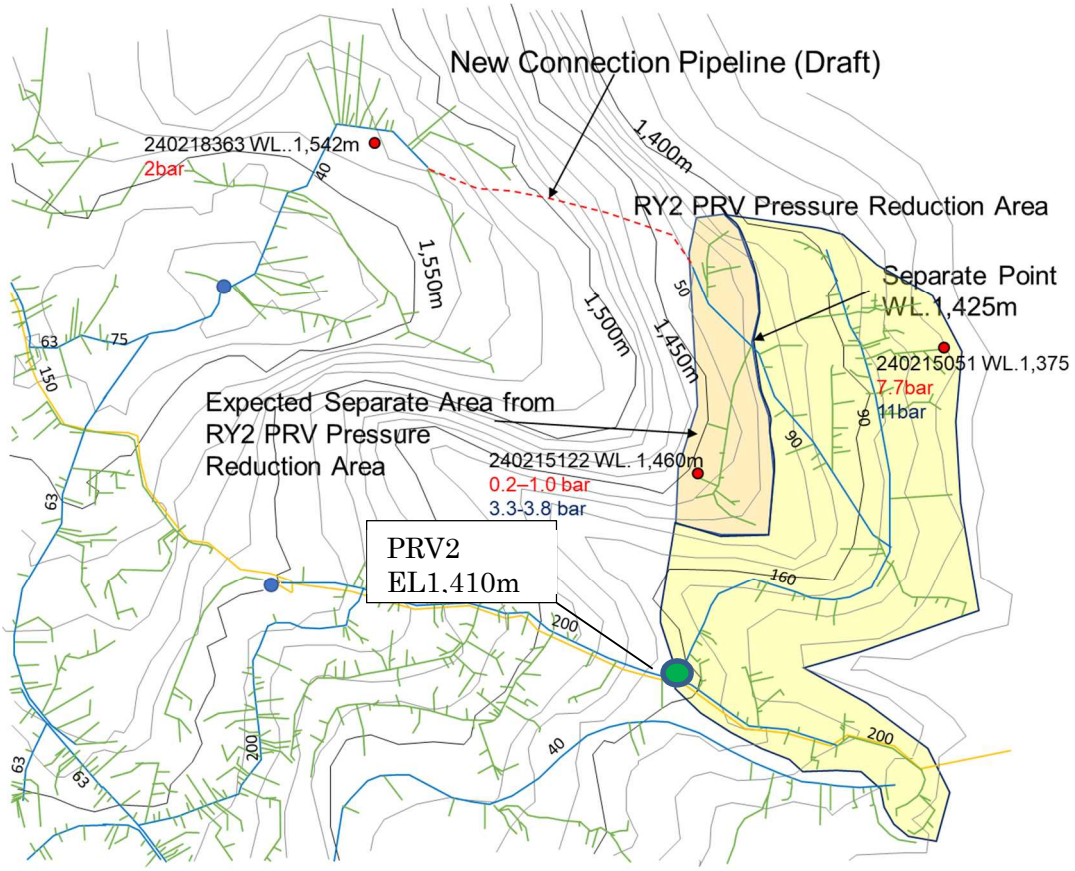


Figure 2.8.8. Distribution area of PRV2

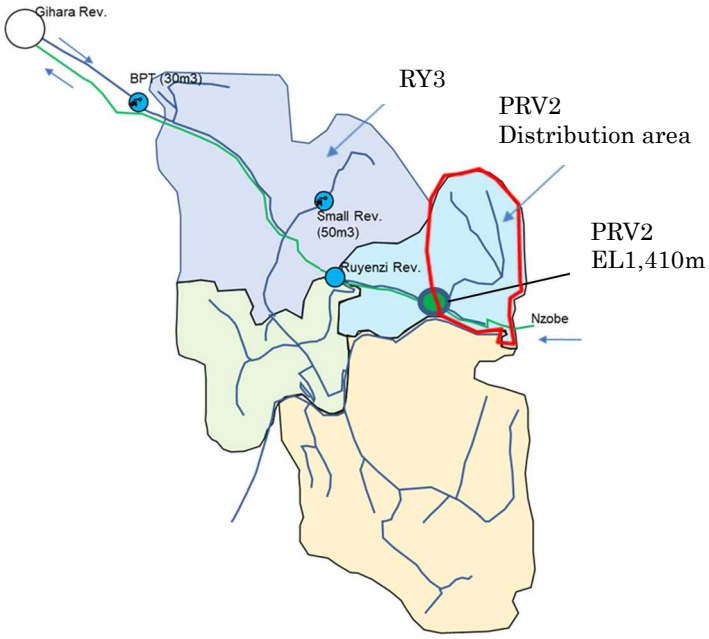


Figure 2.8.9. RY3 and distribution area of PRV2

3) Subzone RY3

In subzone RY3, although there is a central distribution reservoir with an effective capacity of 50 m3, the pipes flowing out from the distribution reservoir are only two 25mm PVC pipes (of which one is for the public tap near the distribution reservoir), the number of customers that are directly supplied is limited to a number of houses near the distribution reservoir.

At present because of shortage of water, delivery of water from the Gihara distribution reservoir (400 m3 effective capacity) is restricted to 3 days per week, on Sundays, Mondays, and Thursdays. In addition, the water supply is often suspended in the daytime because the water in the Gihara Distribution Reservoir is distributed to other areas. Because of the suspension in the daytime, the water consumption in RY3 is high in the night, unlike other subzones. Therefore, it is impossible to measure Qmnf in RY3.

Because of the water supply limitation, most of the water delivered from this distribution reservoir is either distributed directly to residents living along the delivery pipe or is 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 distribution reservoir should have are not being utilized.

When water delivery to RY3 resumes after suspension for the water rationing and water storage tanks of customers have been filled, the volume of water delivery decreases. Because of the large flow rate of the water delivery from the Gihara Distribution Reservoir (72 m3/h), the Ruyenzi 2 Distribution Reservoir, which has a small effective capacity (50 m3), is 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 is a masonry structure. It has 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 through the bypass branching off from the inflow pipe to the reservoir.

There is a 30 m3 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.

2.8.3 Installation of Additional PRVs

(1) Installation of PRV4 in RY1

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 monitoring of the NRW percentage that this measure has had limited effect.

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 in the night was proposed as a compromise between Plans 3 and 4 mentioned in Table 2.8.1. In discussions with the C/P, it was decided that the additional PRV4 should be installed on the distribution pipe directly below the distribution reservoirs. Construction commenced from May 14, 2019, and it was completed on June 30.

The water delivered to the Ruyenzi distribution reservoir by the Nzove water treatment plant pump passes through the bypass of the distribution reservoir, and is distributed to the subzone RY1 pilot area, or it passes through the pilot area becoming leakage water, and about 10% of the volume of inflow water is delivered towards Kigese. Kigese is located at an elevation about 40 m higher than Ruyenzi distribution reservoir, and therefore the water supplied from there has an excess pressure of about 65 m at Ruyenzi distribution reservoir.

In order to reduce the non-revenue water, it was decided to reduce the pressure for 24 hours using PRV4, and because water cannot be delivered to Kigese, it was decided to use PRV4 (the PRV installed on the bypass, for switching with the main pipe) only at night time. Operation at night time commenced from August 29. Attached Document 2.7 shows photographs of the construction.

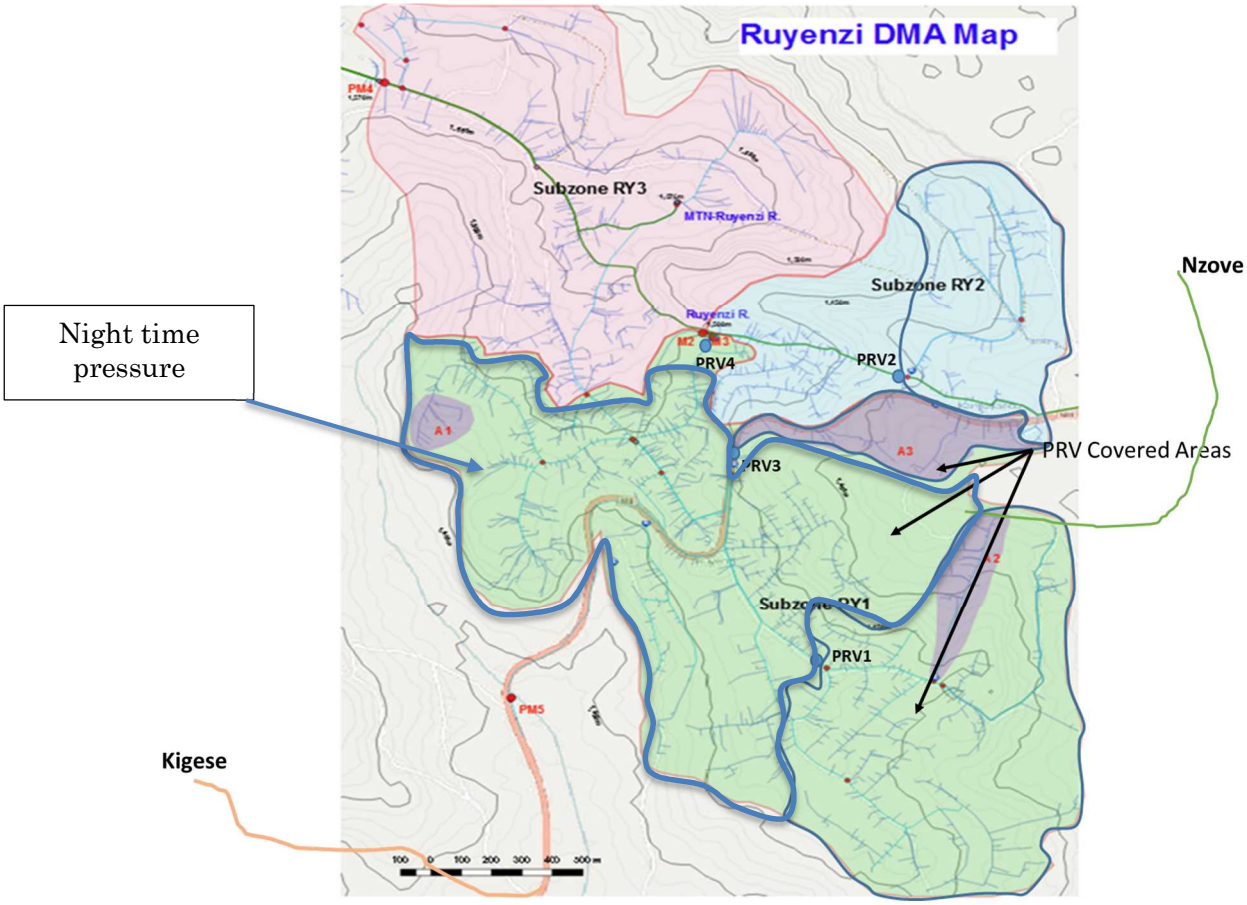


Fig. 2.8.10 Night time pressure adjustment area

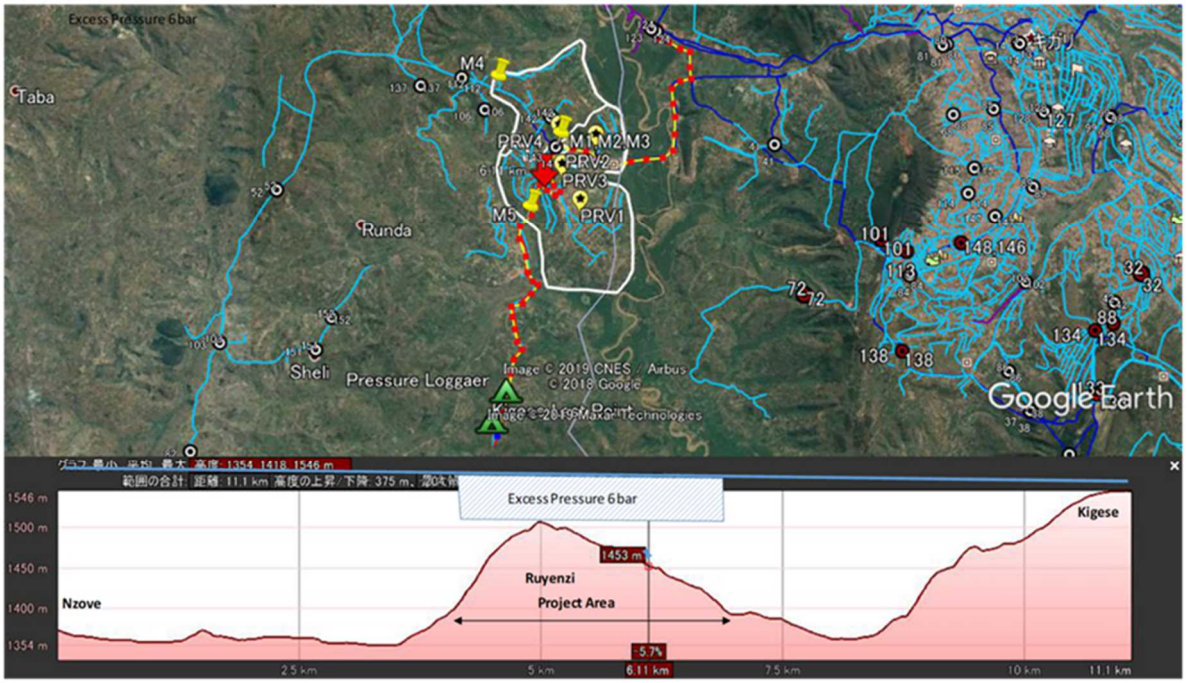


Fig. 2.8.11 Nzove-pilot area-Kigese longitudinal profile

In the flow rate measurements on the bypass at Ruyenzi distribution reservoir (PRV4), the minimum flow

rate at night time is about 40 m³/h, becoming about 90 m³/h during the daytime (Fig. 2.8.12). The measurement on October 7 was 38.7 m³ (Fig. 2.8.13). Incidentally, the accuracy of the existing mechanical flow rate meters was -3.79%. The water delivered to Ruyenzi distribution reservoir by pump from the Nzove water treatment plant passes through the bypass at the distribution reservoir, and is distributed within the subzone RY1 pilot area, and is delivered to Kigese outside the area.

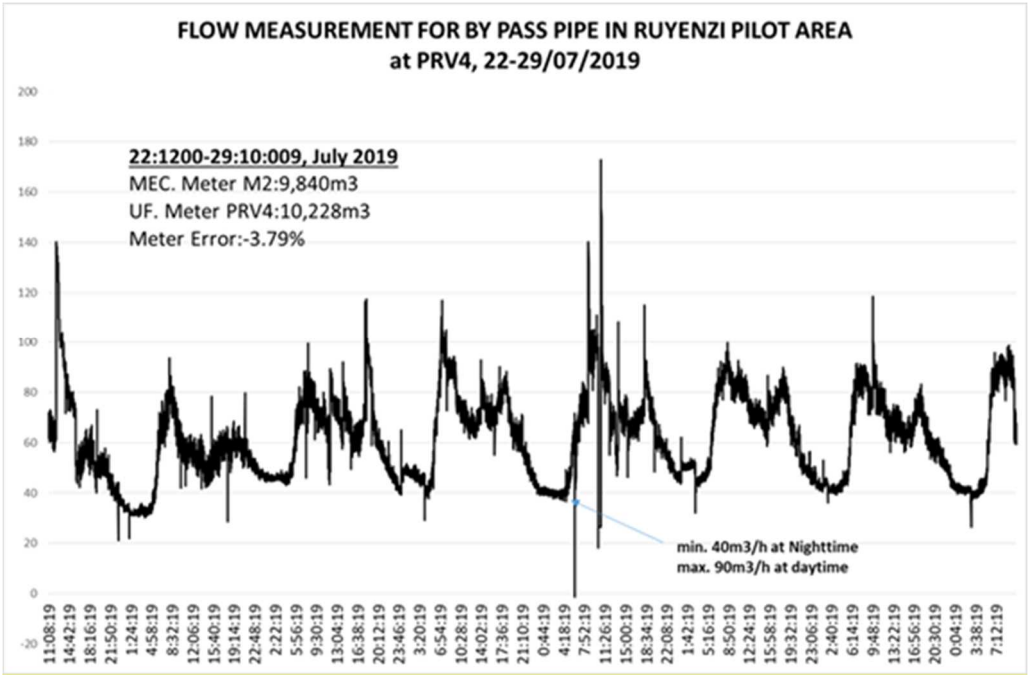


Fig. 2.8.12 Measurement of the flow rate for 7 days directly below the Ruyenzi distribution reservoir (flow rate into the R1 area)

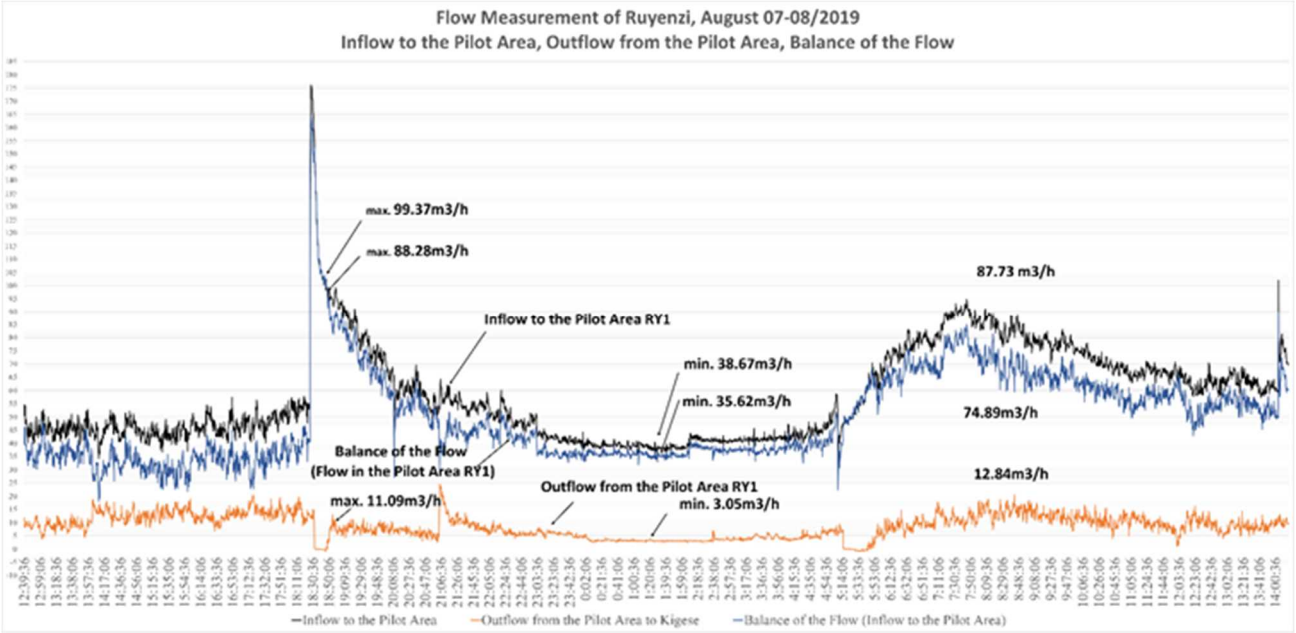


Fig. 2.8.13 Inflow into and outflow from RY1, and quantity distributed within RY1 (July 7-8)

The results of pressure measurements carried out in order to determine the value to which the pressure can

be reduced at night time are shown in attached Document 2.7 (Fig.11, Fig.13). The pressure adjustment by PRV4 at night time obtained from the results of flow rate and pressure measurements in July and August is as follows.

- P2 setting value: 3.5 bar
- PRV4 usage time: 21:00 to 4:00 (opinion of the branch WDO)
- Pressure reduction amount: About 3.0 bar
- P2 setting value: 3.5 bar

Table 2.8.3 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, 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 two pipes	21:00 to 4:00 （7 hours）	Pressure reduction of about 3.0. Pressure within RY1 is envisaged to be 1.0 to 6.0 bar. Night time water leakage within RY1 reduced.	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.

In the future the water supply status in Nyabitare and Kigese within the pilot areas will continue to be monitored, and the potential for further pressure reduction will be studied. The water supply times and the PRV4 setting pressure will be adjusted.

Judging from the quantity of water used during the daytime within the pilot areas, it is envisaged that water can only be supplied to Kigese from 13:00 to 18:00 hours, so in the other time periods it is possible to further reduce the pressure with respect to Kigese. However, it is considered that in the present circumstances pressure reduction greater than 3.0 bar with respect to Nyabitare, which is at a higher elevation than the elevation of the distribution reservoir (1505 m), is not possible, so in order to further reduce the pressure the following measures are necessary.

- Transfer the Nyabitare area within RY1, which is at a higher elevation than the distribution reservoir, to subzone RY3.
- Treat the Nyabitare area in the same way as Kigese, with water supplied a specific time periods.

(2) Installation of 63 mm pipe valves

It was found from the step tests that there was a large amount of water leakage in the water distribution

area of the 63 mm water distribution pipes shown in the figure below. In order to reduce the amount of water leakage in RY1 where the amount of water leakage was large, a control valve (ball valve) was provided at the starting point of the 63 mm water distribution pipe (the branch from the 200 mm bypass), in addition to the PRV4, and day and night pressure control is performed. At this point there was no valve for control installed, even though this was the branch of the water distribution pipe from the main pipe, so if there was water leakage within the area of the 63 mm water distribution pipe, the valve on the main pipe side inevitably had to be closed, thereby shutting off the water in a wide area. This was completed at the end of September 2019, and from October 3 the secondary side pressure was adjusted to 3.5 bar at day time.

In addition in RY3, PRV5 (DN65) was installed for the water distribution pipes in the low elevation area where there was much water leakage, and its operation began on September 23. See Attachment 2.8 for reference.

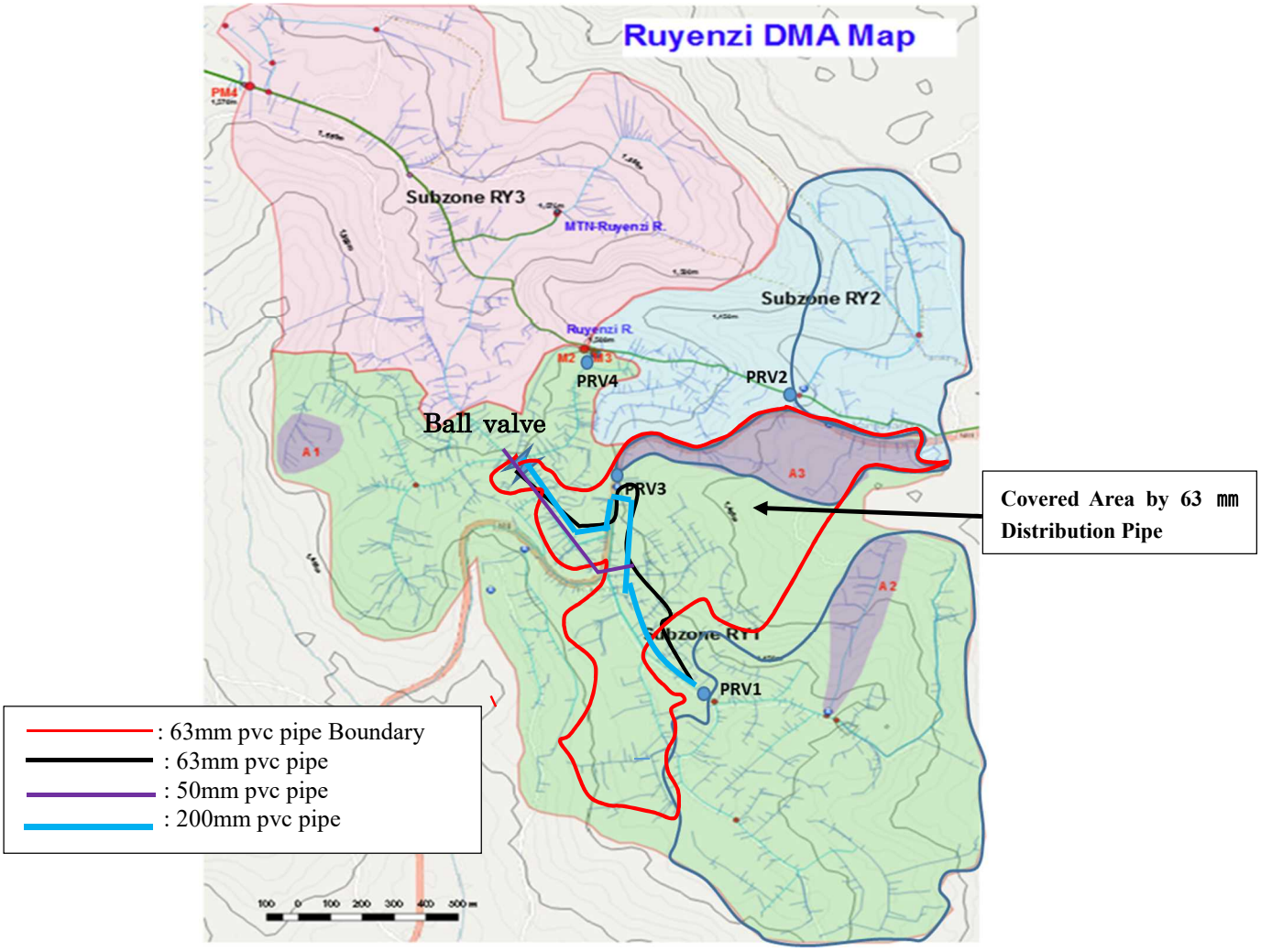


Fig. 2.8.14 Installation of pressure reducing ball valve

Table 2.8.4. PRV pressure settings

PRV number	Subzone	Elevation (m)	P1 (bar)	P2 (bar)	Nominal diameter (mm)
PRV1	RY1	1,476	5.0-9.0	3.5	DN200
PRV2	RY2	1,448	9.5	6.0	DN40
PRV3	RY1	1,410	3.5-6.5	2.0	DN200
PRV4	RY1	1,502	6.0-6.5	3.5	DN200
PRV5	RY3	1,512			63
63mm Valve	RY1	1498	6.0-6.5	3.5	63

2.9 Verification of the Effect of Measures against High Water Pressure

2.9.1 Estimation of the Rate of Qmnf Reduction Rate by Installation of PRVs and Stages Measurement of Water Pressure – Qmnf Relationship

(1) Result of the measurement of the effect

To verify the effect of PRVs on the NRW reduction, the Qmnf values before and after the PRV installation were compared and a staged measurement of Qmnf at different pressure (P2) settings was conducted at the locations of PRV1, PRV2 and PRV3.

Table 2.9.1 below shows the results of the comparison and measurement. The observed rates of Qmnf reduction were between 30 % and 80 %.

In the staged measurement, Qmnf was measured while P2 was reduced by steps of 1.0 bar from the condition that the PRV was fully open.

As shown in the figures below, correlation is found between P2 and Qmnf: As P2 is lowered by a PRV, Qmnf decreases. After the completion of the staged measurement, the pressure settings shown in the table below were applied to the PRVs.

Table 2.9.1 Results of the PRVs effect measurement

Measurement	PRV1	PRV3	PRV2
1. Measurement of baseline values	October 25-26	October 25-26	November 15
Qmnf (m3/h)	7.48m3/h (9.1bar) *Based on the result of staged measurement	1.84 m3/h	3.74m3/h (8.7bar)
2. Staged measurement	October 31	October 31	November 15
Result	See Fig. 2.9.2 below	See Fig. 2.9.6 below	See Fig. 2.9.8 below
	2.1 m3/h (2.5bar)	0.92 m3/h (1.0bar)	2.70 m3/h (6.0bar)
3. Measurement of effect	November 7-8	November 15-16 (The measurement on 7-8 failed.)	November 7 (The minimum P2 setting was 6.0 bar*)
Qmnf (m3/h)	1.5 m3/h (2.2bar)	0.78 m3/h (1.0bar)	2.6 m3/h (6.0bar)
4. Qmnf reduction	5.98m3/h (80%)	1.06m3/h (58%)	1.14m3/h (30%)

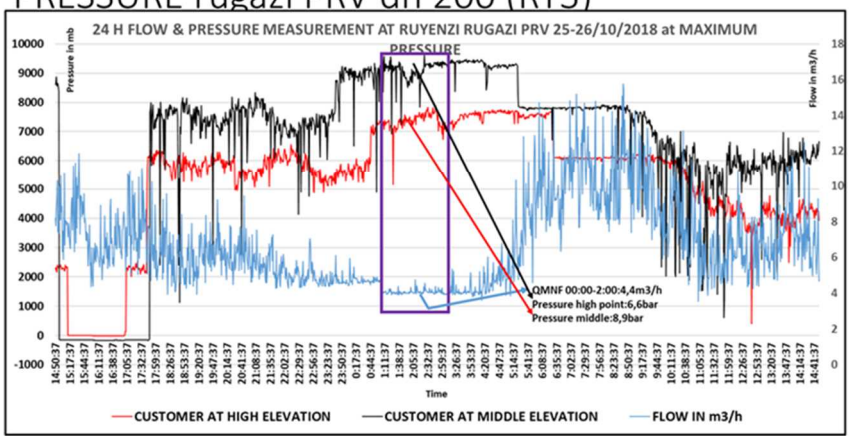
* A Qmnf at the minimum pressure setting of 6.0 bars of approx. 2.6 bars was obtained from the result of the staged measurement. (Fig. 15 PRV2).

(2) Measurement of the effect of PRV 1

Table 2.9.2 Measurement of the effect of PRV1

Date	Activity	Description and result
Oct. 25-26, 2018	Measurement of baseline Qmnf	As there was not an appropriate location to install an ultrasonic flow meter just downstream of PRV1, one of the two diverging pipelines (HDPE 110) further downstream was excavated and the meter was installed on the pipeline. Qmnf was measured at 4.4. m3/h (P2: 6.6 bars). (These values of P2 and Qmnf were almost the same as those measured in the staged measurement conducted on the 31st.) However, because the valve could not be opened fully in the measurement conducted on the 26th, Qmnf of 7.48 m3/h recorded in the beginning of the measurement on the 31st with PRV1 fully open (P2: 9.1 bars) was adopted as the baseline Qmnf.
Oct. 31, 2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was fully open (the condition simulating that without PRV) to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. The final pressure setting: P2 at 2.5 bars (Qmnf: 2.4 m3/h)
Nov. 7-8, 2018	Measurement of Qmnf reduction effect	Qmnf was measured on the 8th. The measurement revealed a decrease of Qmnf from 7.48 m3/h in the case without PRV (P2: 9.1 bar) to 1.5 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 2.2 bars) measured on the 8th, or a Qmnf reduction effect of 5.98 m3/h (or 80 %) (with the pressure reduction of 6.9 bars). The final pressure setting of P2 at 2.5 bars was adopted temporarily. Because the water pressure at water taps near PRV1 was low with this pressure setting, the setting was modified to P2 at 3.5 bars on Feb. 6, 2019.

RUYENZI 24 H FLOW MEASUREMENT AT HIGH PRESSURE rugazi PRV dn 200 (RY3)



Qmnf:4.4m3/h

Figure 2.9.1. Baseline Qmnf measurement at PRV1

Ryenzi
Pressre-Qmnf Measurement
Oct. 31, 2018 01:17-2:25
Bypass PRV1 200mm
Measurement Record

No	Time	P1	P2	Qmnf
		bar	bar	m3/h
	1:05			2.20
1	1:17	9.9	9.1	7.48
2	1:22	10.0	8.1	5.90
3	1:31	10.1	7.0	4.90
4	1:37	10.1	6.1	4.10
5	1:45	10.2	5.0	3.40
6	1:52	10.3	4.0	2.90
7	2:00	10.4	3.0	2.60
8	2:06	10.4	2.0	2.10
9	2:15	11.0	1.0	2.20
10	2:21	11.5	0.0	2.00
11	2:25	11.0	2.5	2.30

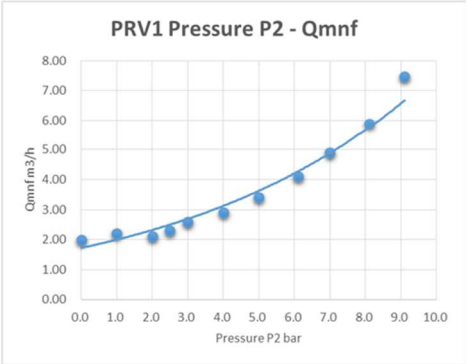


Figure 2.9.2. Staged measurement of Qmnf at PRV1 with different P2 settings

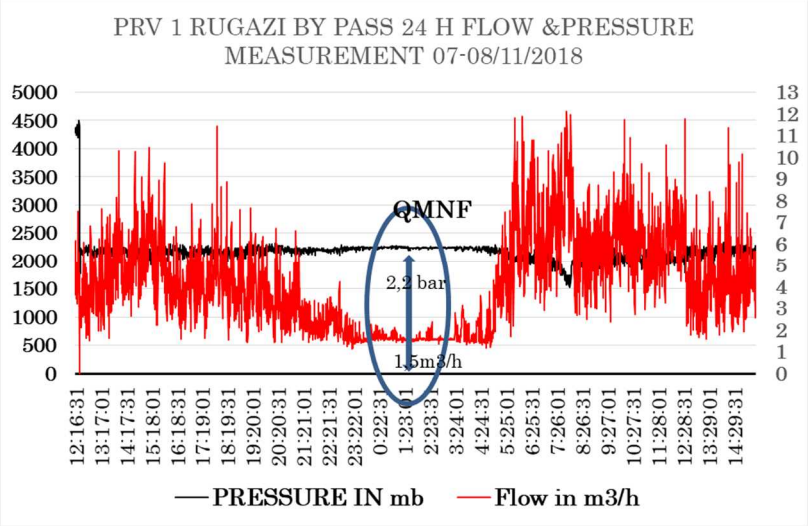


Figure 2.9.3. Effect of PRV1 installation on Qmnf

Table 2.9.3. Measurement of pressure at PRV1 (October 25)

PRV Survey
Date 25th October, 2018
Place Ruyenzi
PRV1: 200mm 1475

Pressure Reading (bar)

Day	Time	Flow Rate	P1	P2	Difference	Opening
		m3/h	bar	bar		
25	10:05	6.4	7.5	2.5	5.0	No touch
25	12:20	8.3	8.0	5.0	3.0	Full Open (Fail)
26	15:26	5.5	8.0	2.0	6.0	
26	15:40		8.0	8.0	0.0	Full Open (Success)
26	15:47		8.0	2.0	6.0	Adjusted to 15:26

Flowmeter (m3/h)

Day	Time		Flow Rate	For		Place
			m3/h			
25	12:10		6.4	Setting Up		Down S of PRV
25	12:05		8.3	Full Open		Down S of PRV
26	14:53		5.5	Removed		Down S of PRV

POC Pressure measurement (bar)

Day	Time		Pressure	Device		POC No
			bar			
25	11:17		–	–		~~240215084~~
25	11:33		2.5	Manometer	Data Logger	240214522
25	13:03	解放後	~~3.4~~	~~Manometer~~		~~240215065~~
25	13:36	解放後	6.9	Manometer	Data Logger	240219069
25	13:45	解放後	–	–		~~240216735~~
25	14:21	解放後	16.0	Manometer		240216098
26	14:50	解放後			Data Logger	240214522
26	13:36	解放後			Data Logger	240219069

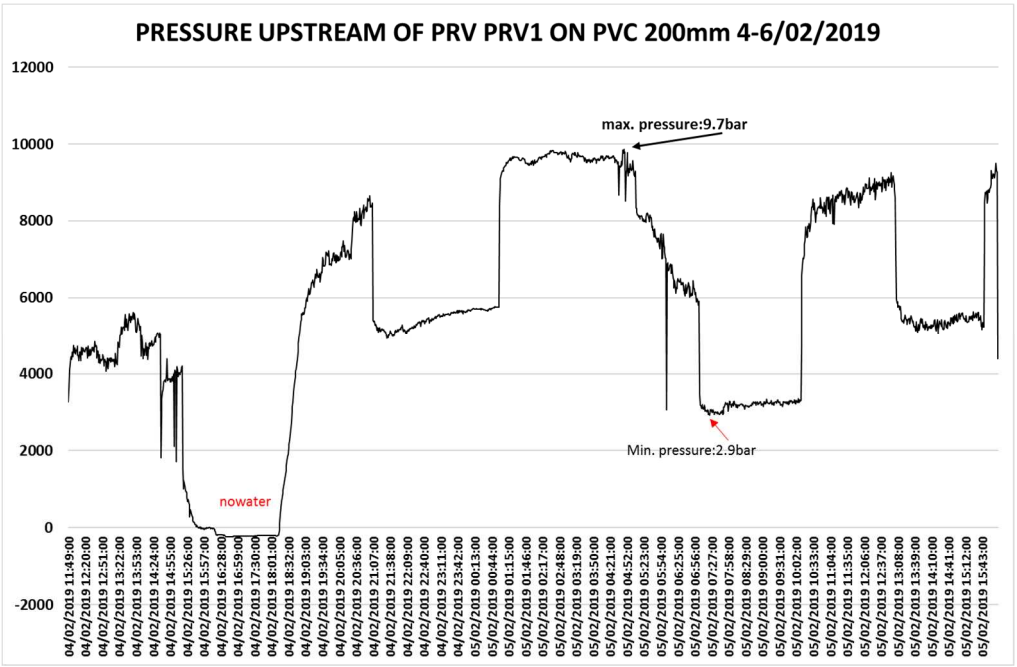


Figure 2.9.4. Measurement of P1 of PRV1

(3) PRV3

Table 2.9.4 Measurement of the effect of PRV3(in Ruyenzi)

Date	Activity	Description and result
Oct. 25-26, 2018	Measurement of baseline Qmnf	The baseline Qmnf was measured with PRV installed on the bypassline fully open (P1:4.0 bars, P2: 4.0 bars). Qmnf was 1.84 m3/h.
Oct. 31, 2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was fully open (the condition simulating that without PRV) to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. The final pressure setting: P2: 1.0 bar (Qmnf: 0.92 m3/h)
Nov. 15-16, 2018 (The measurement attempted on the 7th and 8th failed.)	Measurement of Qmnf reduction effect	Qmnf measurement was conducted. The measurement revealed a decrease of Qmnf from 1.84 m3/h in the case without PRV (P2: 4.0 bars) to 0.78 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 1.0 bar), or a Qmnf reduction effect of 1.06 m3/h (or 58 %) (with the pressure reduction of 3.0 bars).

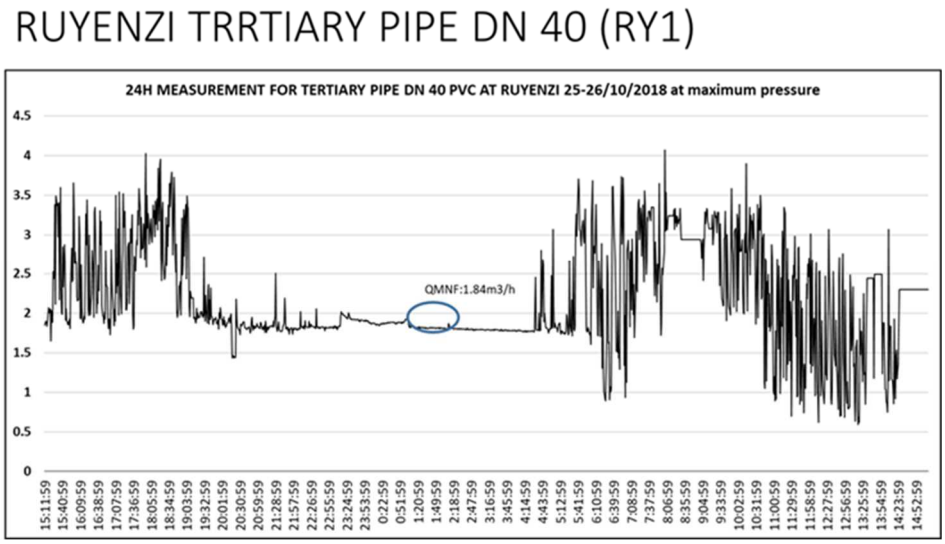


Figure 2.9.5. Measurement of baseline Qmnf at PRV3

Ryenzi
Pressre-Qmnf Measurement
Oct. 31, 2018 01:13-1:47
Bypass PRV3 40mm
Measurement Record

No	Time	P1	P2	Qmnf
		bar	bar	m3/h
1	1:13		7.0	1.637
2	1:19		6.0	1.528
3	1:23		5.0	1.430
4	1:27		4.0	1.332
5	1:31		3.0	1.096
6	1:40		2.0	1.063
7	1:43		1.0	0.920
8	1:47		0.0	0.647

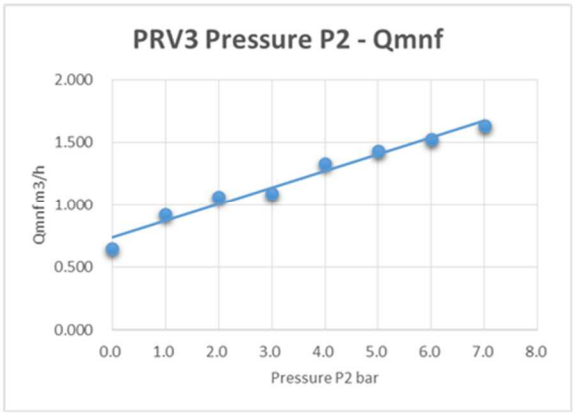


Figure 2.9.6. Staged measurement of Qmnf at PRV3 with different P2 settings

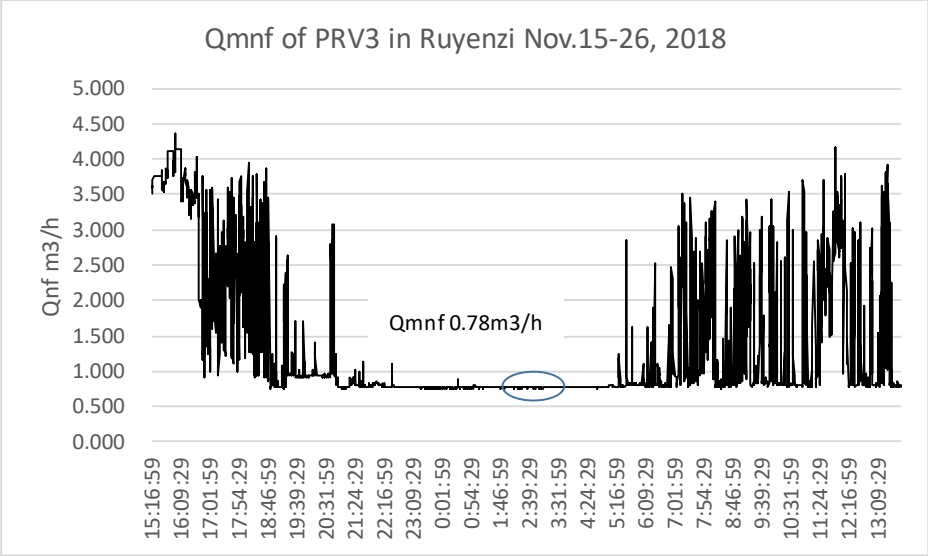


Figure 2.9.7 Effect of PRV3 installation on Qmnf

Table 2.9.5. Pressure measurement at PRV3 (October 25, 26)

PRV Survey
Date 25th October, 2018
Place Ruyenzi
PRV3: 40mm 1462

Pressure Reading (bar)

Day	Time		P1	P2	Difference	Opening
			bar	bar	bar	
25	9:55		5.0	4.0-2.0	1.0-3.0	No touch
25	13:20		5.5	4.9	0.6	No touch
25	13:25		4.0	4.0	0.0	Bypass Full Open
26	16:00		-	-	-	
26	17:30		-	-	-	Bypass Full Close

Flowmeter (m3/h)

Day	Time		Flow Rate	For		Place
			m3/h			
25	15:22		1.8	Setting Up		Down S PRV3
26	16:00		2.3	Removed		Down S PRV3

POC Pressure measurement (bar)

Day	Time		Pressure	Device		POC No
			bar			
25	14:50		12.5	Manometer		240215008

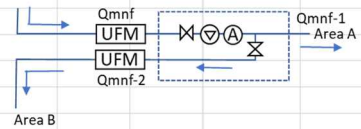
3) PRV2

Table 2.9.6 Measurement of the effect of PRV2

Date	Activity	Description and result
Nov. 15, 2018	Measurement of baseline Qmnf	An ultrasonic flow meter was installed just upstream of the PRV. The Qmnf measurement of 3.74 m3/h taken at the beginning of the staged measurement on the 15th while PRV was kept as open as possible (P2: 8.7 bars) was used as the baseline Qmnf.

Nov. 15, /2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was as open as possible to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. A sharp drop of Qmnf was observed when the pressure was reduced below 4 bars. However, the water flow from water taps in the high elevation area was reduced when P2 was reduced below 6.0 bars. For these reasons, the final pressure setting of P2 = 6.0 bars (Qmnf = 2.70 m3/h) was adopted.
Nov. 7, 2018	Measurement of Qmnf reduction effect	There is an area above the elevation of PRV2, EL 1,410 m, downstream of the valve. The highest point in this area is at EL 1,460 m. The measurement of the water pressure at water taps of customers in the highest area revealed that water barely reached the tap in this area (water pressure of 0.2 - 1.0 bar) when P2 was set at 5.5 bars. Therefore, P2 could only be reduced to around 6.0 bars. The Qmnf measurement taken in November 7 and 8 with P2 set at 6.0 bars was 2.6 m3/h Qmnf decreased from 3.74 m3/h in the case without PRV (P2: 8.7 bars) to 2.6 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 6.0 bars), or a Qmnf reduction effect of 1.14 m3/h (or 30 %) (with the pressure reduction of 2.7 bars).

Ruyenzi
Pressure-Qmnf Measurement
N0v. 15, 2018 01:10-01:54
Sub-zone RY2 DN200mm



Measurement Record

No	Time	P1	P2	Qmnf	Q mnf-1	Q mnf-2	Note
1	1:10	9.5	8.7	3.74	3.64	0.1	Full Open
2	1:18	9.5	8.0	3.45	3.30	-0.5 to +0.8	
3	1:25	9.5	7.0	3.21	3.21	-1.4 to +0.3	
4	1:32	9.5	6.0	2.70	2.70	-0.2 to +0.1	
5	1:40	9.5	5.0	2.63	2.63	-0.6 to +0.5	
6	1:48	9.5	4.0	2.33	2.33	-0.1 to 0.0	
7	1:54	9.5	3.5	0.95	0.95	-0.3	Full Close

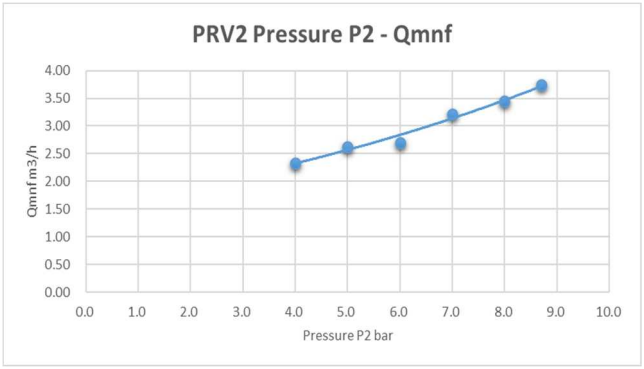


Figure 2.9.8. Staged measurement of Qmnf at PRV2 with different P2 settings

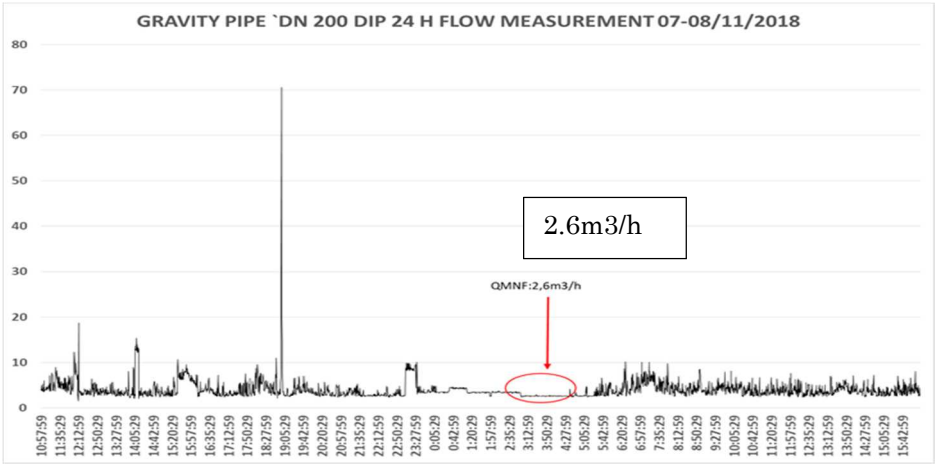


Figure 2.9.9. Effect of PRV2 installation on Qmnf (November 7-8)

Installation of a PRV in Subzone RY2 (PRV2)

Preparation for the casting of protective concrete

Valve assembly chamber and protective concrete

Survey of the relationship between water pressure and Qmnf in Subzone RY1 (PRV2)

Installation of ultrasonic flow meter

Adjustment of PRV

2.9.2 Verification in a Service Area of a Tertiary Distribution System (A2 Area)

To verify the NRW reduction effect of PRVs with NRW rates, a small area in the service area of a tertiary distribution system was demarcated in RY1 and the volume of water leakage in this area was measured from the flow rates measured with an ultrasonic flow meter (continuous logging for four days) and the readings of the water meters of all the customers in the area at different settings of PRV (when the valve was set for the pressure reduction and when it was open) between January 28 and February 1, 2019. The measurement proved that the pressure reduction by the PRV had greatly reduced the water leakage.

As shown in Fig. 15 and Table 3, the NRW rate was 58.9 % when the secondary pressure was regulated at 2.5 bars with the PRV, while the rate was 76.8 % when the PRV was open (P2 within a range between 6.6 and 9.0 bars). These figures verify 17.9 % NRW reduction by the PRV. The Qmnf measured while the pressure was regulated was 0.33 m3/h. When the Qmnf is 0.33 m3/h, the water leakage rate is 58.2 %, which accounts for almost all the total NRW rate of 58.9%. Therefore, the commercial loss, which was obtained by deducting the water leakage rate from the total NRW rate, was 0.7 %. This commercial loss corresponds to approx. 1 % of the billed water consumption, which was within the range of the meter error.

However, even if the pressure has been reduced by the PRV, the NRW rate is high (approx. 59 %) because of the large elevation difference between the site of the PRV and houses of customers (60～90m).

Table 2.9.7 Survey results for demonstrating the effect of comparing NRW rates of PRVs

Schedule of the Effect Measurement Survey of PRV in Ruyenzi RY1

PRV1 in RY1 Ruyenzi

Day		1/28	1/29	1/30	1/31	2/1	2/2
		Mon	Tue	Wed	Thu	Fri	Sat
PRV Pressure P2 (bar)		2.5		Full open: Day 6.0 Night 9.0		Adjust. 3.0	
Flow Meter Setting/Out		●				●	
Customer Meter Index Reading		●	●	●	●	●	

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	1/30-2/1
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)	11.1921	12.1959	23.3880
											Inflow (m3)	27.216	52.673	79.8890
											NRW (m3)	16.0239	40.4771	56.5010
											NRW Rate (%)	58.9%	76.8%	70.7%

Qmnf(m3/h)	0.330
Qmnf 2days(m3)	15.840
Meter Error (m3)	0.1839
Commercial Loss(%)	0.7%
Physical Loss(%)	58.2%

Items	Term1 (2days)	Term2 (2days)
PRV P2 Pressure (bar)	2.5	6.0 - 9.0
Inflow (m3)	27.22	52.67
Consumption (m3)	11.19	12.20
NRW (m3)	16.02	40.48
NRW Rate (%)	58.9%	76.8%
Commercial Loss(%)	0.7%	
Physical Loss(%)	58.2%	

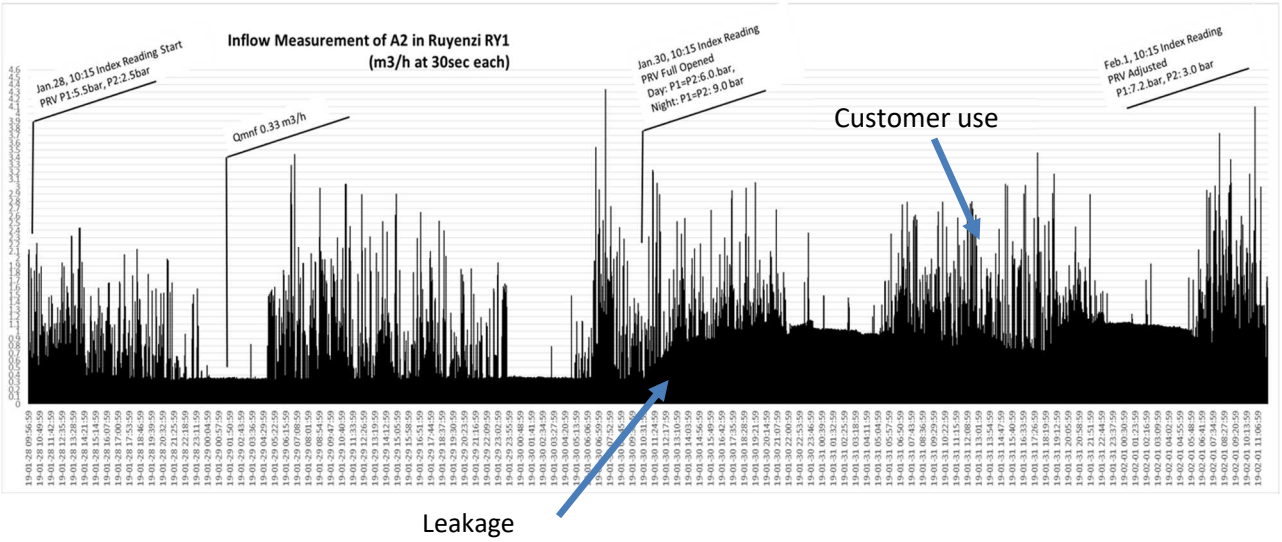


Fig. 2.9.10 Survey results for demonstrating the effect of comparing NRW rates of PRVs

2.9.3 Use of Google Earth Map for the Creation of Water Leakage Repair Map 1902

(1) Plotting locations of leakage repairs

The locations of the leakage repairs in the repair record for the period between August 2017 and December 2018 were plotted on Google Earth. During the same period, leakage repairs were conducted at 10 locations/month and 31 locations/month, on average, in Kadobogo and Ruyenzi, respectively. These figures reveal that water leakage occurred more frequently in Ruyenzi where problems caused by high water pressure were more serious. The map shows that, among the three subzones in Ruyenzi, a particularly large number of the repairs were conducted in RY1 where water was distributed directly from the Nzove Pumping Station through the pipeline that bypassed the Ruyenzi Reservoir (Fig.2.9.12). The map also shows that many leaks occurred from the existing pipes (HDPE) in Subzone PM1 in Kadobogo, which were replaced in February 2019, and the pipes in PM2 that were replaced in June 2018(Fig2.9.11). As mentioned above, plotting the data of leakage repairs on a map enables visual presentation of areas prone to water leakage and the locations of pipes from which water leakage has occurred. Therefore, this method can be an important tool in the preparation of a plan for leakage reduction.

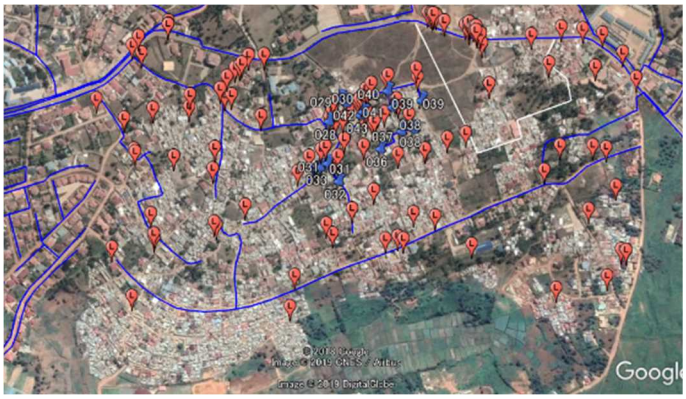


Fig. 2.9.11 Plot of leakage repairs location in Kadobogo

Fig. 2.9.12 Plot of leakage repairs location in Ruyenzi

Kacyiru and Nyarugenge Branches began measuring XY coordinates of the locations of leakage repairs and entering the coordinate data in a record book by hand in August 2017. Since around June 2018, they have been using personal computers to enter the data in the form designated in 5YSP. To convert the hand-written data into Microsoft Excel format, workers were employed to transfer the hand-written data to Microsoft Excel spreadsheets in this project. Considerable labor was spent on data collation. It is essential to enter the data of leakage repairs correctly in personal computers and collate them daily to analyze water leaks in the past and prepare a work plan for the activities to reduce water leakage. The use of Microsoft Excel improves the efficiency of data analysis.

Data should be entered in Excel spreadsheets in such a way that they can be easily used in the analysis. The following should be observed when entering the data in the form designated in 5YSP.

- X-coordinate and Y-coordinate of a location of leakage repair shall be entered in separate cells.
- Enter the data of district, sector, cell and village of each leak site in separate cells without omission because all of them are essential for the analysis.

To evaluate the effect of leakage reduction measures, a study should be conducted to confirm whether the measures had reduced the number of leakage repairs. No reduction in the number of repairs suggest the possibility of recurrence of water leakage.

Table 2.9.8. Changes in the number of leakage repairs (in the pilot area)

	Kadobogo			Ruyenzi		
Month	2017	2018	2019	2017	2018	2019
Jan	2	16		42	50	
Feb	13	11		53	39	
Mar	3	11		43	45	
Apr	6	13		38	44	
May	15	11		30	17	
Jun	8	7		32	24	
Jul	9	NA		28	26	
Aug	8	11		27	5	

Sep	14	9		27	36	
Oct	15	15		38	10	
Nov	21	4		49	42	
Dec	9	NA		26	33	
Total	123	108		433	371	0
Average	10.3	10.8		36.1	30.9	0.0

(2) Changes in the number of leakage repairs

Since the location of PRVs in Ruyenzi is limited to downstream areas of subzones, the reduction in quantity can not be judged in the whole subzones. However, when looking at the plot of the leakage repair location, in the downstream area of the PRVs installation site, a decrease in the Leakage Repair Number after installation of the PRVs is observed.

Ruyenzi Pilot Area

Leakage Repair Number

	RY1	RY2	RY3	Total	Note
Jan-17	n/a	n/a	n/a	42	
Feb-17	n/a	n/a	n/a	53	
Mar-17	n/a	n/a	n/a	43	
Apr-17	n/a	n/a	n/a	38	
May-17	n/a	n/a	n/a	30	
Jun-17	n/a	n/a	n/a	32	
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	Baseline
Apr-18	37	3	2	42	Baseline
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	20	6	3	29	
Mar-19	27	2	2	31	
Total	455	56	51	585	
Average	21.7	2.7	2.4	27.9	
Before Oct. 2018	22.1	2.5	1.7	27.8	
After Nov. 2018	20.2	3.2	4.8	28.2	

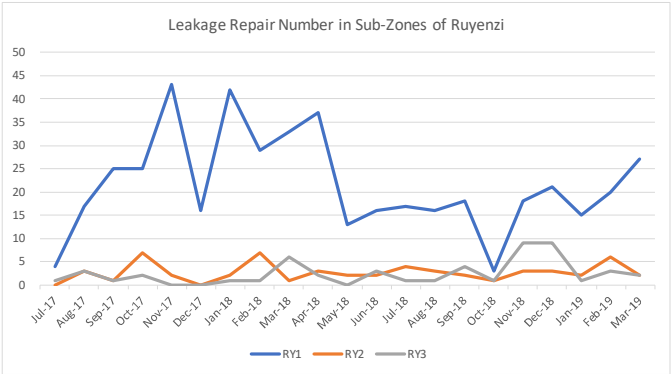
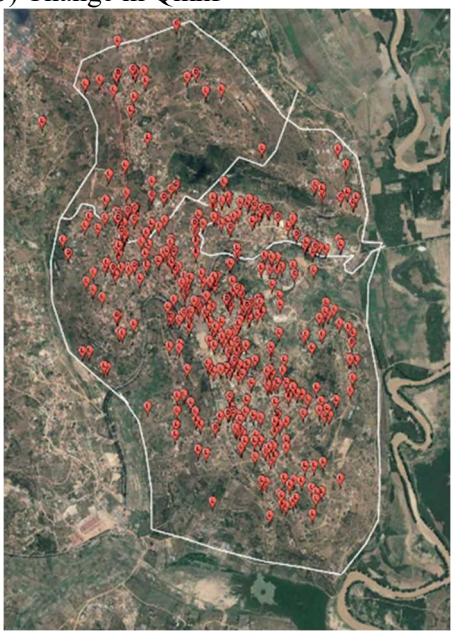
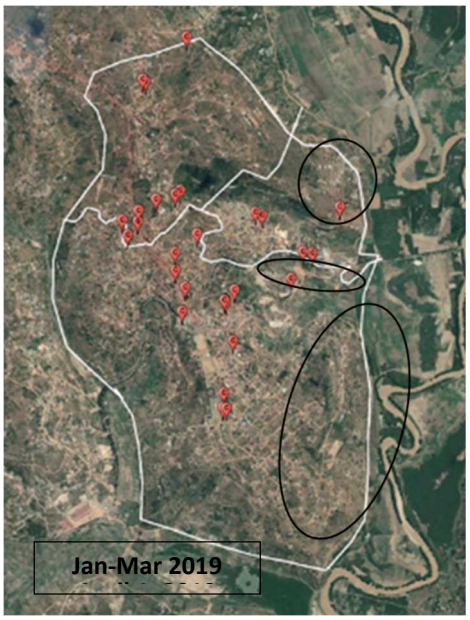


Fig. 2.9.13 Leakage repairs history of Kadobogo

(3) Change in Qmnf



Before PRV Installatio



After PRV Installation

Fig. 2.9.14 Plot of leakage repairs location in Kadobogo（After PRV Installation）

2.10 Measurement of NRW Rates and Verification of Effect

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 (See Attachment S2, Effect of the Pilot Project Activities, for reference.).

① Change in NRW rate

② Change in the number of the repair

③ Change in Qmnf

④ Cost-benefit analysis

(1) Change in NRW Rate

Table 2.10.1 Achievement value of NRW Rate

Item	Ruyenzi	Remarks
Baseline	68%	Average of March and April 2018
Target value	25%	
Achievement value October 2019	55.5%	12.5% reduction (18% of baseline)
Achievement value November 2019	58.7%	9.3% reduction (14% of baseline)

Table 2.10.2. Comparison of averages in the period between March and October in 2018 and 2019

Item	Unit	2018	2019	Difference
Water distribution	m3/month	47,479	46,560	-1,531

Billed water consumption	m3/month	19,501	21,032	+1,531
Volume of NRW	m3/month	27,978	25,528	- 2,450
NRW rate	%	58.9	54.8	-4.1

The NRW rate has decreased by approx. 10 % (15 % of the baseline value) from the baseline value of 68 % in March and April 2018 to 59 % (as of November 2019). The current value is still far larger than the target of 25 %.

The comparison of data of the same period (eight-month period between March and August) in 2018 and 2019 revealed a 4.1 % reduction in the NRW rate, as seen in Table 2.10.2.

Table 2.12 shows the NRW calculation table, Fig. 2.13 shows the NRW trend in the area overall, and Figs. 2.14 to 2.17 show the NRW trend in each subzone.

A pipe that was used for transporting water from the pilot area to the Kigese Area was discovered in February 2018. Therefore, the calculated volumes of NRW in the period from the installation of additional flow meters by WASAC up to February 2018 can be used only as reference data. The volume of water distribution to the pilot area is obtained by subtracting the measured volume of water outflow to Kigese from the sum of the volumes of water distribution measured with the flow meter at PM4 and the two flow meters at the Ruyenzi 1 Distribution Reservoir (on the bypass and the distribution pipe to RY2).

Table 2.10.3 Ruyenzi NRW calculation table

Table-Ruyenzi NRW Analysis

		2018												2019										Mar-Oct	Mar-Oct
DMA Number		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	2018	2019
Input Volume (m3/M)		58,710	51,769	48,969	56,814	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	47,479	46,560
IVave.			53,149	52,517	52,203	48,359	42,830	41,605	44,847	48,519	48,981	49,235	48,496	48,046	45,030	45,073	43,772	45,119	44,762	47,621	50,361	50,055			
	RY1	36,506	31,146	31,237	40,144	35,550	20,439	25,125	27,140	31,371	34,239	30,247	27,636	33,465	32,215	23,971	35,279	28,190	27,490	32,152	36,365	35,270	32,534	30,656	31,406
			32,963	34,176	35,644	32,044	27,038	24,235	27,879	30,917	31,952	30,707	30,449	31,105	29,884	30,488	29,147	30,320	29,277	32,002	34,596	34,723			
	RY2	12,330	12,070	8,930	8,090	7,290	9,340	7,420	10,750	7,720	7,940	8,790	10,510	6,220	6,240	6,230	5,500	4,300	5,910	6,910	7,040	8,660	6,360	8,435	6,364
			11,110	9,697	8,103	8,240	8,017	9,170	8,630	8,803	8,150	9,080	8,507	7,657	6,230	5,990	5,343	5,237	5,707	6,620	7,537	7,353			
	RY3	9,874	8,553	8,802	8,580	7,986	7,658	7,681	9,263	8,070	9,063	9,502	9,777	9,341	8,734	8,674	8,377	10,795	9,517	9,022	8,458	7,205	8,274	8,388	8,790
			9,076	8,645	8,456	8,075	7,775	8,201	8,338	8,799	8,878	9,447	9,540	9,284	8,916	8,595	9,282	9,563	9,778	8,999	8,228	7,979			
Billed Water (m3/M)		22,103	17,993	19,723	18,147	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	19,501	21,032
BWave.			19,940	18,621	17,541	16,807	17,728	20,750	21,758	21,650	19,186	19,106	20,001	21,543	20,807	19,937	19,493	19,549	20,835	22,393	23,829	22,333			
	RY1	13,804	11,744	12,666	11,555	8,909	11,067	13,443	15,821	13,676	12,216	10,819	12,496	14,012	14,098	11,649	13,861	12,910	12,019	16,358	15,639	15,310	13,953	12,419	13,962
			12,738	11,988	11,043	10,510	11,140	13,444	14,313	13,904	12,237	11,844	12,442	13,535	13,253	13,203	12,807	12,930	13,762	14,672	15,769	14,967			
	RY2	3,054	2,138	2,719	2,700	1,993	2,848	2,999	2,757	2,404	2,871	1,909	2,920	3,555	2,820	2,843	2,879	2,739	2,494	3,443	3,462	2,923	2,180	2,661	2,870
			2,637	2,519	2,471	2,514	2,613	2,868	2,720	2,677	2,395	2,567	2,795	3,098	3,073	2,847	2,820	2,704	2,892	3,133	3,276	2,855			
	RY3	5,245	4,111	4,338	3,892	3,851	3,605	4,468	5,242	4,463	5,501	3,699	4,888	5,704	4,137	3,602	3,922	4,073	3,751	4,717	5,296	4,338	3,897	4,420	4,200
			4,565	4,114	4,027	3,783	3,975	4,438	4,724	5,069	4,554	4,696	4,764	4,910	4,481	3,887	3,866	3,915	4,180	4,588	4,784	4,510			
NRW (m3/M)		36,607	33,776	29,246	38,667	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	27,978	25,528
NRWave.			33,210	33,896	34,662	31,552	25,102	20,855	23,089	26,868	29,795	30,128	28,495	26,503	24,223	25,136	24,279	25,570	23,927	25,228	26,532	27,723			
	RY1	22,702	19,402	18,571	28,589	26,641	9,372	11,682	11,319	17,695	22,023	19,428	15,140	19,453	18,117	12,322	21,418	15,280	15,471	15,794	20,726	19,960	18,581	18,237	17,444
			20,225	22,187	24,600	21,534	15,898	10,791	13,565	17,012	19,715	18,864	18,007	17,570	16,631	17,286	16,340	17,390	15,515	17,330	18,827	19,756			
	RY2	9,276	9,932	6,211	5,390	5,297	6,492	4,421	7,993	5,316	5,069	6,881	7,590	2,665	3,420	3,387	2,621	1,561	3,416	3,467	3,578	5,737	4,180	5,774	3,493
			8,473	7,178	5,633	5,726	5,403	6,302	5,910	6,126	5,755	6,513	5,712	4,558	3,157	3,143	2,523	2,533	2,815	3,487	4,261	4,498			
	RY3	4,629	4,442	4,464	4,688	4,135	4,053	3,213	4,021	3,607	3,562	5,803	4,889	3,637	4,597	5,072	4,455	6,722	5,766	4,305	3,162	2,867	4,377	3,968	4,591
			4,512	4,531	4,429	4,292	3,800	3,762	3,614	3,730	4,324	4,751	4,776	4,374	4,435	4,708	5,416	5,648	5,598	4,411	3,445	3,469			
NRW ratio (%)		62.4%	65.2%	59.7%	68.1%	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%	58.9%	54.8%
NRWRave.			62.4%	64.3%	66.3%	64.1%	57.4%	50.2%	51.3%	55.2%	60.8%	61.2%	58.8%	55.2%	53.8%	55.6%	55.3%	56.6%	53.6%	53.1%	52.6%	55.5%			
	RY1	62.2%	62.3%	59.5%	71.2%	74.9%	45.9%	46.5%	41.7%	56.4%	64.3%	64.2%	54.8%	58.1%	56.2%	51.4%	60.7%	54.2%	56.3%	49.1%	57.0%	56.6%	57.1%	59.5%	55.5%
			61.3%	64.3%	68.5%	64.0%	55.8%	44.7%	48.2%	54.1%	61.7%	61.1%	59.0%	56.4%	55.3%	56.1%	55.4%	57.1%	53.2%	54.1%	54.2%	56.9%			
	RY2	75.2%	82.3%	69.6%	66.6%	72.7%	69.5%	59.6%	74.4%	68.9%	63.8%	78.3%	72.2%	42.8%	54.8%	54.4%	47.7%	36.3%	57.8%	50.2%	50.8%	66.2%	65.7%	68.4%	54.9%
			75.7%	72.8%	69.6%	69.6%	67.3%	67.8%	67.6%	69.0%	70.3%	71.4%	64.4%	56.6%	50.7%	52.3%	46.1%	47.3%	48.1%	52.9%	55.7%	60.9%			
	RY3	46.9%	51.9%	50.7%	54.6%	51.8%	52.9%	41.8%	43.4%	44.7%	39.3%	61.1%	50.0%	38.9%	52.6%	58.5%	53.2%	62.3%	60.6%	47.7%	37.4%	39.8%	52.9%	47.3%	52.2%
			49.8%	52.4%	52.4%	53.1%	48.8%	46.1%	43.3%	42.5%	48.4%	50.1%	50.0%	47.2%	50.0%	54.8%	58.0%	58.7%	56.9%	48.6%	41.6%	43.4%			
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	1,592	1,764
POCave.			1,515	1,554	1,576	1,580	1,585	1,591	1,602	1,611	1,619	1,623	1,639	1,656	1,671	1,688	1,710	1,732	1,743	1,763	1,798				
	RY1	900	944	968	971	969	976	979	989	996	995	997	1,001	1,024	1,028	1,029	1,051	1,065	1,068	1,070	1,096	1,119	1,119	980	1,077
			937	961	969	972	975	981	988	993	996	998	1,007	1,018	1,027	1,036	1,048	1,061	1,068	1,078	1,095				
	RY2	218	224	227	228	230	228	227	229	231	232	232	233	235	235	235	243	244	244	246	248	254	254	229	246
			223	226	228	229	228	228	229	231	232	232	233	234	235	238	241	244	245	246	249				
	RY3	341	346	377	376	382	381	384	380	391	389	394	395	405	411	411	421	430	431	432	455	474	474	383	441
			355	366	378	380	382	382	385	387	391	393	398	404	409	414	421	427	431	439	454				
NRW/POC		25.1	22.3	18.6	24.6	22.8	12.6	12.1	14.6	16.5	19.0	19.8	17.0	15.5	15.6	12.4	16.6	13.5	14.1	13.5	15.3	15.5	14.7	17.6	14.5
NRW/POCave			22.0	21.8	22.0	20.0	15.8	13.1	14.4	16.7	18.4	18.6	17.4	16.0	14.5	14.9	14.2	14.8	13.7	14.3	14.7				
	RY1	104.1	86.6	81.8	125.4	115.8	41.1	51.5	49.4	76.6	94.9	83.7	65.0	82.8	77.1	52.4	88.1	62.6	63.4	64.2	83.6	78.6	73.2	79.6	70.9
			90.9	97.9	107.7	94.1	69.5	47.3	59.2	73.7	85.1	81.2	77.2	75.0	70.8	72.6	67.7	71.4	63.4	70.4	75.5				
	RY2	42.6	44.3	27.4	23.6	23.0	28.5	19.5	34.9	23.0	21.8	29.7	32.6	11.3	14.6	14.4	10.8	6.4	14.0	14.1	14.4	22.6	16.5	25.2	14.2
			38.1	31.8	24.7	25.0	23.7	27.6	25.8	26.6	24.8	28.0	24.5	19.5	13.4	13.3	10.5	10.4	11.5	14.2	17.0				
	RY3	13.6	12.8	11.8	12.5	10.8	10.6	8.4	10.6	9.2	9.2	14.7	12.4	9.0	11.2	12.3	10.6	15.6	13.4	10.0	6.9	6.0	9.2	10.4	10.4
			12.8	12.4	11.7	11.3	9.9	9.9	9.4	9.7	11.0	12.1	12.0	10.8	10.8	11.4	12.9	13.2	13.0	10.1	7.7				
Billed Water/POC		15.1	11.9	12.5	11.5	9.3	11.1	13.2	14.9	12.7	12.7	10.1	12.5	14.0	12.6	10.8	12.0	11.3	10.5	14.0	13.6	12.2	10.8	12.3	11.9
Zero Consumption Loss						2,147	1,807	1,752	1,443	1,845	1,545	1,897	1,382	1,319	1,269	1,699	1,532								
Zero Consumption NRW Rate						4.2%	4.8%	4.4%	3.1%	3.9%	3.0%	3.9%	2.9%	2.7%	2.7%	4.4%	3.1%								

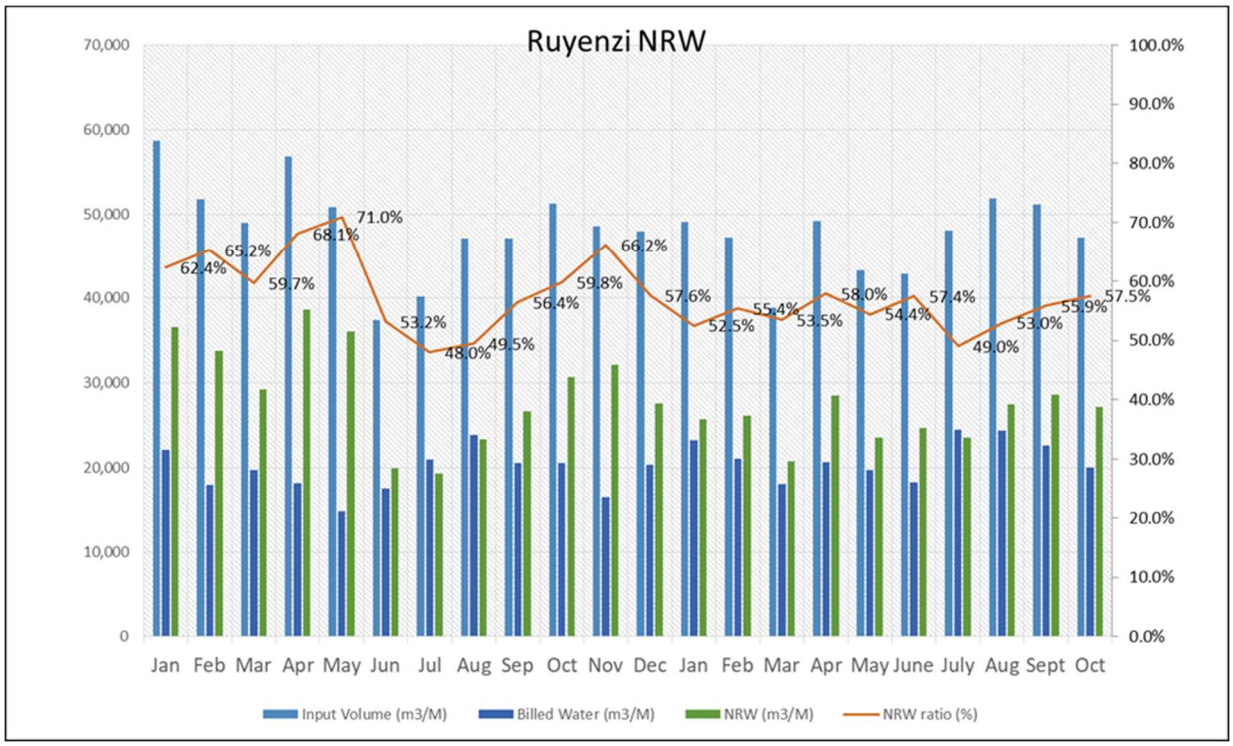


Fig. 2.10.1 Ruyenzi NRW trend

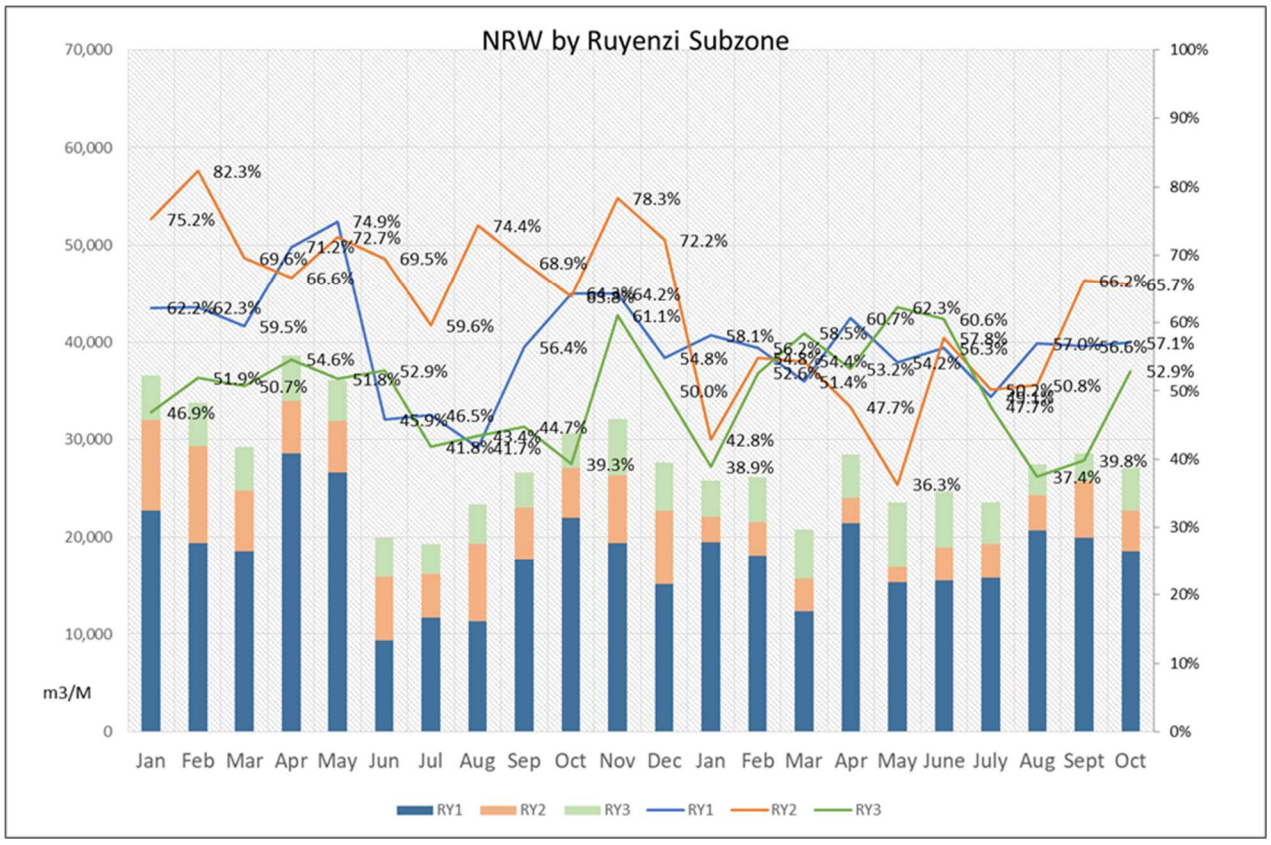


Fig. 2.10.2 Ruyenzi NRW trend by subzone

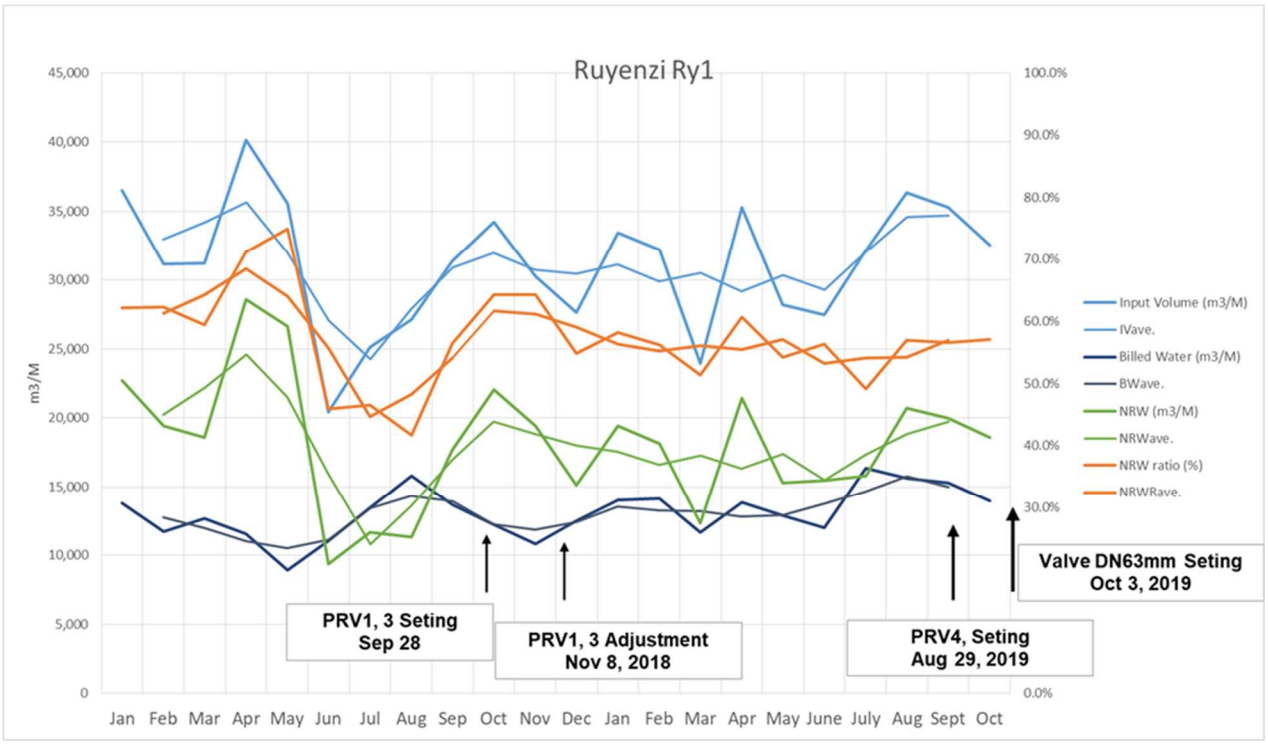


Fig. 2.10.3 Subzone RY1 NRW

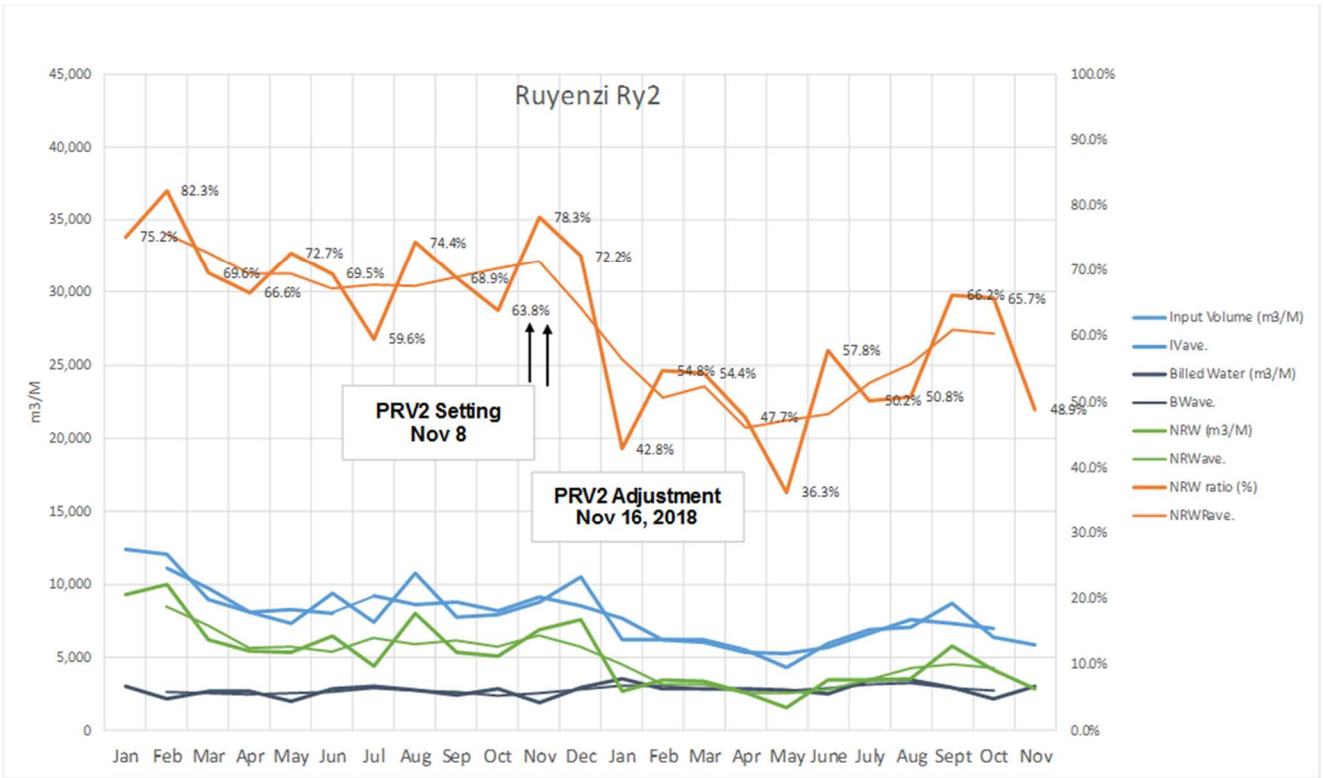


Fig. 2.10.4 Subzone RY2 NRW

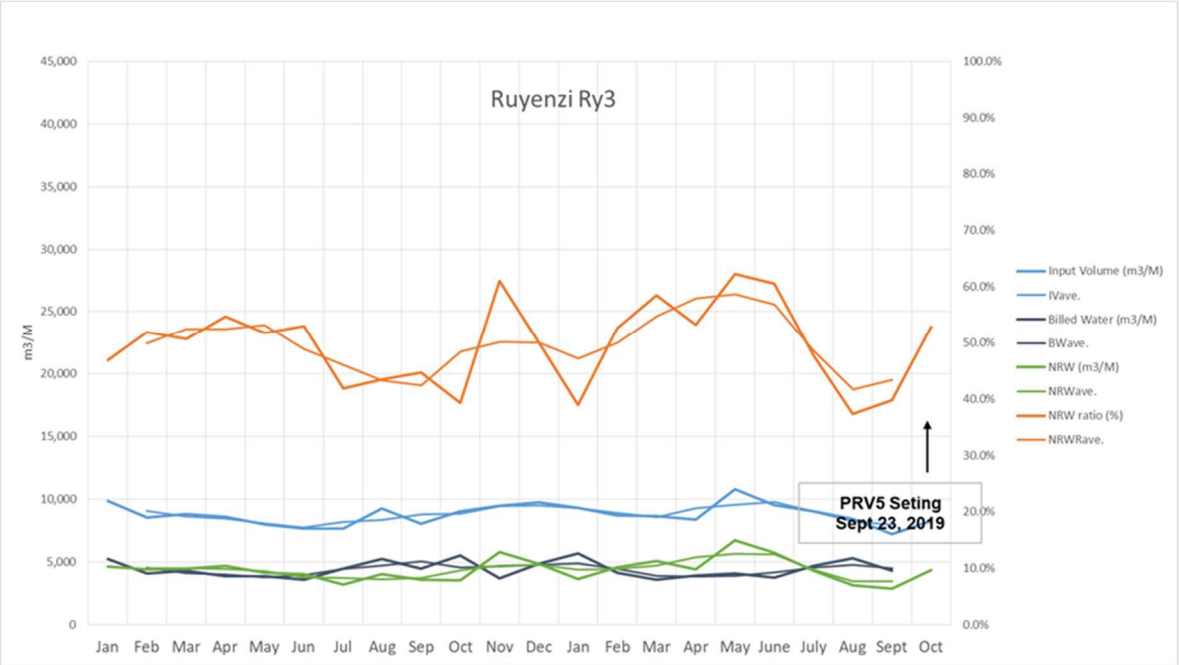


Fig.2.10.5 Subzone RY3 NRW

Change in NRW rate

The NRW rate decreased to approx. 50 % in the period between June and August 2018, although no NRW reduction activity was implemented in the period. The cause of the decrease was a large drop in water distribution from the Nzove Purification Station to Pilot Area 2 as flooding of the Nyabugogo River damaged the water delivery pipe between the station and Pilot Area 2. The same decrease was also observed in the Pilot Area 1. However, despite the large change in water distribution, billed water consumption changed little. Sometimes, when water distribution increased, billed water consumption decreased. No correlation has been found between them. The NRW rate decreased presumably because the reduction in water distribution reduced water leakage. When water distribution increases, water leakage also increases.

In May 2018, water distribution fell significantly compared with the previous month because the water delivery pipe to the pilot area was damaged and the water delivery from an alternative water source was unstable. The repair of the damaged delivery pipe was completed on June 25. From that day on, it was possible to deliver water as before. However, the volumes of water delivery in July and August were around 60 % and 85 % of the volume of monthly water delivery before the damage. The delivery pipe was damaged at a different point in August and the damage reduced the volume of water delivery significantly. The large increase in the NRW rate from August was presumably caused by the restoration of the water delivery pipe, which restored the volume of water delivery and the water distribution pressure to the levels observed before the damage occurred in May. (See Attachment 2.10 for the route of the delivery pipe.)

The commencement of the operation of the PRVs at three locations is considered to have reduced NRW rate significantly (approx. 13 %) in the period between November 2018 and January 2019. However, the

NRW rate has remained almost at the same level (approx. 55 %) with small increase and decrease since then. Although the effect of the PRVs installed at the three locations in limited parts of the area had an effect on the area as a whole, there were large parts where the pressure could not be controlled. The positions of installation of the PRVs were in the area downstream of RY1 only (about 30% of the area), so the effect from the point of view of the pilot area as a whole was small. PRV4 was installed in order to control the night time pressure in the remaining areas, and its operation commenced on August 29. Also, a valve was installed on the 63 mm pipe and its operation commenced on October 3, but its effect cannot be seen yet in the NRW calculation.

Also, in the RY2 area, there is a small part with high elevation within the area in which the PRV is installed, so it is not possible to reduce the secondary pressure below 6 bar, and this is a factor preventing achievement of effect.

(2) Numbers of Leakage Repairs (as emergency measures)

The number of leakage repairs in PY1 was overwhelmingly large. However, the installation of PRVs has sharply reduced the number of leakage repairs to almost zero. The same reduction is also observed in PY2. Water leaks occurred upstream of the PRVs in the areas between PRVs and the Ruyenzi Distribution Reservoir. Leakage repairs without water pressure control will not reduce the number of leakage repairs per month.

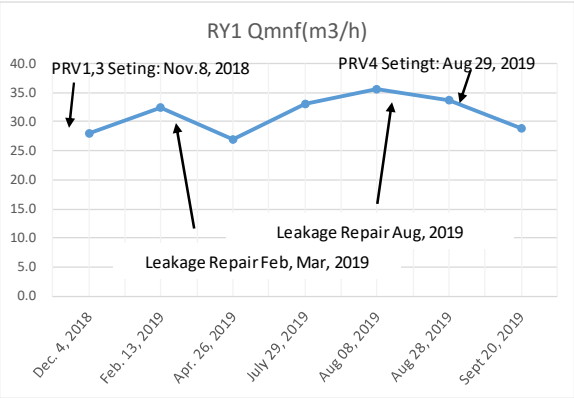
(3) Changes in Qmnf 1904

Because the PRVs installed in Ruyenzi do not regulate the water pressure in the entire subzones, the effect of the installation is not found in Fig. 25. However, the leakage survey and repairs conducted in the project have reduced Qmnf.

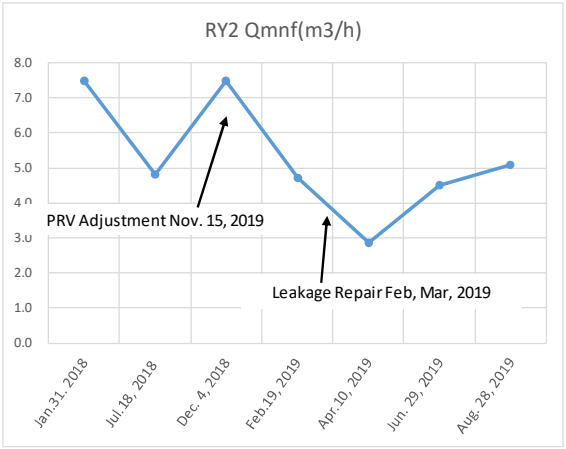
Omnf Trend

Ruyenzi

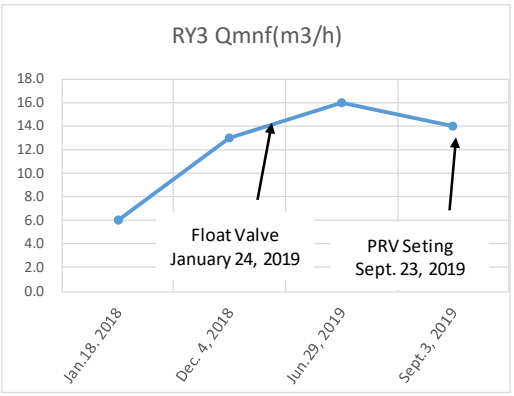
RY1	Qmnf (m3/h)
Dec. 4, 2018	28.0
Feb. 13, 2019	32.4
Apr. 26, 2019	26.9
July 29, 2019	33.0
Aug 08, 2019	35.6
Aug 28, 2019	33.6
Sept 20, 2019	28.8



RY2	Qmnf (m3/h)
Jan.31. 2018	7.5
Jul.18, 2018	4.8
Dec. 4, 2018	7.5
Feb.19, 2019	4.7
Apr.10, 2019	2.9
Jun. 29, 2019	4.5
Aug. 28, 2019	5.1



RY2	Qmnf (m3/h)
Jan.18. 2018	6.0
Dec. 4, 2018	13.0
Jun.29, 2019	16.0
Sept.3, 2019	14.0



RY1: Decline after Leakage repair and PRV adjustment
RY2: Decline after Leakage repair and PRV adjustment
RY3: Unknown

Figure 25. Changes in Qmnf (Ruyenzi)

2.11 Cost/Benefit Analysis of NRW Reduction Activities

The calculation for pilot area 1 was carried out in May 2019, but the calculation will be updated using the actual data. Also a new calculation will be carried out for area 2.

The implementation of the NRW reduction activities in the pilot project had led to the achievement of the NRW rate reduction target of the project for Kadobogo (Area 1). To evaluate the outcome of the implementation, a cost-benefit analysis of the activities was conducted.

(1) Method and conditions for cost-benefit analysis

i) Benefit and cost of activities

Benefit and cost of an activity were calculated as the differences between those when the activity was to be implemented (With-project) and when it was not to be implemented (Without-project).

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

Benefit is generated and cost is incurred over the years. For an activity that takes time to generate benefit, 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, benefit and cost in each year were corrected to those in a reference year, "present values."

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

where PV : Present value,

A : Benefit generated or cost incurred in the nth years after 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)

Net benefit is obtained by subtracting gross cost from gross benefit. A net present value (NPV) is obtained by subtracting net benefit in the case of Without-project from that in the case With-project.

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

where Bt : Benefit in the t th year

Ct : Cost in the t th year

T : Numbers of years after the completion

I : Discount rate

iii) Comparison of benefit and cost

Investment in an activity is considered appropriate if the benefit of implementing it is larger than the cost and the return of the investment is large. The implementation of an activity is considered appropriate if NPV > 0 and B/C > 1, where

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

iv) Comparison of benefit and cost

The benefit is generated in the following two cases:

Case 1: Increase in the water bill revenue resulting from the increase in the volume of revenue water due to the NRW reduction; and

Case 2: Reduction in the water purification and supply cost (O&M cost) at a purification plant due to the water leakage reduction.

In practice, the quantitative effect of the leakage reduction was measured by the sales of water per water consumption in the service area of Kacyiru Branch (Case 1) and the reduction in the water purification and supply cost per volume at the Nzove Purification Plant, the source of the piped water (Case 2).

v) Miscellaneous issues

- The cost included the costs for the activities for NRW reduction (leakage survey and repair, replacement of meters, etc.) and for the preparation for the NRW reduction activities (installation of flow meters and chambers, etc.) in the pilot areas. The total costs of the project activities are shown below (See attachment 14 for details).

  Total cost including the cost of meter replacement : 64,567,000 RWF (8.39 million JPY)

  Total cost excluding the cost of meter replacement : 41,515,000 RWF (5.40 million JPY)
- Period for the calculation: 10 years from 2018
- Values used in the calculation

  In the case of With-project: The actual NRW rate the volumes of billed and distributed water up to March 2019 were used.

  In the case of Without-project: The NRW rate was expected to decrease by 2 % per year. The same value of the volume of billed water as the case of With-project was used. The volume of distributed water was calculated from the volume of billed water using the NRW rate.

  While the values for 2018 were actual values, those for 2019 and later were estimated from the actual values in 2018.

- Water price:

  Selling prices: 567 RWF/m3 in Kacyiru and 592 RWF/m3 in Nyarugenge (monthly averages in 2018)

  Purified water production cost: 319 RWF/m3 at the Nzove Purification plant (monthly averages in 2018)

The table below shows the total monthly volumes of the billed water in 2018 and the water bills per POC (Frw/POC) and those per the water consumption (Frw/m3) in Kacyiru and Nyarugenge Branches. While the water bills included tax, fee for meter rental (100 Frw) and regulator fee, the average of the water bills per m3 exclusive of the tax and the fees were used in the cost-benefit analysis.

Table 2.54 Monthly average water bill (2018)

Item	Unit	Kacyiru	Nyarugenge	All 20Branch
POC		18,413	18,127	192,349
Consumption	m3	338,058	339,915	2,403,970
Unit Consumption	m3/POC	18.4	18.8	12.5
Billing	Frw	191,590,224	201,278,615	1,232,017,358
Billing/POC	Frw/POC	10,405	11,104	6,405
Billing/m3	Frw/m3	567	592	512

(2) Calculation of benefit

Fig. 2.29 shows the benefit of the project implementation. While the baseline NRW rate was the same in both With- and Without- Project cases, the rate decreased significantly in the cases of With-Project with the implementation of NRW reduction activities. Therefore, there is a difference between the volume of distributed water in the case of Without-Project calculated from the volume of billed water and the actual volume of distributed water in the case of With-Project and the difference between the two shows the volume of the leakage reduction. The benefit is obtained by multiplying the volume of the leakage reduction by the cost of the water supply per volume.

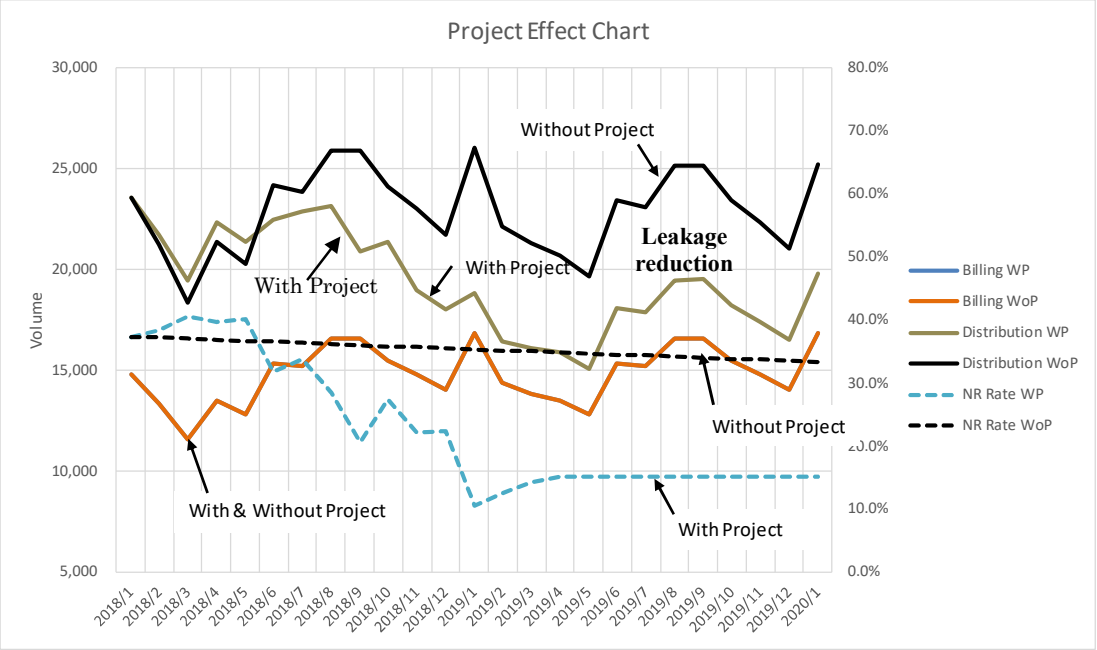


Fig. 2.31. Diagram used for cost-benefit analysis of NRW reduction activities in Kadobogo

1） Evaluation of the individual NRW reduction activities in the pilot project

The table below summarizes the result of the cost-benefit analysis of the NRW reduction effect of the replacement of water supply and distribution pipes and installation of PRVs (See Attachment 14 for details). All these activities began to show their effect quickly, as they began to generate benefit larger than the cost between one and ten months after the completion of the activities.

Table 2.60 Cost-benefit analysis of installation of PRVs and replacement of water supply and distribution pipes

Kadobogo

Activity	Area	Cost Recovery Month			Qmnf Effect
		Month	NPV (RWF)	B/C	m3/h
Pipe Replacement	PM1	8th	1,186,196	1.2	2.28
PRV Setup	PM2	6th	258,324	1.3	0.43
	PM3	2nd	1,177,220	1.7	3.64

Ruyenzi

Activity	Area	Cost Recovery Month			Qmnf Effect
		Month	NPV (RWF)	B/C	m3/h
PRV Setup	PRV1	1st	342,168	1.2	5.98
	PRV2	10th	308,829	1.1	1.14
	PRV3	3rd	373,155	1.4	1.06

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 manuals preparation team of the pilot project inside WASAC and prepare the manuals in coordination with this team. The manuals preparation meeting (kickoff) is held on January 29th, and meetings are held regularly. The table of contents of the manuals is shown in Attachment 15.

- ✓ Purpose: To show all staff the appropriate methods implemented in the pilot project applied to each of the NRW reduction activities.
- ✓ Goal of use: Achievement target of 5-year strategic plan
- ✓ User: All WASAC staff
- ✓ Period of use: At the start of each activity
- ✓ How to make: Organize each individual work manual
- ✓ Deadline for preparation: May 2019

Cost-Benefit Analysis

The NRW reduction activities in the pilot project have not been completed in Ruyenzi (Area 2) because the current NRW rate of 55 % is larger than the target of 25 % by far. Therefore, the cost-effectiveness of the pilot project activities was analyzed only for those implemented in Kadobogo (Area1), where the target rate had been achieved. The assumptions used in the analysis and the analysis sheets are shown below:

Cost/benefit:	Cost required for and benefit gained from the implementation of the project
Evaluation indicators:	Net present value (NPV), benefit to cost ratio (B/C)
Discount rate:	6 % (Consumer price index, inflation rate and bank interest rate in Rwanda (averages over 10 years))
Water prices:	Selling prices – 567 RWF in Kacyiru and 592 RWF in Nyarugenge (monthly averages of 2018) Producer's price - 312 RWF at Nzove (monthly average of 2018)

If the surplus water produced by NRW reduction is sold and the production adjustment is commenced in the first fiscal year after the completion of the main project activities, the benefit will exceed the cost and profit will be produced in the second fiscal year after the completion of the activities. Thus, the NRW reduction activities will have a large effect.

4. Ruyenzi PRV

Ruyenzi Pilot Area
PRV1

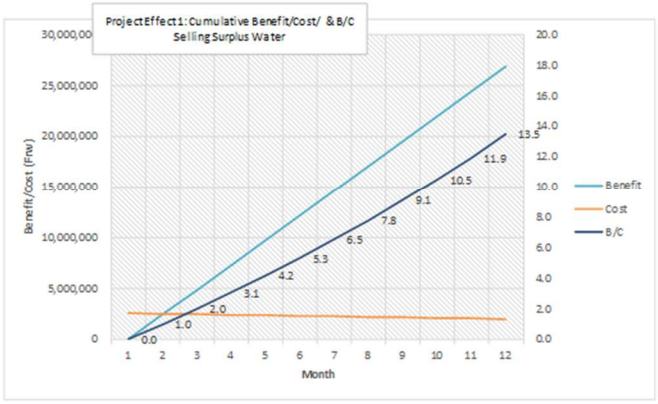
Project Effect 1: Selling of Surplus Water by NRW Reduction Activity

	Year Month	Benefit	NRW Reduction Activity Cost			Effect of the Action			
		WP	WP	WoP	Balance	Benefit	Cost	NPV	B/C
1	2019/1	0	2,594,957	50,000	2,544,957	0	2,544,957	-2,544,957	0.0
2	2019/2	2,441,275	0	50,000	-50,000	2,441,275	2,494,957	-53,682	1.0
3	2019/3	2,441,275	0	50,000	-50,000	4,882,550	2,444,957	2,437,593	2.0
4	2019/4	2,441,275	0	50,000	-50,000	7,323,826	2,394,957	4,928,869	3.1
5	2019/5	2,441,275	0	50,000	-50,000	9,765,101	2,344,957	7,420,144	4.2
6	2019/6	2,441,275	0	50,000	-50,000	12,206,376	2,294,957	9,911,419	5.3
7	2019/7	2,441,275	0	50,000	-50,000	14,647,651	2,244,957	12,402,694	6.5
8	2019/8	2,441,275	0	50,000	-50,000	17,088,926	2,194,957	14,893,969	7.8
9	2019/9	2,441,275	0	50,000	-50,000	19,530,202	2,144,957	17,385,245	9.1
10	2019/10	2,441,275	0	50,000	-50,000	21,971,477	2,094,957	19,876,520	10.5
11	2019/11	2,441,275	0	50,000	-50,000	24,412,752	2,044,957	22,367,795	11.9
12	2019/12	2,441,275	0	50,000	-50,000	26,854,027	1,994,957	24,859,070	13.5

PiPM1 in Kadobogo

Construction Cost		2,594,957
Water Price	Frw/m3	567.00
Production Cost	Frw/m3	319.00
Effect Qmnf(2018/10/24)	m3/h	5.98
Effect Qmnf(2018/10/24)	m3/month	4,306
Selling Water	Frw/month	2,441,275
Production Cost Reduction	Frw/month	1,373,486
Leakage Repair WoP	Times/Month	1
Leakage Repair WP	Times/Month	0

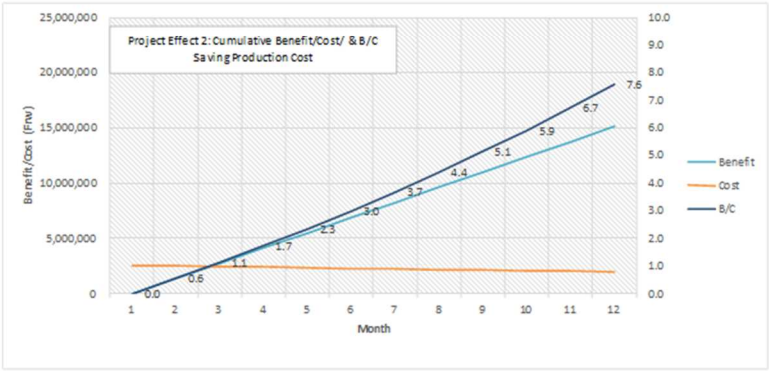
Repair 1 places/month: Without Project 50,000



Project Effect 2: Saving of Production Cost by NRW Reduction Activity

	Year Month	Benefit	NRW Reduction Activity Cost			Effect of the Action			
		WP	WP	WoP	Balance	Benefit	Cost	NPV	B/C
1	2019/1	0	2,594,957	50,000	2,544,957	0	2,544,957	-2,544,957	0.0
2	2019/2	1,373,486	0	50,000	-50,000	1,373,486	2,494,957	-1,121,471	0.6
3	2019/3	1,373,486	0	50,000	-50,000	2,746,973	2,444,957	302,016	1.1
4	2019/4	1,373,486	0	50,000	-50,000	4,120,459	2,394,957	1,725,502	1.7
5	2019/5	1,373,486	0	50,000	-50,000	5,493,946	2,344,957	3,148,989	2.3
6	2019/6	1,373,486	0	50,000	-50,000	6,867,432	2,294,957	4,572,475	3.0
7	2019/7	1,373,486	0	50,000	-50,000	8,240,918	2,244,957	5,995,961	3.7
8	2019/8	1,373,486	0	50,000	-50,000	9,614,405	2,194,957	7,419,448	4.4
9	2019/9	1,373,486	0	50,000	-50,000	10,987,891	2,144,957	8,842,934	5.1
10	2019/10	1,373,486	0	50,000	-50,000	12,361,378	2,094,957	10,266,421	5.9
11	2019/11	1,373,486	0	50,000	-50,000	13,734,864	2,044,957	11,689,907	6.7
12	2019/12	1,373,486	0	50,000	-50,000	15,108,350	1,994,957	13,113,393	7.6

Repair 1 places/month: Without Project 50,000



Ruyenzi Pilot Area
PRV2

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

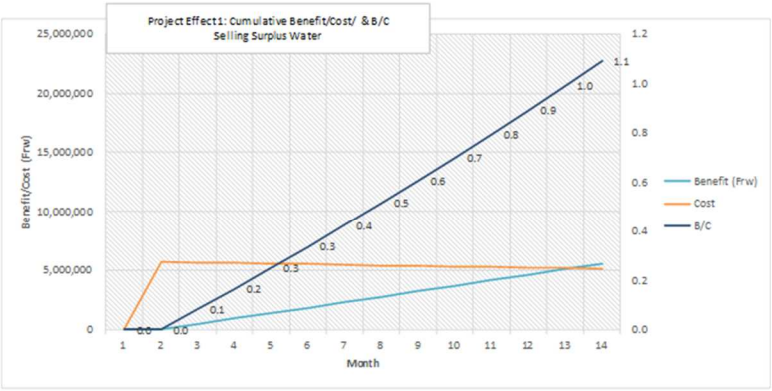
	Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Cumulative Value			
		WP	WP	WoP	Balance	Benefit (Frw)	Cost	B/C	
1	2019/1	0	50,000	50,000	0	0	0	#DIV/0!	Preparation
2	2019/2	0	5,776,227	50,000	5,726,227	0	5,726,227	0.0	Replacement
3	2019/3	465,394	0	50,000	-50,000	465,394	5,676,227	0.1	
4	2019/4	465,394	0	50,000	-50,000	930,787	5,626,227	0.2	
5	2019/5	465,394	0	50,000	-50,000	1,396,181	5,576,227	0.3	
6	2019/6	465,394	0	50,000	-50,000	1,861,574	5,526,227	0.3	
7	2019/7	465,394	0	50,000	-50,000	2,326,968	5,476,227	0.4	
8	2019/8	465,394	0	50,000	-50,000	2,792,362	5,426,227	0.5	
9	2019/9	465,394	0	50,000	-50,000	3,257,755	5,376,227	0.6	
10	2019/10	465,394	0	50,000	-50,000	3,723,149	5,326,227	0.7	
11	2019/11	465,394	0	50,000	-50,000	4,188,542	5,276,227	0.8	
12	2019/12	465,394	0	50,000	-50,000	4,653,936	5,226,227	0.9	
13	2020/1	465,394	0	50,000	-50,000	5,119,330	5,176,227	1.0	
14	2020/2	465,394	0	50,000	-50,000	5,584,723	5,126,227	1.1	

Repair 1 places/month: Without Project 50,000

Pipe Replacement in Kadobogo

Cost Benefit

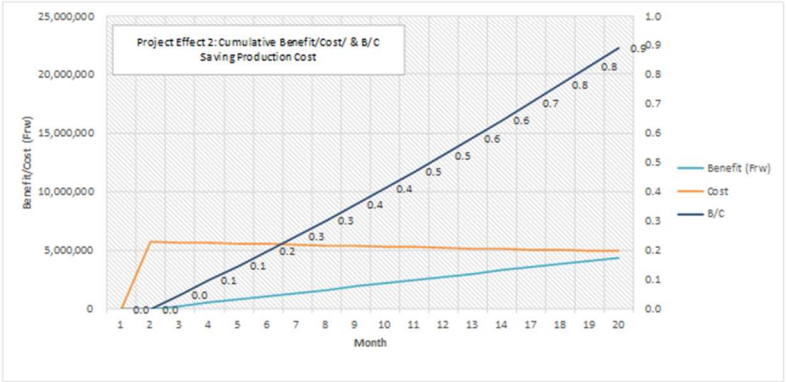
Construction Cost	
Production Cost	Frw/m3
Water Price	Frw/m3
Effect Qmnf(2018/10/24)	m3/h
Effect Qmnf(2018/10/24)	m3/month
Selling Water	Frw/month
Production Cost Reduction	Frw/month



Project Effect 2: Saving of Production Cost by NRW Reduction Activity

	Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Cumulative Value		
		WP	WP	WoP	Balance	Benefit (Frw)	Cost	B/C
1	2019/1	0	50,000	50,000	0	0	0	#DIV/0!
2	2019/2	0	5,776,227	50,000	5,726,227	0	5,726,227	0.0
3	2019/3	274,147	0	50,000	-50,000	274,147	5,676,227	0.0
4	2019/4	274,147	0	50,000	-50,000	548,294	5,626,227	0.1
5	2019/5	274,147	0	50,000	-50,000	822,442	5,576,227	0.1
6	2019/6	274,147	0	50,000	-50,000	1,096,589	5,526,227	0.2
7	2019/7	274,147	0	50,000	-50,000	1,370,736	5,476,227	0.3
8	2019/8	274,147	0	50,000	-50,000	1,644,883	5,426,227	0.3
9	2019/9	274,147	0	50,000	-50,000	1,919,030	5,376,227	0.4
10	2019/10	274,147	0	50,000	-50,000	2,193,178	5,326,227	0.4
11	2019/11	274,147	0	50,000	-50,000	2,467,325	5,276,227	0.5
12	2019/12	274,147	0	50,000	-50,000	2,741,472	5,226,227	0.5
13	2020/1	274,147	0	50,000	-50,000	3,015,619	5,176,227	0.6
14	2020/2	274,147	0	50,000	-50,000	3,289,766	5,126,227	0.6
17	2020/3	274,147	0	50,000	-50,000	3,563,914	5,076,227	0.7
18	2020/4	274,147	0	50,000	-50,000	3,838,061	5,026,227	0.8
19	2020/5	274,147	0	50,000	-50,000	4,112,208	4,976,227	0.8
20	2020/6	274,147	0	50,000	-50,000	4,386,355	4,926,227	0.9

Repair 1 places/month: Without Project 50,000



Ruyenzi Pilot Area
PRV3

Project Effect 1 : Selling of Surplus Water by NRW Reduction Activity

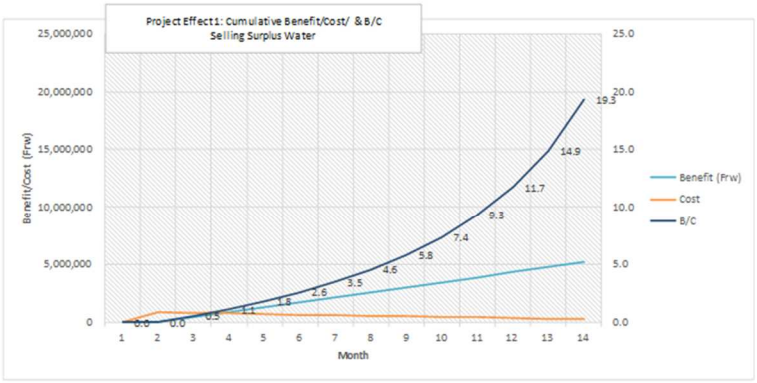
	Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Cumulative Value			
		WP	WP	WoP	Balance	Benefit (Frw)	Cost	B/C	
1	2019/1	0	50,000	50,000	0	0	0	#DIV/0!	Preparation
2	2019/2	0	919,168	50,000	869,168	0	869,168	0.0	Replacement
3	2019/3	432,734	0	50,000	-50,000	432,734	819,168	0.5	
4	2019/4	432,734	0	50,000	-50,000	865,469	769,168	1.1	
5	2019/5	432,734	0	50,000	-50,000	1,298,203	719,168	1.8	
6	2019/6	432,734	0	50,000	-50,000	1,730,938	669,168	2.6	
7	2019/7	432,734	0	50,000	-50,000	2,163,672	619,168	3.5	
8	2019/8	432,734	0	50,000	-50,000	2,596,406	569,168	4.6	
9	2019/9	432,734	0	50,000	-50,000	3,029,141	519,168	5.8	
10	2019/10	432,734	0	50,000	-50,000	3,461,875	469,168	7.4	
11	2019/11	432,734	0	50,000	-50,000	3,894,610	419,168	9.3	
12	2019/12	432,734	0	50,000	-50,000	4,327,344	369,168	11.7	
13	2020/1	432,734	0	50,000	-50,000	4,760,078	319,168	14.9	
14	2020/2	432,734	0	50,000	-50,000	5,192,813	269,168	19.3	

Repair 1 places/month: Without Project 50,000

Pipe Replacement in Kadobogo

Cost Benefit

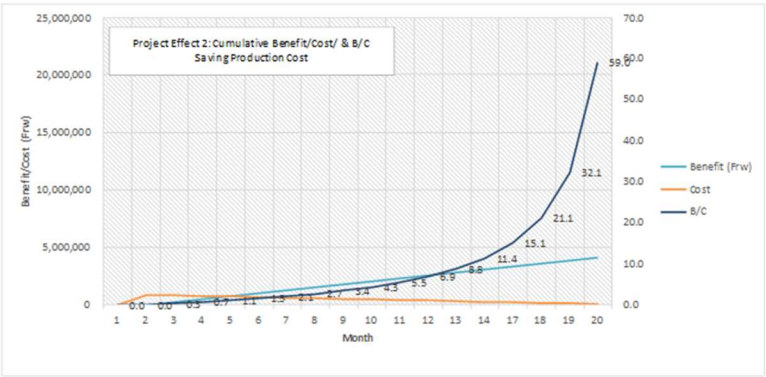
Construction Cost	
Production Cost	Frw/m3
Water Price	Frw/m3
Effect Qmnf(2018/10/24)	m3/h
Effect Qmnf(2018/10/24)	m3/month
Selling Water	Frw/month
Production Cost Reduction	Frw/month



Project Effect 2: Saving of Production Cost by NRW Reduction Activity

	Month	Benefit (Frw)	NRW Reduction Activity Cost (Frw)			Cumulative Value		
		WP	WP	WoP	Balance	Benefit (Frw)	Cost	B/C
1	2019/1	0	50,000	50,000	0	0	0	#DIV/0!
2	2019/2	0	919,168	50,000	869,168	0	869,168	0.0
3	2019/3	254,909	0	50,000	-50,000	254,909	819,168	0.3
4	2019/4	254,909	0	50,000	-50,000	509,818	769,168	0.7
5	2019/5	254,909	0	50,000	-50,000	764,726	719,168	1.1
6	2019/6	254,909	0	50,000	-50,000	1,019,635	669,168	1.5
7	2019/7	254,909	0	50,000	-50,000	1,274,544	619,168	2.1
8	2019/8	254,909	0	50,000	-50,000	1,529,453	569,168	2.7
9	2019/9	254,909	0	50,000	-50,000	1,784,362	519,168	3.4
10	2019/10	254,909	0	50,000	-50,000	2,039,270	469,168	4.3
11	2019/11	254,909	0	50,000	-50,000	2,294,179	419,168	5.5
12	2019/12	254,909	0	50,000	-50,000	2,549,088	369,168	6.9
13	2020/1	254,909	0	50,000	-50,000	2,803,997	319,168	8.8
14	2020/2	254,909	0	50,000	-50,000	3,058,906	269,168	11.4
17	2020/3	254,909	0	50,000	-50,000	3,313,814	219,168	15.1
18	2020/4	254,909	0	50,000	-50,000	3,568,723	169,168	21.1
19	2020/5	254,909	0	50,000	-50,000	3,823,632	119,168	32.1
20	2020/6	254,909	0	50,000	-50,000	4,078,541	69,168	59.0

Repair 1 places/month: Without Project 50,000



2.19 Manual preparation

It was decided to set up the manuals preparation team of the pilot project inside WASAC and prepare the manuals in coordination with this team. The manuals preparation meeting (kickoff) is held on January 29th 2019, and meetings are held regularly.

- ✓ Purpose: To show all staff the appropriate methods implemented in the pilot project applied to each of the NRW reduction activities.
- ✓ Goal of use: Achievement target of 5-year strategic plan
- ✓ User: All WASAC staff
- ✓ How to make: Organize each individual work manual

(a) Manual Preparation Meetings in Pilot Project

1st meeting: January 29	Kick-off meeting
2nd meeting: February 5	Explanation of the purpose of manual preparation
3rd meeting: February 18	Finalization of table of contents
4th meeting: March 6	Appointment of persons in charge of each chapter
5th meeting: March 21	Confirmation of progress with produced outputss
6th meeting: May 7	Confirmation of progress, revision of preparation policy
7th meeting: May 9	Revision of table of contents
8th meeting: May 13 and 14	Joint meeting

3.19 Miscellaneous Matters

(6) Data of new customers

The POC numbers of 29 new customers in Kadobogo (total billed water consumption of 300 m3/month) and 41 new customers in Ruyenzi were entered into the POC list when NRW rates in the pilot areas in January 2019 were estimated from the data of monthly billed water consumption, including the consumption by the new customers. It is assumed that there are 53 or so unlisted POCs in Ruyenzi. However, as their X Y coordinates are not known, their locations have not been confirmed on a map. If WASAC collects X and Y coordinates of a new customer when they conclude a service contact, it will be possible to decide whether the new customer is in the pilot area on the Google Earth Map and include the data of billed water consumption of the customer in the calculation of NRW rate.

If a CFO has an electronic map that shows GIS data of area boundaries, the CFO will be able to confirm whether a new customer is in the pilot area on site with a portable terminal and give a DMA code to the new customer at the time of the conclusion of a new service contract. If a system for the above-mentioned process is developed, total billed water consumption in a DMA will be automatically calculated in CMS. The system will eliminate the need to select the data of billed water consumption of customers in a DMA from the national database using the VLookup function of Microsoft Excel in the calculation of NRW rate.

Although the Project Team has explained the benefit of the system to WASAC and advised WASAC to use the system in the NRW calculation since last October, WASAC has not developed the system yet.

There is a need to transfer the technology for the calculation and analysis of NRW rates to staff of WASAC in charge of NRW rate calculation and data analysis. However, for now, the technology will be transferred to the WASAC staff involved in the project, because they know the project well. It is considered reasonable to raise the awareness of WASAC of the necessity to strengthen its organization by providing advice on the organization strengthening while implementing the technology transfer.

The table below shows the numbers of new customers in 2018. The average numbers of new customers in the entire service area and the pilot area of Nyarugenge Branch (130 per month and 12 per month, respectively) were much larger than the corresponding numbers of Kacyiru Branch (78 per month and 3 per month, respectively).

Table 5. Numbers of 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

3.5 Water Charge Collection 1902

The water rates were revised and the revised rates were to come into effect on February 1, 2019. Table below shows the water rates per m3 before and after the revision.

Table 6. Water Tariff (Frw/ m^3)

Monthly Consumption		Tariff	Tariff	Difference
		before Fab. 2019	from February 1st, 2019	
At Public Water Kiosk		323	323	0
Residential	Between 0 and 5 m^3	323	340	17
	Between 6 and 20m^3	331	720	389
	Between 21 and 50m^3	413	845	432
	Between 51 and 100m^3	736	877	141
	Above 101 m^3	847	877	30
Non Residential	Between 0 and 50 m^3	Was not mentioned	877	
	Above 50 m^3	Was not mentioned	895	
Industries		736	736	0

Excluding VAT (18%)

The method described in the table below is used for the calculation of water charges.

Table 7. Calculation of water charge

Item		Calculation formula	
Charge	a	(Billed water consumption) x (unit price)	
Rental	b	100 Frw	100
Sub total	c	Charge + Rental	a + 100
Regulator fees	d	Charge x 0.3%	a x 0.003
Tax	e	Subtotal x18%	(a+100) x 0.18
Total	f	Subtotal+Regulator fee+Tax	1.183a+118

＊ What is a regulator fee?

＊ The depreciation period of a water meter is 25 years if its price is assumed at 30,000 Frw and a customer pay a rental fee of 100 Frw/month for it. WASAC procures water meters, rent them to customers and maintain them. In Japan, local governments procure and maintain water meters.

The table below shows the sums of the monthly billed water consumption, water charges per POC (Frw/POC) and water charges per water consumption (Frw/m3) of Kacyiru and Nyarugenge Branches. A water charge includes tax, meter rental fee (100 Frw) and regulator fee. In the cost-benefit analysis, the tax and fees were subtracted from the average water charges per m3. As the water rates was revised and the revise rate came into effect in February 2019, the averages of March were used in the analysis for February and following months

Table 8. Average water charges per month (2018)

Item	Unit	Kacyiru	Nyarugenge	All 20Branch
POC		18,413	18,127	192,349
Water consumption	m3	338,058	339,915	2,403,970
Water consumption per POC	m3/POC	18.4	18.8	12.5
Billed water charge	Frw	191,590,224	201,278,615	1,232,017,358

Water charge per POC	Frw/POC	10,405	11,104	6,405
Water charge per unit volume	Frw/m3	567	592	512

It is practically impossible to evaluate above-ground and underground water leaks separately in separate periods. Most of above-ground leaks are discovered accidentally by people, who inform WASAC of the leaks, and staff members of WASAC on duty. These discovered leaks are quickly repaired one by one. In the cases of invisible (underground) leaks, water continues to leak out of pipes unnoticed. When a leakage survey is conducted systematically as in the Pilot Project, both above-ground and underground leaks are to be detected and repaired simultaneously. It is possible to estimate the volume of above-ground and underground leakages by measuring the volume of discovered water leaks.

[Problem]

WASAC staff did not check materials and tools to be used and work site before the work or a day before the day of work and they realized shortage of materials or tools after arriving at the site. If they have a list of required materials, manuals and check sheets for each job, the job will be implemented smoothly without reworking. The Project Team intends to provide small proposals one after another to make job without reworking a norm.

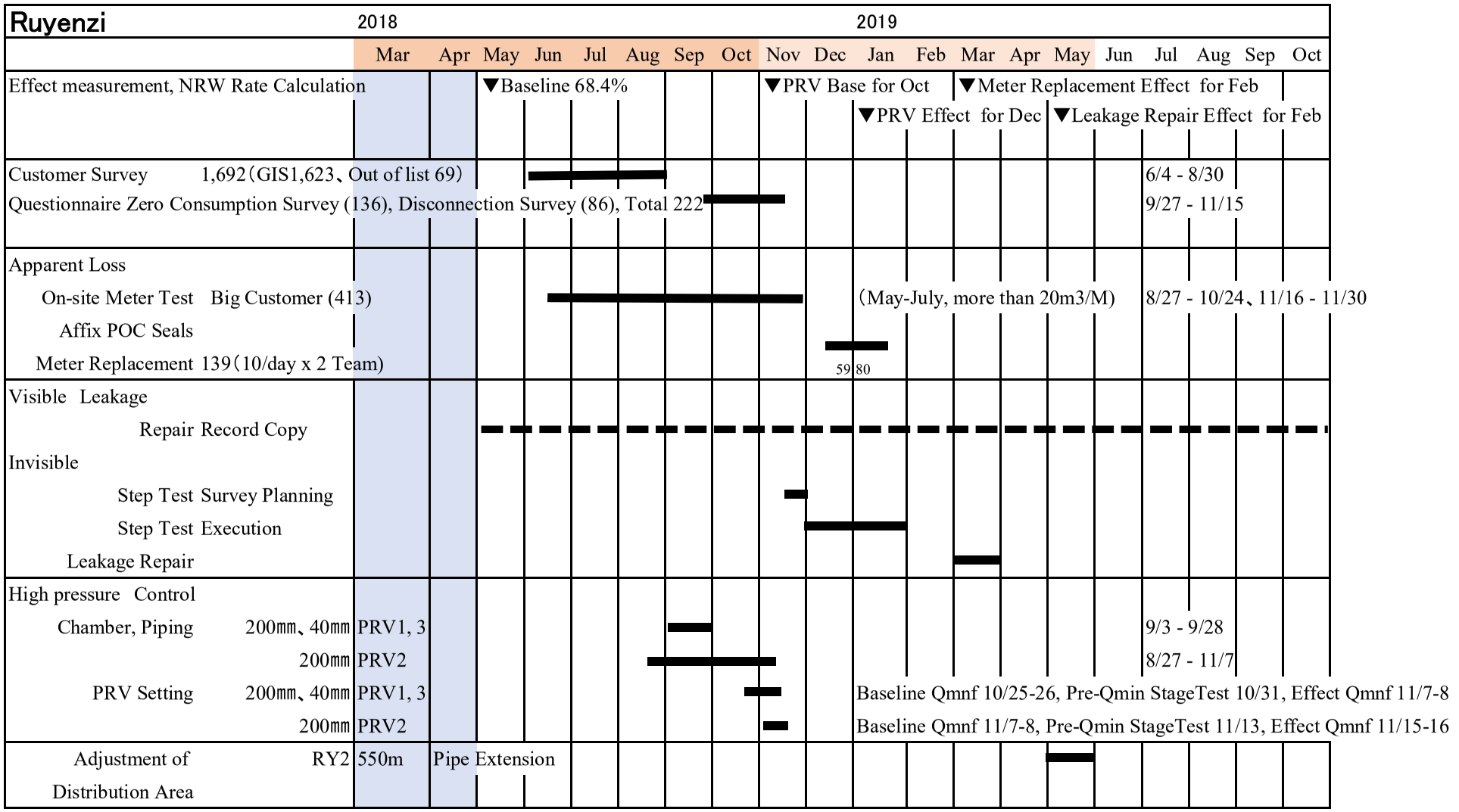
【Appendix】

1. Implementation schedule
2. Apparent loss
3. Physical loss
4. High water pressure management
5. NRW measurement effect
6. Cost-benefit

1. Implementation schedule

PILOT PROJECT FOR STRENGTHENING NON-REVENUE WATER CONTROL IN KIGALI CITY WATER NETWORK (Update August, 2018)

Activity	June	July	August	September	October	November	December	January	February	March	April	May
A. Pilot Area 1 (Kadobogo)												
3. Pressure control	PM2											
3.1 Installation of PRVs in PM2 and PM3												
4. NRW rates calculation												
4.1 Index Reading, Analysis												
4.2 Calculation												
5. Preparation of Reports and Holding of Workshop and Seminars												
5.4 Holding a workshop/seminar and presentation of the completion report of the pilot project												
6. Monitoring Leakage												
6.1 Step test & Qmnf measurement												
6.2 Pipeline and visible leakage survey (for modified step test)		PM2	PM	PM3								
6.3 Modified step test (for invisible leakage detection)												
7. Replacement of service pipes at the selected area												
・Prepare BOQ												
・Procure materials												
・Replace substandard service pipes												
B. Pilot Area 2 (Ruyenzi)												
1. Organization of Action Teams and Preparatory Work												
1.1 Organization of action teams												
・Organize action team in Nyarugenge branch												
1.2 Preparatory Work												
・Customer's spot confirmation investigation with POC number (CFO work base)												
・Compilation of the list of POC per every Sub-zone												
・Preparation of location map of POC（GIS)												
・Giving DMA cord to POC												
・Compilation of the database for analysis of customer billed consumption												
1.3 Prepare work schedule of the pilot project in Ruyenzi												
1.4 Purchase POC Seals for Ruyenzi												
1.5 Affix POC Seals to all Customers												
1.6 Pressure gage installation at Ruyenzi Reservoir (for By-pass Line)(?)												
2. Construction of Pilot Areas												
2.1 Installation of flow meters and pressure gauges at the inlets of the Pilot Area												
2.2 Hydraulic isolation of Sub-zones in pilot area (3 Sub-zones)												
・Install valves for step test												
2.3 Pressure control												
・Measurement of pressure in the pilot area and preparation of the water pressure distribution map												
・Pressure Control Plan (Separation of the low altitude area and bypass)												
・Study and survey on installation spot of PRV												
・Installation of PRV												
3. Inflow measurement and NRW rate calculation												
3.1 Flow rate measurement at inlets												
・Monthly measurement of total inflow												
・Tertiary Pipe Survey at 3 typical pressure zones		PM4										
・Breakdown NRW rate												
・Continuous flow rate and pressure measurement at Ruyenzi 1and 3 Subzones (one week)		Ruyenzi Reservoir										
3.2 Establishment of the baseline NRW rate												
・Estimate baseline NRW rate from total inflow and billed consumption (March and April)												
3.3 Monthly NRW rate estimation for monitoring and examining effectiveness of the activities												
4. Conducting measures for reducing "Apparent Losses"												
4.1 Customer data analysis and identification of POC for detailed customer survey, customer meter test and water theft												
4.2 Customer meter survey at all connections												
・Design worksheet for meter survey												
・Conduct meter survey to identify default meters and prepare customer list	# # # # # # # # # # # # # # # # # # # #											
・Prepare a list of all customers (POC)												
・Affix POC seal on customers gates and doors												
4.3 Select customers with big water consumption and zero/abnormal consumption) and disconnected customers												
・Prepare a customer list of big or abnormal water consumption, and disconnected customers												
4.4 On-site meter calibration at big customers												
4.5 Replace default meters												
4.6 Replace malfunctioning (working but excess error) meters												
4.7 In-room meter calibration of replaced customer meters by test bench												
4.8 Illegal water user survey simultaneously with the diconnected customer survey above												
・Conduct customer survey on disconnected customers, customers with abnormal water consumption												
・Take proper action by registering/disconnecting illegal water users												
5. Conducting measures for reducing "Physical Losses"												
5.1 Step test and leak detection												
・Detect visible leakage by inspecting the pipe route (simultaneously with meter survey and flow measurement on-sites)												
・Carry out step test for prioritization in RY 1, 2, and 3							RY1, RY2, RY3					
・Select priority area for leak detection												
・Detect invisible leakage by modified step test								RY1, RY2, RY3				
5.2 Repair visible leakages and record properly (May, June, July)												
5.3 Repair invisible leakages and record properly												
6. Preparation of Reports and Holding of Workshop and Seminars												
6.1 Analysis of the NRW component												
6.1 Undertaking cost-benefit analysis of NRW for each Activity												
6.2 Preparation of manuals on methods and use of survey equipment learned through the pilot project												
6.3 Holding a workshop/seminar and presentation of the completion report of the pilot project												


Ruyenzi
2018
2019
Mar Apr May Jun Jul Aug Sep Oct Nov Dec Jan Feb Mar Apr May Jun Jul Aug Sep Oct
Effect measurement, NRW Rate Calculation
▼Baseline 68.4%
▼PRV Base for Oct
▼Meter Replacement Effect for Feb
▼PRV Effect for Dec
▼Leakage Repair Effect for Feb
Customer Survey 1,692（GIS1,623、Out of list 69）
6/4 - 8/30
Questionnaire Zero Consumption Survey (136), Disconnection Survey (86), Total 222
9/27 - 11/15
Apparent Loss
On-site Meter Test Big Customer (413)
（May-July, more than 20m3/M)
8/27 - 10/24、11/16 - 11/30
Affix POC Seals
Meter Replacement 139（10/day x 2 Team)
59 80
Visible Leakage
Repair Record Copy
Invisible
Step Test Survey Planning
Step Test Execution
Leakage Repair
High pressure Control
Chamber, Piping 200㎜、40㎜ PRV1, 3
9/3 - 9/28
200㎜ PRV2
8/27 - 11/7
PRV Setting 200㎜、40㎜ PRV1, 3
Baseline Qmnf 10/25-26, Pre-Qmin StageTest 10/31, Effect Qmnf 11/7-8
200㎜ PRV2
Baseline Qmnf 11/7-8, Pre-Qmin StageTest 11/13, Effect Qmnf 11/15-16
Adjustment of Distribution Area
RY2 550m
Pipe Extension

2. Apparent loss

IDENTIFICATION

1 Numbers of surveyed

	Customer	
RY1	1,046	61%
RY2	242	14%
RY3	417	24%
Total	1,705	100%

2 User category

	Domestic		Public tap		Ind. & Comm.		Others		N/A		
RY1	970	92.7%	11	1.1%	37	3.5%	28	2.7%	0	0.0%	1,046
RY2	231	95.5%	1	0.4%	7	2.9%	0	0%	3	1.2%	242
RY3	400	95.9%	5	1.2%	6	1.4%	6	1.4%	0	0.0%	417
Total	1,601	93.9%	17	1.0%	50	2.9%	34	2.0%	3	0.2%	1,705

3 Connection type

	Yard Con.		Others		N/A		
RY1	475	45.4%	569	54.4%	2	0.2%	1,046
RY2	109	45.0%	133	55.0%	0	0%	242
RY3	209	50.1%	208	49.9%	0	0%	417
Total	793	46.5%	910	53.4%	2	0.1%	1,705

4 User type

	Owner		Tenant		N/A		
RY1	931	89.0%	114	10.9%	1	0%	1,046
RY2	208	86.0%	34	14.0%	0	0%	242
RY3	378	90.6%	36	8.6%	3	0.7%	417
Total	1,517	89.0%	184	10.8%	4	0.2%	1,705

I. Meter Condition

1 Meter working

	YES		NO		N/A		
RY1	1,024	97.9%	21	2.0%	1	0.1%	1,046
RY2	222	91.7%	19	7.9%	1	0.4%	242
RY3	409	98.1%	7	1.7%	1	0.2%	417
Total	1,655	97.1%	47	2.8%	3	0.2%	1,705

2 Meter working condition

	Normal		Blocked		Broken		Red ball		Unreadable		Others		N/A		
RY1	1,025	98.0%	11	1.1%	4	0.4%	0	0%	2	0.2%	4	0.4%	0	0%	1,046
RY2	228	94.2%	8	3.3%	5	2.1%	0	0%	0	0%	0	0%	1	0.4%	242
RY3	409	98.1%	3	0.7%	2	0.5%	0	0%	0	0%	1	0.2%	2	0.5%	417
Total	1,662	97.5%	22	1.3%	11	0.6%	0	0%	2	0.1%	5	0.3%	3	0.2%	1,705

3 Meter to be replaced

	YES		NO		N/A		
RY1	20	1.9%	1,026	98.1%	0	0%	1,046
RY2	17	7.0%	225	93.0%	0	0%	242
RY3	10	2.4%	406	97.4%	1	0.2%	417
Total	47	2.8%	1,657	97.2%	1	0.1%	1,705

II. Connection Status

1 Status — Multiple answers

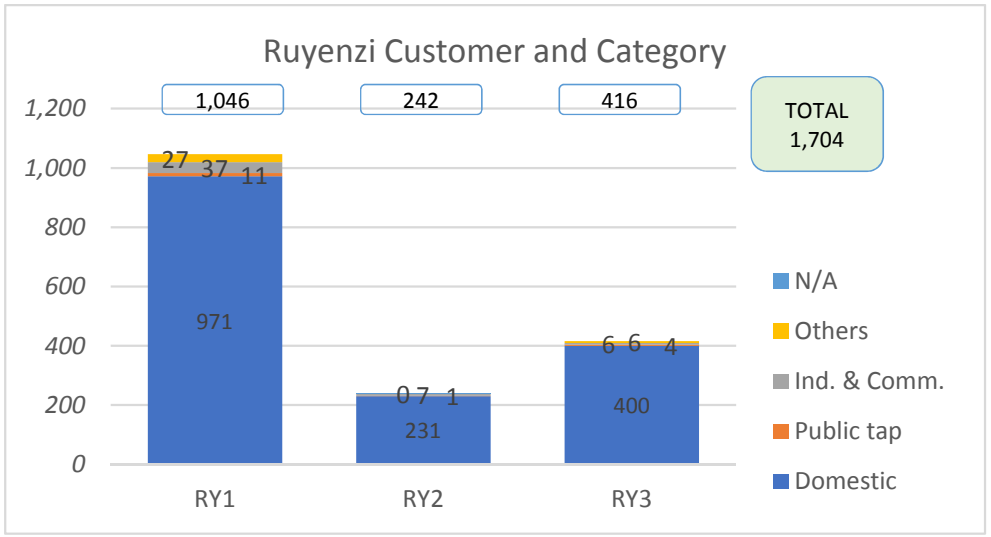
	Normal		Disconnected		Encased in meter box		Meter box locked		Stop valves not working		Others		
RY1	1,017	97.2%	65	6.2%	163	15.6%	18	1.7%	0	0%	1	0.1%	1,264
RY2	194	80.2%	16	6.6%	74	30.6%	20	8.3%	5	2.1%	1	0.4%	310
RY3	378	90.6%	26	6.2%	118	28.3%	10	2.4%	1	0.2%	0	0.0%	533
Total	1,589	93.2%	107	6.3%	355	20.8%	48	2.8%	6	0.4%	2	0.1%	2,107

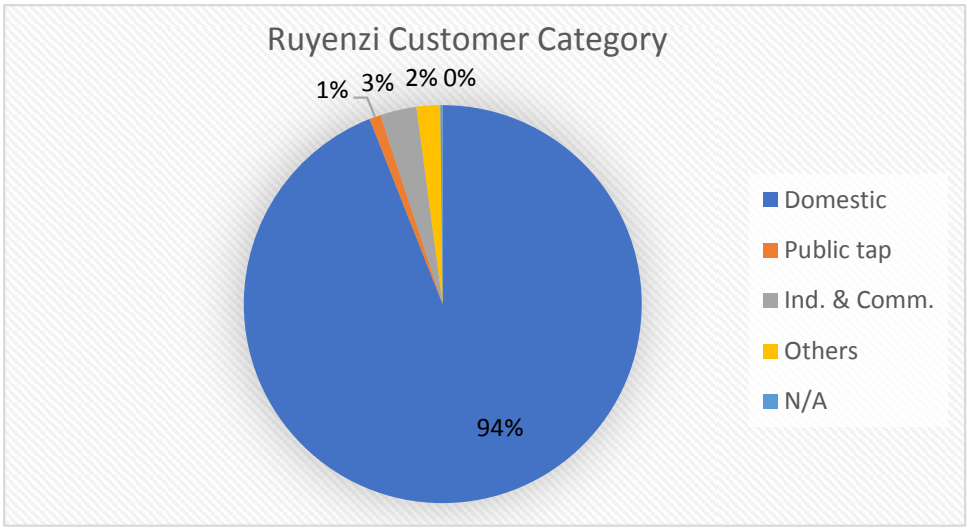
2 Leak level

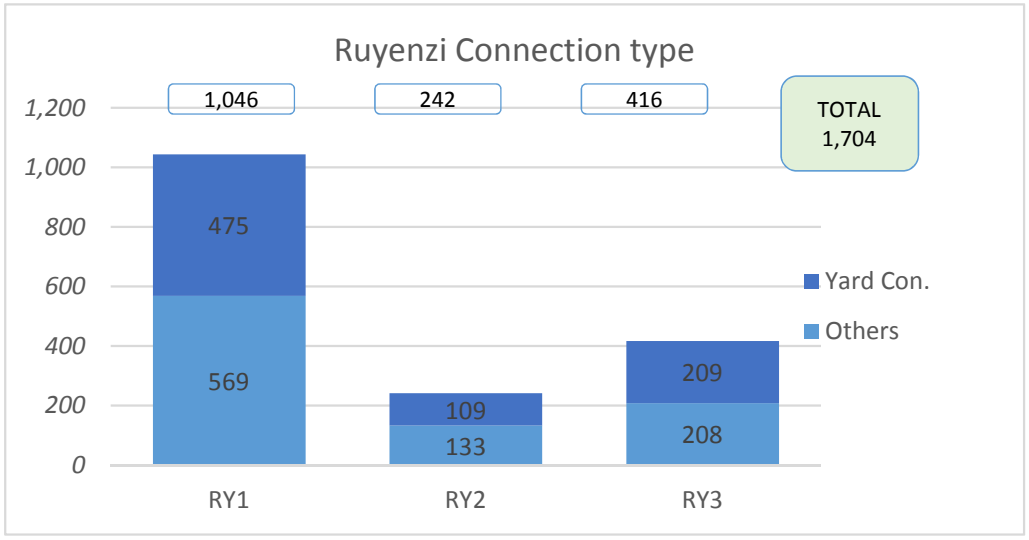
	0	1	2	3	NA	
RY1	870	152	15	5	4	1,046
RY2	107	127	1	2	5	242
RY3	331	74	2	2	8	417
Total	1,308	353	18	9	17	1,705
TOTAL (1+2+3)				380		

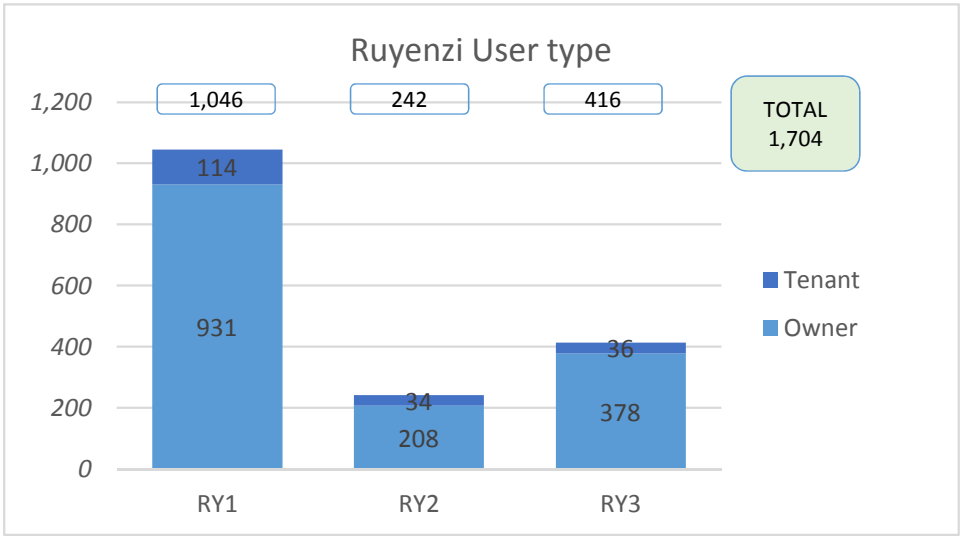
3 Possible leak point — Multiple answers

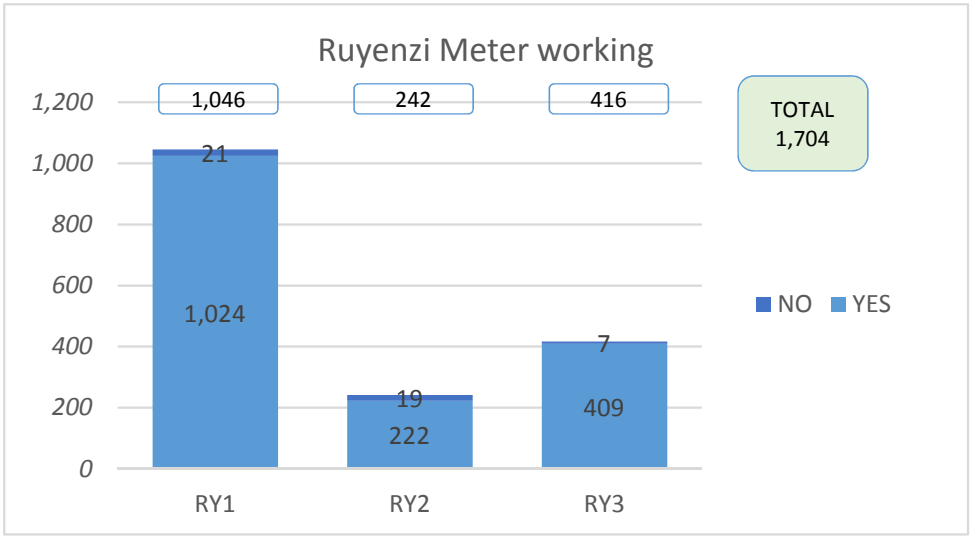
	Unknown	Fittings	Stop valves	Meters	Taps	Pipes	Others	
RY1	39	9	8	2	114	11	1	184
RY2	99	2	7	0	20	3	1	132
RY3	41	4	5	0	28	2	1	81
Total	179	15	20	2	162	16	3	397

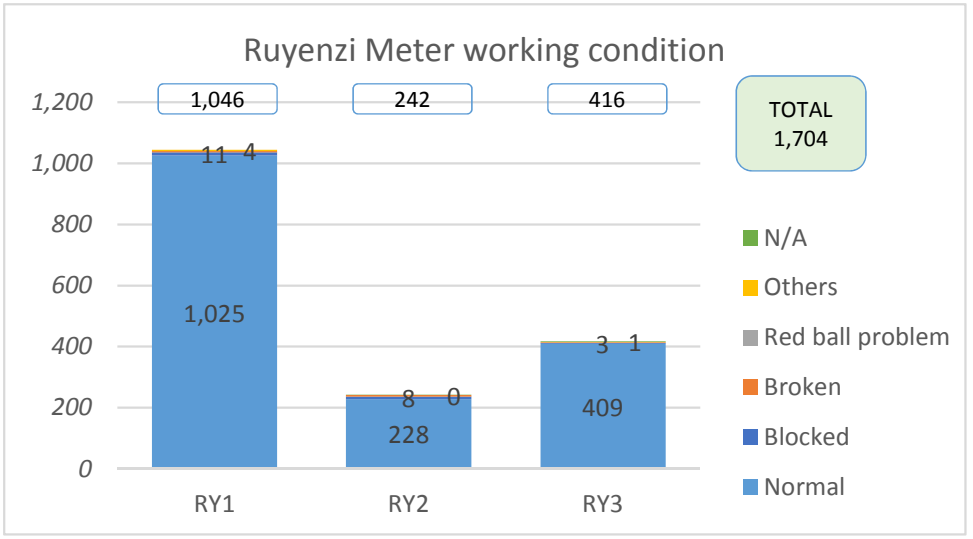

Ruyenzi Customer and Category
1,046
242
416
TOTAL
1,704
1,200
1,000
800
600
400
200
0
27
37
11
971
0 7 1
231
6 6 4
400
RY1
RY2
RY3
N/A
Others
Ind. & Comm.
Public tap
Domestic

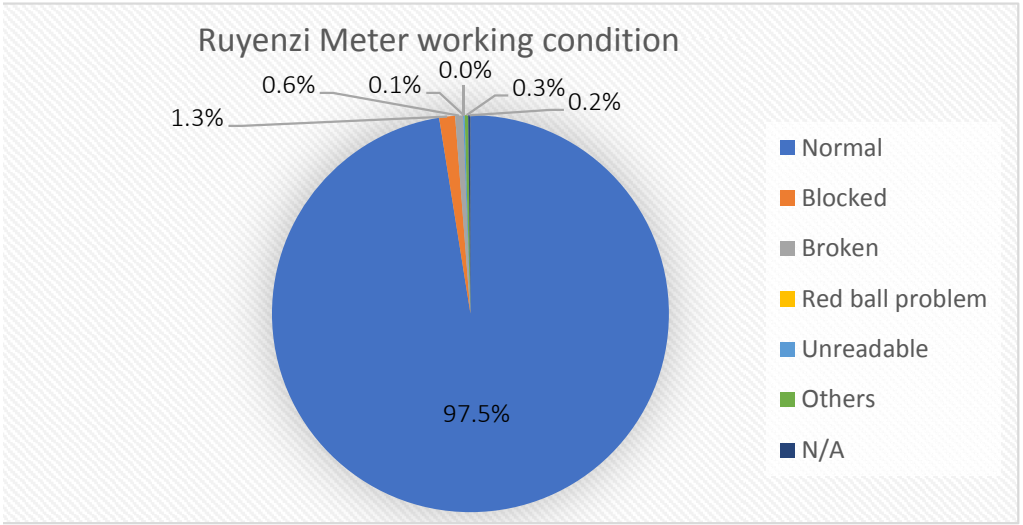

Ruyenzi Customer Category
1%
3%
2%
0%
94%
Domestic
Public tap
Ind. & Comm.
Others
N/A

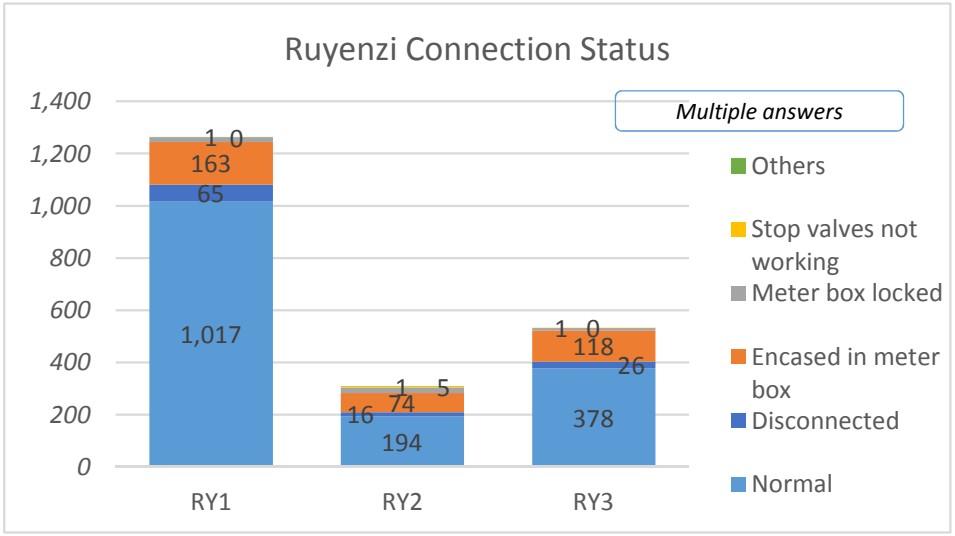

Ruyenzi Connection type
1,046
242
416
TOTAL
1,704
1,200
1,000
800
600
400
200
0
475
569
109
133
209
208
RY1
RY2
RY3
Yard Con.
Others

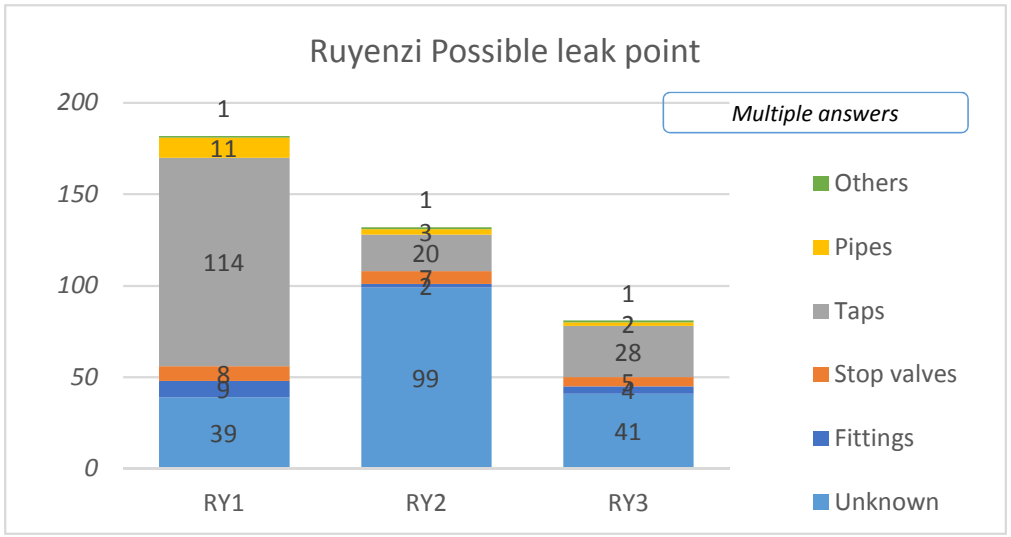

Ruyenzi User type
1,046
242
416
TOTAL
1,704
1,200
1,000
800
600
400
200
0
114
931
34
208
36
378
RY1
RY2
RY3
Tenant
Owner

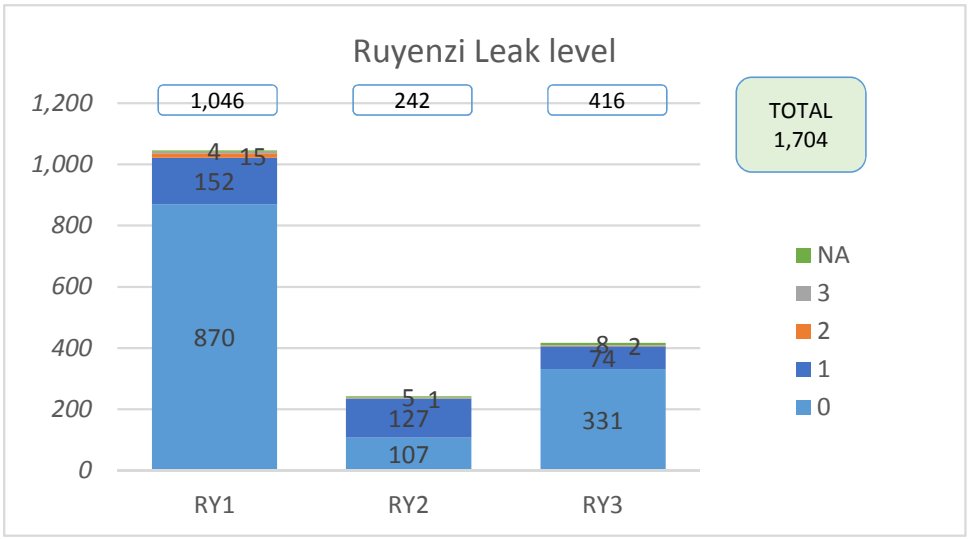

Ruyenzi Meter working
1,200
1,000
800
600
400
200
0
1,046
242
416
TOTAL
1,704
21
1,024
19
222
7
409
NO
YES
RY1
RY2
RY3


Ruyenzi Meter working condition
1,200
1,000
800
600
400
200
0
1,046
242
416
TOTAL
1,704
11
4
1,025
8
0
228
3
1
409
N/A
Others
Red ball problem
Broken
Blocked
Normal
RY1
RY2
RY3


Ruyenzi Meter working condition
0.6%
0.1%
0.0%
0.3%
0.2%
1.3%
97.5%
Normal
Blocked
Broken
Red ball problem
Unreadable
Others
N/A


Ruyenzi Connection Status
Multiple answers
1,400
1,200
1,000
800
600
400
200
0
1
0
163
65
1,017
1
5
16
74
194
1
0
118
26
378
Others
Stop valves not working
Meter box locked
Encased in meter box
Disconnected
Normal
RY1
RY2
RY3


Ruyenzi Possible leak point
Multiple answers
200
150
100
50
0
RY1
RY2
RY3
1
11
114
8
9
39
1
3
20
7
2
99
1
2
28
5
4
41
Others
Pipes
Taps
Stop valves
Fittings
Unknown


Ruyenzi Leak level
1,200
1,000
800
600
400
200
0
RY1
RY2
RY3
1,046
242
416
TOTAL
1,704
4
15
152
870
5
1
127
107
8
2
74
331
NA
3
2
1
0

Ruyenzi Customer Survey

IDENTIFICATION						Meter condition			Connection status												OTHERS					POC on Original list
No	POC	DMA	User catego	Conn. Type	User	Working	Condition	Replaced	Status						Leak Level	Possible leak point						Others	Customer comment	Surveyor comment	Not on map	Date	Surveyor	
1	240211747	1	4	2	NA	2	1	1	1						ok										1			#N/A
2	240211782	1	1	1	2	1	1	2	1						2				4						1	2018/6/22	Anicet	#N/A
3	240211800	3	2	1	1	1	1	2	1						NA									it has been removed.	1	2018/6/12	vedaste	#N/A
4	240213073	1	1	2	2	1	1	2	1						ok											2018/6/26	vedaste	240213073
5	240214438	1	1	2	1	1	1	2	1						ok											2018/7/5	Anicet	240214438
6	240214481	1	1	2	1	1	1	2	1						ok											2018/7/3	vedaste	240214481
7	240214482	1	1	2	1	1	1	2	1						1	1										2018/6/18	Vedaste	240214482
8	240214484	1	1	NA	1	1	1	2	1						ok											2018/6/18	Vedaste	240214484
9	240214485	1	1	1	1	1	1	2	1	2					ok									disconnected one week ago		2018/6/19	Anicet	240214485
10	240214486	1	1	2	1	1	1	2	1						ok											2018/6/20	Vedaste	240214486
11	240214487	1	1	1	1	1	1	2	1						ok											2018/6/19	Anicet	240214487
12	240214488	1	1	2	1	1	1	2	1						ok											2018/6/20	Anicet	240214488
13	240214489	1	1	2	1	1	1	2	1						ok											2018/6/20	Anicet	240214489
14	240214491	2	1	2	1	1	1	2	1						1	1										2018/6/7	Anicet	240214491
15	240214492	2	1	2	1	1	1	2	1						ok										1	2018/6/7	Anicet	#N/A
16	240214493	2	1	2	1	1	1	2	1		3				ok											2018/6/7	Anicet	240214493
17	240214494	2	1	2	1	1	1	2	1						ok											2018/6/7	Anicet	240214494
18	240214495	1	4	2	2	1	1	2	1		3				ok											2018/6/21	Anicet	240214495
19	240214496	1	1	2	1	1	1	2	1						ok											2018/6/19	Anicet	240214496
20	240214501	2	1	2	1	1	1	2	1						ok											2018/6/7	Anicet	240214501
21	240214502	2	1	1	1	1	1	2	1						ok											2018/6/7	Anicet	240214502
22	240214504	2	1	2	1	1	3	1	1						ok											2018/6/7	Anicet	240214504
23	240214505	2	1	2	1	1	1	2	1						ok											2018/6/7	Anicet	240214505
24	240214506	2	1	2	1	1	1	2	1						1	1									1	2018/6/7	Anicet	#N/A
25	240214510	1	1	2	1	1	1	2	1						ok											2018/6/26	Anicet	240214510
26	240214513	1	1	1	2	1	1	2	1						ok									typing error on map	1	2018/7/12	vedaste	#N/A
27	240214521	3	1	1	2	1	1	2	1	2					ok									disconnected for 2years and not on map	1	2018/6/14	Vedaste	#N/A
28	240214522	1	1	2	2	1	1	2	1						ok											2018/7/5	Anicet	240214522
29	240214529	1	1	2	1	1	1	2	1						ok											2018/7/6	Anicet	240214529
30	240214532	1	1	2	2	1	1	2	1						ok											2018/6/26	Anicet	240214532
31	240214535	1	1	2	1	1	1	2	1						ok											2018/7/11	Anicet	240214535
32	240214537	1	1	2	1	1	1	2	1						ok											2018/7/11	Anicet	240214537
33	240214538	1	4	2	1	1	1	2	1						ok									not on map	1	2018/7/11	Anicet	#N/A
34	240214539	1	1	2	1	1	1	2	1						ok											2018/7/6	vedaste	240214539
35	240214540	2	1	2	1	1	1	2	1						ok											2018/6/4	Anicet	240214540
36	240214541	3	1	1	1	1	1	2	1						1					5						2018/7/13	vedaste	240214541
37	240214544	1	1	2	1	1	1	2	1						1	1										2018/7/13	vedaste	240214544
38	240214545	2	1	2	2	1	1	2	1						1	1										2018/6/7	Vedaste	240214545
39	240214546	1	1	2	1	1	1	2	1						2						6					2018/7/3	Anicet	240214546
40	240214547	1	1	1	2	1	1	2	1		3				ok											2018/7/3	Anicet	240214547
41	240214548	1	1	1	1	1	1	2	1						1					5						2018/6/21	Anicet	240214548
42	240214550	1	1	1	1	1	1	2	1						ok											2018/7/6	Anicet	240214550
43	240214553	1	1	2	1	1	1	2	1						ok											2018/6/19	Vedaste	240214553
44	240214554	1	1	1	1	1	1	2	1						ok											2018/6/21	Vedaste	240214554
45	240214555	1	1	1	1	1	1	2	1		3				ok											2018/6/20	Anicet	240214555
46	240214557	1	1	1	1	1	1	2	1						ok											2018/7/12	vedaste	240214557
47	240214558	1	1	1	1	1	1	2	1	2					NA									disconnected today.		2018/6/18	Vedaste	240214558
48	240214559	1	1	1	1	1	1	2	1						ok											2018/6/18	Vedaste	240214559
49	240214560	1	1	1	2	1	1	2		2					1	1								one year disconnected.		2018/6/18	Vedaste	240214560
50	240214561	1	1	1	1	1	1	2	1						1					5						2018/6/22	Anicet	240214561
51	240214562	1	1	1	1	1	1	2	1						ok											2018/7/6	Anicet	240214562
52	240214563	1	1	1	1	1	1	2	1						ok											2018/6/18	Vedaste	240214563
53	240214564	1	1	2	1	1	1	2	1						ok											2018/6/18	Vedaste	240214564
54	240214565	1	1	1	1	1	1	2	1						ok											2018/6/19	Vedaste	240214565
55	240214568	1	1	1	1	1	1	2	1						ok											2018/8/1	Anicet	240214568
56	240214569	1	1	1	1	1	1	2	1						1					5						2018/7/3	Anicet	240214569
57	240214572	1	1	2	1	1	1	2	1						ok											2018/6/18	Vedaste	240214572
58	240214575	1	1	1	1	1	1	2	1						ok											2018/6/19	Vedaste	240214575
59	240214576	1	1	1	1	1	1	2	1	2					ok									disconnected a while ago	1	2018/6/19	Anicet	#N/A
60	240214577	1	1	2	1	1	1	2	1						ok											2018/6/19	Anicet	240214577
61	240214490	1	3	2	1	1	1	2	1						ok											2018/6/20	Vedaste	240214490
62	240214579	3	1	1	1	1	1	2	1						ok											2018/6/11	Vedaste	240214579
63	240214580	1	1	2	1	1	1	2	1						ok											2018/6/19	Vedaste	240214580
64	240214581	1	1	2	1	1	1	2	1						ok											2018/7/5	Anicet	240214581
65	240214582	1	1	2	1	1	1	2	1						ok									not on map	1	2018/6/18	Vedaste	#N/A
66	240214583	3	1	2	1	1	1	2	1						ok											2018/6/11	Anicet	240214583
67	240214584	1	1	2	1	1	1	2	1						ok											2018/6/22	Anicet	240214584
68	240214585	1	1	1	1	1	1	2	1						1					5						2018/7/11	vedaste	240214585
69	240214586	3	1	2	1	1	1	2	1						ok											2018/6/11	Anicet	240214586
70	240214588	1	1	2	1	1	1	2	1						ok											2018/6/21	Anicet	240214588
71	240214589	1	1	2	1	1	1	2	1						1					5						2018/7/10	vedaste	240214589
72	240214590	1	1	1	2	1	1	2	1						ok											2018/6/21	Anicet	240214590
73	240214591	3	1	1	1	1	1	2	1		3				ok											2018/6/11	Vedaste	240214591

Meter and Connection Survey in Ruyenzi

No: _____
Date: _____
Surveyor:_____

POC: 24021_____	**DMA: RY_____**	**User category: 1) Domestic, 2) Public tap, 3) Industry & commerce, 4) Others**

Connection type: 1) Yard connection, 2) Others	**User: 1) Owner, 2) Tenant**

I. Meter Condition

Working: 1) Yes, 2) No
(to be checked by opening tap)

Condition: 1) Normal, 2)Blocked, 3) Broken, 4) Red ball problem, 5) Unreadable, 6) Others_____

Meter to be replaced: 1) Yes, 2) No **Comment, if any: _____**

II. Connection Status

Status: 1) Normal, 2) Disconnected, 3) Encased in meter box, 4) Meter box locked, 5) Stop valves not working, 6) Others_____

Leak level: _____ **Possible leak point: 1) Unknown, 2) Fittings, 3) Stop valves, 4) Meters, 5) Taps, 6) Pipes, 7) Others_____**

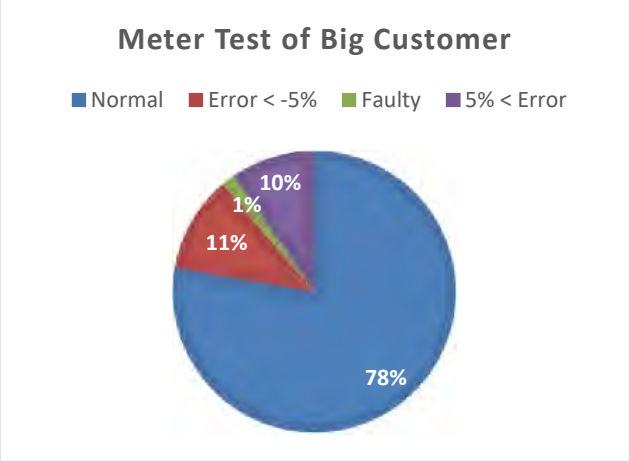
III. Others

Others: 1) Poor masonry, 2) Difficult access, 3) Poor quality materials, 4) Improper size of pipe and meter, 5) Traces of illegal water use 6) Others_____

<Any opinion by customer>

<Observation by Surveyor>

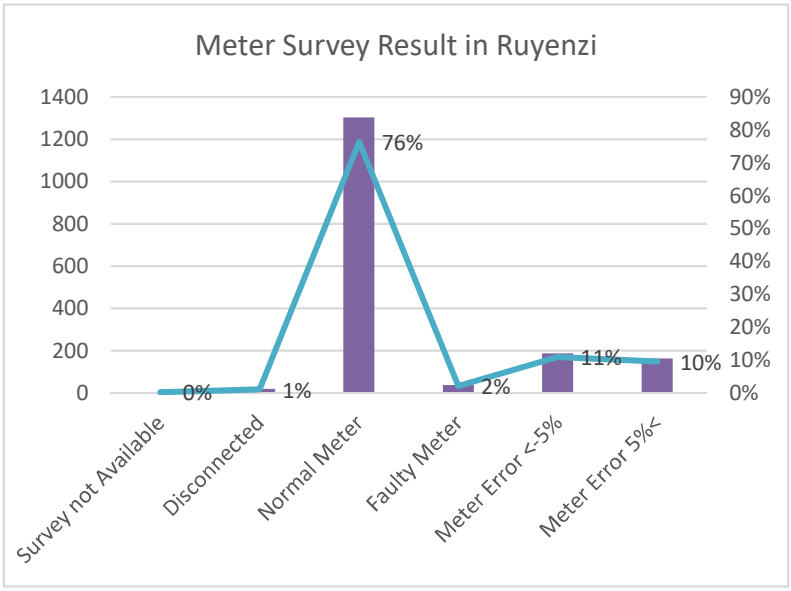
Item	Number	Rate
Normal	321	78%
Error < -5%	46	11%
Faulty	6	1%
5% < Error	40	10%
Total	413	100%



Meter Survey Result in Ruyenzi

Sub-zone	Survey not Available	Disconnected	Normal Meter	Faulty Meter	Meter Error <-5%	Meter Error 5%<	Total
TOTAL	3	17	1302	35	186	162	1705
%	0%	1%	76%	2%	11%	10%	100%

Note: Ratio of the meter number with more than ±5% is estimated by the meter test result of big customer



Meter Survey of Ruyenzi (Pilot Area 2)

On-site Meter Test

Ruyenzi Pilot Area

No.	Date	POC	Diameter	Start-Exist	Finish-Exist	Start-Test	Finish-Test	Flow Rate	Meter-error (%)	Meter-error (%)	Observation
1		240215399		752.7821	752.8132	64.6095	64.6289	570	60.31	0.00	
2		240215651		1516.7127	1516.7398	64.4144	64.4321	520	53.11	0.00	
3		240218091		459.2413	459.2691	85.7525	85.7707	560	52.75	0.00	
4		240216161		544.6483	544.6797	65.0312	65.0527	630	46.05	0.00	
5		240215133		331.7090	331.7341	65.6398	65.6570	600	45.93	0.00	
6		240215614		748.6100	748.6353	64.1541	64.1715	520	45.40	0.00	
7		240215150		1129.3310	1129.3710	85.9638	85.9916	620	43.88	0.00	
8		240216223		522.8819	522.9066	85.6233	85.6408	520	41.14	0.00	
9		240214807		888.3408	888.3681	86.7169	86.7371	630	35.15	0.00	
10		240215624		890.7390	890.7651	81.9965	82.0159	570	34.54	0.00	
11		240216087		543.6505	543.6801	86.6138	86.6362	660	32.14	0.00	
12		240214553		1416.7127	1416.7378	82.9208	82.9400	560	30.73	0.00	
13		240215836		267.3490	267.3730	88.6401	88.6592	600	25.65	0.00	
14		240215723		931.1729	931.1933	63.4144	63.4311		22.16	0.00	
15		240215235		1048.8560	1048.8782	63.1167	63.1349	540	21.98	0.00	
16		240215845		2163.3635	2163.3851	82.0641	82.0819	560	21.35	0.00	
17		240214564		1354.3122	1354.3345	87.06	87.0788	560	18.62	0.00	
18		240218123		369.3673	369.3832	84.4946	84.5086	560	13.57	0.00	
19	24/10/2018	240216310		741.6576	741.6803	66.9329	66.9531	600	12.38	0.00	
20		240215354		1589.2117	1589.2341	83.4824	83.5026	600	10.89	0.00	
21		240218994		101.5618	101.5867	86.6666	86.6891	570	10.67	0.00	
22		240215009		317.208	317.229	81.4152	81.4342	570	10.53	0.00	
23		240215340		5575.2925	5575.3125	87.8913	87.9094	540	10.50	0.00	
24		240217534		593.6897	593.7105	82.9545	82.9736	540	8.90	0.00	
25		240217476		1145.3213	1145.3450	85.3207	85.3425	650	8.72	0.00	
26		240214491		466.4833	466.5078	83.2975	83.3201	660	8.41	0.00	
27		240215931		514.773	514.7938	67.0424	67.0616	600	8.33	0.00	
28		240215897		1493.6413	1493.6623	88.1465	88.1659	600	8.25	0.00	
29		240218522		225.1352	225.1540	82.0287	82.0461	510	8.05	0.00	
30		240214901		1454.1748	1454.193	64.6949	64.7118	520	7.69	0.00	
31		240214804		49.514	49.537	81.1968	81.2182	630	7.48	0.00	
32	2018/2/10	240214968		1168.9868	1169.0097	87.2295	87.2509	630	7.01	0.00	
33		240214715		2976.888	2976.908	81.3606	81.3793	560	6.95	0.00	
34		240218468		354.7131	354.7337	63.2403	63.2596	560	6.74	0.00	
35		240217981		332.3565	332.3758	86.2995	86.3177	590	6.04	0.00	
36		240214760		977.9356	977.9563	63.1715	63.1911	570	5.61	0.00	
37		240217870		300.1900	300.2098	82.6569	82.6757	560	5.32	0.00	
38		240214859		175.5212	175.5395	86.5174	86.5348	520	5.17	0.00	
39		240214724		1211.5752	1211.5935	84.9415	84.9589		5.17	0.00	
40		240214529		620.4829	620.5039	82.3010	82.3210	620	5.00	0.00	
41		240215061		928.3286	928.3669	65.8172	65.8537	620	4.93	4.93	
42		240217887		412.0022	412.0246	84.2694	84.2908	620	4.67	4.67	
43		240216059		596.2876	596.3102	83.4485	83.4701	630	4.63	4.63	
44	28/9/2018	240214926		949.8303	949.8488	86.8391	86.8568	510	4.52	4.52	
45		240215827		1296.968	1296.9902	66.7481	66.7694	630	4.23	4.23	
46		240215453		269.0351	269.0574	64.4553	64.4767	620	4.21	4.21	
47		240215292		485.1741	485.1998	85.1626	85.1873	700	4.05	4.05	
48		240216238		406.9766	406.9998	84.3959	84.4182	650	4.04	4.04	
49		240214771		1370.249	1370.275	81.1398	81.1648	770	4.00	4.00	
50		240218068		281.082	281.1056	87.659	87.6817	660	3.96	3.96	
51	12/9/2018	240214816		159.3532	159.3746	83.9770	83.9976		3.88	3.88	
52		240217615		578.9792	579.0008	84.3665	84.3873	600	3.85	3.85	
53		240214693		839.7081	839.7278	84.9941	85.0131	560	3.68	3.68	
54		240216233		560.1683	560.1886	88.7086	88.7282	590	3.57	3.57	
55		240218807		199.3620	199.3826	82.1846	82.2045	600	3.52	3.52	
56		240214877		8.7530	8.7738	82.9856	83.0057	570	3.48	3.48	
57	20/9/2018	240215485		345.2211	345.2397	85.4011	85.4191	520	3.33	3.33	
58		240215449		1201.5035	1201.5228	82.2128	82.2315	570	3.21	3.21	
59		240217260		1567.4459	1567.466	64.9411	64.9606	560	3.08	3.08	
60		240217547		734.4851	734.5052	87.7189	87.7384	570	3.08	3.08	
61		240215108		686.425	686.442	81.9439	81.9604	490	3.03	3.03	
62		240215351		1008.2300	1008.2505	63.2129	63.2328	590	3.02	3.02	
63	19/9/2018	240215312		885.8776	885.9018	63.0794	63.1029	650	2.98	2.98	
64		240214603		1153.3720	1153.3933	83.6791	83.6998	600	2.90	2.90	
65		240215158		1561.2681	1561.2897	64.7286	64.7496	630	2.86	2.86	
66	17/10/2018	240214871		227.7565	227.7781	66.5363	66.5573	60	2.86	2.86	
67		240214736		1631.256	1631.274	81.0140	81.0315	480	2.86	2.86	
68		240215259		1338.9252	1338.9433	83.5773	83.5949	540	2.84	2.84	
69		240214783		1565.0944	1565.1169	63.7605	63.7824	620	2.74	2.74	
70		240214583		332.9286	332.9476	88.2034	88.2219	560	2.70	2.70	
71	23/10/2018	240216196		398.074	398.0969	88.8056	88.8279	340	2.69	2.69	
72		240215509		2309.9940	2310.0136	82.0896	82.1087	590	2.62	2.62	
73		240215491		704.6330	704.653	83.7082	83.7277	590	2.56	2.56	
74	2018/1/10	240215241		1605.9768	1605.9972	64.6568	64.6767	620	2.51	2.51	
75		240216177		1656.6113	1656.6325	87.7471	87.7678	630	2.42	2.42	
76		240216122		120.5022	120.5201	86.4711	86.4886	520	2.29	2.29	
77		240214990		1209.5793	1209.6018	62.9690	62.9910	630	2.27	2.27	
78	6/9/2018	240214557		634.6205	634.6389	82.7920	82.8100	540	2.22	2.22	
79		240219061		69.9845	70.0075	65.9977	66.0202	570	2.22	2.22	
80	15/10/2018	240215478		1996.8436	1996.8622	66.3147	66.3329	520	2.20	2.20	
81		240218383		371.0627	371.0818	63.1394	63.1581	560	2.14	2.14	
82		240219120		149.1268	149.147	87.8418	87.8616	570	2.02	2.02	
83		240214999		700.7973	700.8179	65.4489	65.4691	600	1.98	1.98	

84		240215180		410.7044	410.7254	84.6348	84.6554	630	1.94	1.94	
85		240217898		413.1664	413.1876	65.7152	65.736	620	1.92	1.92	
86		240218228		91.6894	91.7111	66.463	66.4843	600	1.88	1.88	
87	25/9/2018	240218198		482.059	482.0817	86.0974	86.1197	650	1.79	1.79	
88		240218921		55.8743	55.8972	64.7593	64.7818	660	1.78	1.78	
89		240215841		1355.3406	1355.3591	66.8182	66.8364	540	1.65	1.65	
90		240214956		341.5327	341.5515	88.247	88.2655	560	1.62	1.62	
91		240215871		492.1064	492.1262	65.8874	65.9069	590	1.54	1.54	
92		240218785		72.6585	72.6791	88.278	88.2983	600	1.48	1.48	
93		240215425		848.1241	848.1457	82.8845	82.9058	570	1.41	1.41	
94		240215636		262.1083	262.1299	88.7392	88.7605	630	1.41	1.41	
95		240215228		1319.0673	1319.089	86.4095	86.4309	630	1.40	1.40	
96		240215630		750.523	750.5453	65.3609	65.3829	650	1.36	1.36	
97		240217370		249.7393	249.7564	65.7758	65.7927	510	1.18	1.18	
98		240217835		532.4266	532.4443	63.3045	63.3220	570	1.14	1.14	
99		240217986		186.7108	186.7286	88.6531	88.6707	520	1.14	1.14	
100		240216290		462.6494	462.6681	66.3991	66.4176	620	1.08	1.08	
101		240219144		116.228	116.2468	66.2365	66.2551	560	1.08	1.08	
102		240214923		5065.2318	5065.2517	64.9927	65.0124	570	1.02	1.02	
103		240217305		752.3219	752.3423	85.9008	85.921	590	0.99	0.99	
104	16/10/2018	240219140		105.1506	105.1712	66.3662	66.3866	600	0.98	0.98	
105	2018/10/10	240218923		265.5013	265.5222	88.3105	88.3312	620	0.97	0.97	
106	2018/3/10	240216162		688.3727	688.3938	64.9096	64.9305	600	0.96	0.96	
107		240215086		2464.2083	2464.2298	66.4948	66.5161	600	0.94	0.94	
108	27/8/2018	240214991	3/4″	1348.603	1348.625	81.2195	81.2413	630	0.92	0.92	
109		240215111		423.1150	423.1314	84.774	84.7903	570	0.61	0.61	
110		240215680		606.3422	606.3600	88.5747	88.5924	550	0.56	0.56	
111		240214843		1525.8538	1525.8717	62.8500	62.8678	520	0.56	0.56	
112		240214640		1459.4434	1459.4614	84.8626	84.8805	560	0.56	0.56	
113		240214717		216.9728	216.9914	62.8203	62.8388	540	0.54	0.54	
114		240218786		211.3417	211.3612	84.9173	84.9367	590	0.52	0.52	
115		240214620		879.4056	879.4252	62.9184	62.9379		0.51	0.51	
116		240215007		314.4701	314.4898	83.2228	83.2424	590	0.51	0.51	
117		240218304		412.0683	412.088	66.7093	66.7289	560	0.51	0.51	
118		240218428		330.8208	330.8413	63.6690	63.6894	600	0.49	0.49	
119		240215850		506.2031	506.2240	83.1765	83.1973	630	0.48	0.48	
120		240218387		240.277	240.298	86.971	86.9919	630	0.48	0.48	
121		240215067		57.6791	57.7003	81.9641	81.9852		0.47	0.47	
122		240214915		1623.7387	1623.7599	82.5623	82.5834	620	0.47	0.47	
123		240215768		376.4254	376.447	83.5477	83.5692	630	0.47	0.47	
124	2018/4/10	240219180		127.4763	127.4945	65.2225	65.241	320	0.08	0.08	
125		240214742		555.9592	555.9710	63.6441	63.6561	170	0.03	0.03	Low pressure
126		240216221		550.4422	550.4611	88.0139	88.0328	540	0.00	0.00	
127		240214555		1353.098	1353.116	81.7998	81.8178	550	0.00	0.00	
128		240214772		936.7792	936.8004	85.1306	85.1518	670	0.00	0.00	
129		240215204		856.3434	856.365	89.1857	89.2073	660	0.00	0.00	
130	4/9/2018	240218902		112.3864	112.4074	82.3734	82.3944	620	0.00	0.00	
131		240214875		385.1810	385.2016	82.6028	82.6234	600	0.00	0.00	
132		240217917		186.9727	186.9942	84.3301	84.3516	630	0.00	0.00	
133		240214687		398.5437	398.5636	84.7393	84.7592	600	0.00	0.00	
134		240214708		1549.366	1549.3841	64.3412	64.3593	540	0.00	0.00	
135		240217576		531.2592	531.281	84.2262	84.248	630	0.00	0.00	
136		240217466		561.4081	561.429	66.5864	66.6073	590	0.00	0.00	
137		240281845		361.1708	361.1903	86.8667	86.8862	570	0.00	0.00	
138		240218079		404.7871	404.8083	66.1687	66.1899	630	0.00	0.00	
139		240217701		719.3043	719.3234	85.4905	85.5096	560	0.00	0.00	
140	24/9/2018	240216096		325.7982	325.8171	85.8173	85.8362	540	0.00	0.00	
141		240214813		282.9651	282.9831	83.8037	83.8217	540	0.00	0.00	
142		240218071		461.4001	461.4181	63.4660	63.4840		0.00	0.00	
143		240214970		657.2437	657.2666	64.5139	64.5369	630	−0.43	−0.43	
144		240215166		985.1321	985.1545	65.3267	65.3492	660	−0.44	−0.44	
145		240215911		679.6641	679.6854	87.4796	87.501	630	−0.47	−0.47	
146		240214565		941.7731	941.7941	85.0541	85.0752	620	−0.47	−0.47	
147		240215076		955.2582	955.2787	84.5824	84.603	620	−0.49	−0.49	
148	18/9/2018	240218194		350.0485	350.0686	84.8929	84.9131	600	−0.50	−0.50	
149		240217271		430.5361	430.5561	88.934	88.9541	600	−0.50	−0.50	
150		240219095		125.7747	125.7947	66.9793	66.9994	590	−0.50	−0.50	
151		240215396		796.5513	796.5712	65.6643	65.6843	510	−0.50	−0.50	
152		240215419		1160.1115	1160.1312	66.8585	66.8783	590	−0.51	−0.51	
153		240214718		925.8993	925.919	87.2754	87.2952	560	−0.51	−0.51	
154		240216335		394.1046	394.1241	82.4018	82.4214	590	−0.51	−0.51	
155		240217488		304.4104	304.4297	88.7754	88.7948	570	−0.52	−0.52	
156		240218768		45.6370	45.6545	82.1563	82.1739	520	−0.57	−0.57	
157		240214959		775.9615	775.9789	84.9688	84.9863	510	−0.57	−0.57	
158		240214541		1564.6408	1564.6581	65.5467	65.5641	510	−0.57	−0.57	
159	2018/8/10	240214876		121.5853	121.6026	65.3974	65.4148	510	−0.57	−0.57	
160		240217857		487.2584	487.2749	84.4590	84.4756	520	−0.60	−0.60	
161		240214702		476.135	476.150	80.9593	80.9744	430	−0.66	−0.66	
162		240214562		1590.7037	1590.7259	64.2709	64.2933	660	−0.89	−0.89	
163		240215570		984.1848	984.2069	83.2558	83.2781	660	−0.90	−0.90	
164	26/9/2018	240216822		587.6127	587.6348	64.0255	64.0478	590	−0.90	−0.90	
165		240214842		1117.9191	1117.9412	86.1684	86.1907	660	−0.90	−0.90	
166		240216591		608.0662	608.0881	87.3077	87.3298	650	−0.90	−0.90	
167	2018/12/10	240215237		1094.1502	1094.1716	66.141	66.1626	630	−0.93	−0.93	
168		240215510		30.6020	30.6233	83.3750	83.3965	540	−0.93	−0.93	
169	2018/9/10	240216437		334.9151	334.9358	87.9788	87.9997	620	−0.96	−0.96	
170		240215097		267.3956	267.4163	66.78	66.8009		−0.96	−0.96	
171		240214719		1299.3174	1299.3379	64.8046	64.8253	400	−0.97	−0.97	
172		240216315		774.5813	774.6015	63.6190	63.6394	600	−0.98	−0.98	

173		240218171		684.4529	684.4728	87.3844	87.4045	570	−1.00	−1.00	
174		240217864		831.6214	831.6407	65.9538	65.9733	570	−1.03	−1.03	
175		240216323		321.5676	321.5865	63.9529	63.972	570	−1.05	−1.05	
176		240215940		362.6413	362.66	87.9425	87.9614	570	−1.06	−1.06	
177	22/11/2018	240217678		413.571	413.5893	88.8977	88.9162	570	−1.08	−1.08	
178		240215276		1054.9341	1054.9523	63.0533	63.0717	560	−1.09	−1.09	
179		240214889		550.998	551.041	81.3020	81.3455	660	−1.15	−1.15	
180		240215387		679.1373	679.1539	65.8621	65.8789	510	−1.19	−1.19	
181	10/9/2018	240214835		1631.3600	1631.3822	83.1501	83.1726	660	−1.33	−1.33	
182		240216070		1008.0115	1008.0337	82.3384	82.3609		−1.33	−1.33	
183		240215682		955.0096	955.0312	63.9874	64.0093	660	−1.37	−1.37	
184		240218274		301.9189	301.9405	85.5675	85.5894	650	−1.37	−1.37	
185		240214858		908.1293	908.1449	63.8122	63.8283	240	−1.41	−1.41	Low pressure
186	13/9/2018	240218672		244.0059	244.0127	84.1579	84.1648	430	−1.45	−1.45	Low pressure
187		240214545		1136.0200	1136.0403	82.4677	82.4883	620	−1.46	−1.46	
188	17/9/2018	240214981		649.1975	649.2176	84.6976	84.7180	620	−1.47	−1.47	
189		240215192		1149.1766	1149.1966	64.233	64.2533	600	−1.48	−1.48	
190		240216232		1064.595	1064.615	81.7712	81.7915	600	−1.48	−1.48	
191		240215281		640.6377	640.6575	66.1096	66.1297	600	−1.49	−1.49	
192		240218262		296.5004	296.5201	83.8679	83.8879	590	−1.50	−1.50	
193	30/8/2018	240214653		551.570	551.589	81.8815	81.9008	600	−1.55	−1.55	
194		240214744		1626.5043	1626.5228	83.0404	83.0592	600	−1.60	−1.60	
195		240215131		1298.0316	1298.0500	63.7025	63.7212	560	−1.60	−1.60	
196		240214778		1195.0626	1195.0807	63.7324	63.7508	600	−1.63	−1.63	
197		240215102		1356.3841	1356.4022	87.4198	87.4382	540	−1.63	−1.63	
198		240214829		1309.9546	1309.9726	83.9144	83.9327		−1.64	−1.64	
199		240214754		154.1247	154.1426	82.8188	82.8370	540	−1.65	−1.65	
200		240215314		1213.8655	1213.8827	63.8923	63.9098	520	−1.71	−1.71	
201		240215316		445.572	445.5886	65.6905	65.7074	510	−1.78	−1.78	
202		240215771		624.0132	624.0352	87.5905	87.6129	660	−1.79	−1.79	
203		240216842		759.9276	759.9493	82.6855	82.7076		−1.81	−1.81	
204		240214482		1255.2193	1255.2408	64.5615	64.5834	650	−1.83	−1.83	
205		240218176		391.9066	391.9281	87.1878	87.2097	650	−1.83	−1.83	
206		240218116		344.1747	344.1961	84.8176	84.8394	650	−1.83	−1.83	
207		240218166		301.3630	301.3843	86.3383	86.3600	630	−1.84	−1.84	
208		240216829		640.0960	640.1171	82.5215	82.5430	630	−1.86	−1.86	
209		240215949		225.8912	225.9121	88.0445	88.0658	630	−1.88	−1.88	
210		240214808		641.9618	641.9827	63.0051	63.0264	630	−1.88	−1.88	
211		240214546		621.4577	621.4782	86.2119	86.2328	630	−1.91	−1.91	
212		240216069		412.6727	412.6924	88.6712	88.6913	530	−1.99	−1.99	
213		240215278		451.0425	451.0683	85.8559	85.8827	350	−2.03	−2.03	Low pressure
214		240214966		1009.856	1009.880	81.2474	81.2719	660	−2.04	−2.04	
215		240214995		1524.6466	1524.6657	87.6281	87.6476	580	−2.05	−2.05	
216		240214621		1255.6869	1255.7059	88.1093	88.1287	570	−2.06	−2.06	
217		240216388		728.0536	728.0725	88.3971	88.4164	590	−2.07	−2.07	
218		240214510		1294.8429	1294.8615	63.7884	63.8074	560	−2.11	−2.11	
219		240215718		608.3036	608.3218	87.0169	87.0355	560	−2.15	−2.15	
220		240215096		859.4739	859.4921	87.5196	87.5382	520	−2.15	−2.15	
221		240281795		2220.8414	2220.8594	87.3516	87.37	540	−2.17	−2.17	
222		240214741		278.2544	278.2765	83.0689	83.0915	680	−2.21	−2.21	
223		240215332		983.8346	983.8563	83.6009	83.6231	630	−2.25	−2.25	
224		240215210		1923.2285	1923.2500	82.7131	82.7351		−2.27	−2.27	
225		240216296		658.2285	658.2457	82.7412	82.7588	520	−2.27	−2.27	
226		240218363		317.1039	317.1254	85.7781	85.8001	320	−2.27	−2.27	
227		240216540		480.9820	481.0034	84.0839	84.1058	690	−2.28	−2.28	
228		240214868		330.6452	330.6664	66.4362	66.4579	460	−2.30	−2.30	
229		240214493		945.4323	945.4535	65.5787	65.6004	630	−2.30	−2.30	
230		240214782		1423.5428	1423.5639	86.0583	86.0799	400	−2.31	−2.31	Low pressure
231		240219058		193.3345	193.3512	85.6773	85.6944	510	−2.34	−2.34	
232		240215520		555.5449	555.5656	86.3816	86.4028	610	−2.36	−2.36	
233		240281798		5399.5284	5399.5488	86.2658	86.2867	590	−2.39	−2.39	
234		240216210		223.9811	224.0014	88.7061	88.7269	600	−2.40	−2.40	
235	2018/5/10	240215084		482.5024	482.5226	65.2762	65.2969	600	−2.42	−2.42	
236		240216105		716.4675	716.4876	85.7110	85.7316	620	−2.43	−2.43	
237		240214731		967.695	967.715	81.3825	81.4030	600	−2.44	−2.44	
238	28/8/2018	240215418		695.202	695.218	81.5139	81.5303	480	−2.44	−2.44	
239		240217610		814.7619	814.7813	64.1884	64.2083	590	−2.51	−2.51	
240		240215619		949.8413	949.8603	88.5396	88.5591	570	−2.56	−2.56	
241		240218139		406.7667	406.7844	85.4398	85.4583	300	−2.62	−2.62	Low pressure
242	22/10/2018	240214484		924.7219	924.7397	88.5494	88.5677	540	−2.73	−2.73	
243		240215304		1845.7087	1845.7261	86.4441	86.462	560	−2.79	−2.79	
244		240215002		1270.835	1270.852	81.1693	81.1868	530	−2.86	−2.86	
245		240215299		389.4835	389.5035	82.4330	82.4536	600	−2.91	−2.91	
246		240215668		587.1500	587.1696	83.3386	83.3588	660	−2.97	−2.97	
247		240214606		1013.019	1013.035	80.9882	81.0047	480	−3.03	−3.03	
248		240214495		1315.0809	1315.0992	87.4471	87.466	560	−3.17	−3.17	
249		240218856		114.152	114.1671	66.2815	66.2971	510	−3.21	−3.21	
250		240215232		297.798	297.819	81.2766	81.2983	650	−3.23	−3.23	
251	29/8/2018	240214505		1901.022	1901.043	81.7427	81.7644	650	−3.23	−3.23	
252		240215683		1142.0979	1142.1155	85.5960	85.6142	540	−3.30	−3.30	
253		240215413		738.7023	738.7228	83.5120	83.5332	590	−3.30	−3.30	
254		240218067		282.543	282.5658	64.3756	64.3992	700	−3.39	−3.39	
255		240214856		151.0669	151.0859	86.0149	86.0346	590	−3.55	−3.55	
256	2018/11/10	240215989		611.8759	611.8945	88.4303	88.4496	570	−3.63	−3.63	
257		240215036		933.6221	933.6406	88.5776	88.5968	570	−3.65	−3.65	
258		240215287		1422.1396	1422.1603	85.2648	85.2863	630	−3.72	−3.72	
259		240215317		902.1117	902.1323	82.1132	82.1346	630	−3.74	−3.74	
260		240214624		488.800	488.818	81.0604	81.0791	560	−3.74	−3.74	
261		240215806		507.4785	507.4962	87.5498	87.5682	540	−3.80	−3.80	

262		240214513		512.3167	512.3368	66.2064	66.2273	620	−3.83	−3.83	
263		240214891		774.1944	774.2144	87.7863	87.8071	630	−3.85	−3.85	
264		240214666		1649.7069	1649.7243	86.1299	86.148	540	−3.87	−3.87	
265		240214662		1792.6118	1792.629	64.8503	64.8682	560	−3.91	−3.91	
266		240217258		172.3837	172.4033	64.3062	64.3266	600	−3.92	−3.92	
267		240218581		125.9604	125.9773	63.3684	63.386	540	−3.98	−3.98	
268		240215218		1076.3702	1076.3893	85.0816	85.1015	600	−4.02	−4.02	
269		240215832		506.1023	506.121	66.0421	66.0616	570	−4.10	−4.10	
270		240215545		1246.1752	1246.1915	86.7412	86.7582	520	−4.12	−4.12	
271		240217117		737.8485	737.8671	63.4382	63.4576	570	−4.12	−4.12	
272		240215291		1117.3435	1117.3618	65.9173	65.9364	570	−4.19	−4.19	
273		240215722		1012.344	1012.364	81.4653	81.4862	620	−4.31	−4.31	
274		240214961		679.309	679.333	81.0820	81.1071	740	−4.38	−4.38	
275	18/10/2018	240215870		741.8079	741.8251	88.6077	88.6257	540	−4.44	−4.44	
276		240217282		436.8894	436.9061	63.3906	63.4081	520	−4.57	−4.57	
277		240214637		1332.2469	1332.2669	83.74554	83.7665	650	−4.58	−4.58	
278		240214809		181.8539	181.8725	86.7669	86.7864	570	−4.62	−4.62	
279		240218646		321.473	321.4957	84.1866	84.2104	660	−4.62	−4.62	
280		240218005		344.3159	344.3324	64.1081	64.1254	590	−4.62	−4.62	
281	5/9/2018	240215211		1581.4845	1581.5010	82.7628	82.7801		−4.62	−4.62	
282		240218636	1″	104.8832	104.9017	62.8829	62.9023	570	−4.64	−4.64	
283		240216163		542.1539	542.1765	63.8548	63.8785	450	−4.64	−4.64	
284		240215051		338.6959	338.7133	84.6600	84.6783	540	−4.92	−4.92	
285		240281791		5861.0512	5861.0686	86.4917	86.51	520	−4.92	−4.92	
286		240214831		155.6318	155.651	65.4793	65.4995	600	−4.95	−4.95	
287		240216058		657.2366	657.2403	83.7322	83.7361	250	−5.13	0.00	
288		240214936		952.323	952.347	81.5973	81.6226	700	−5.14	0.00	
289		240214688		2280.467	2280.487	81.6680	81.6891	620	−5.21	0.00	
290		240218477		249.9565	249.9728	85.3750	85.3922	510	−5.23	0.00	
291		240214490		24.718	24.735	81.9119	81.9299	540	−5.56	0.00	
292		240214953		1324.6528	1324.6743	88.6094	88.6322	660	−5.70	0.00	
293		240214494		670.913	670.931	81.6389	81.6580	560	−5.76	0.00	
294		240218912		144.6129	144.6324	83.4115	83.4322	620	−5.80	0.00	
295		240214438		1263.087	1263.103	81.0389	81.0559	600	−5.88	0.00	
296		240214839		1319.3368	1319.3564	83.9438	83.9647	600	−6.22	0.00	
297		240214828		1147.3327	1147.3532	65.1543	65.1762	630	−6.39	0.00	
298		240215684		571.3865	571.4096	82.2648	82.2895	630	−6.48	0.00	
299		240215912		1336.2526	1336.2722	85.1914	85.2124	620	−6.67	0.00	
300		240215898		1247.6805	1247.6984	85.2191	85.2383	570	−6.77	0.00	
301		240214860		1284.109	1284.128	81.6929	81.7134	600	−7.32	0.00	
302		240214572		989.3756	989.3943	85.0255	85.0457	590	−7.43	0.00	
303	19/10/2018	240214795		754.8559	754.8695	66.8845	66.8992	540	−7.48	0.00	
304		240215277		1339.8341	1339.8529	66.6200	66.6404	570	−7.84	0.00	
305		240215092		722.3794	722.3981	82.4938	82.5141		−7.88	0.00	
306		240214554		2579.446	2579.461	81.1149	81.1312	480	−7.98	0.00	
307		240218850		124.1347	124.1461	85.5453	85.5580	240	−8.54	0.00	
308		240218367		238.305	238.324	63.9220	63.9428	630	−8.65	0.00	3 digit to be replaced
309		240214761		738.6556	738.6724	85.2915	85.3099	540	−8.70	0.00	
310		240215908		741.6888	741.7073	85.3479	85.3682	600	−8.87	0.00	
311		240215489		227.223	227.244	81.4900	81.5131	680	−9.09	0.00	
312		240214832		623.6751	623.6952	65.5135	65.5357	660	−9.46	0.00	
313		240216397		639.6290	639.6403	84.6812	84.6940	200	−10.02	0.00	Low pressure
314		240215265		916.9303	916.9482	63.2768	63.2969	590	−10.95	0.00	
315		240216985		391.6752	391.6903	88.076	88.093	510	−11.18	0.00	
316		240215179		843.4665	843.4786	63.8351	63.8491	150	−12.07	0.00	Low pressure
317		240215933		914.1597	914.1747	86.5493	86.5664	510	−12.28	0.00	
318		240215929		809.3114	809.3281	63.3310	63.3501	520	−12.57	0.00	
319	14/9/2018	240215085		566.5508	566.5714	84.5175	84.5415	680	−14.17	0.00	
320		240215173		24.5697	24.5845	84.5620	84.5794	520	−14.94	0.00	
321		240215688		411.2083	411.2248	86.9066	86.9273		−20.29	0.00	
322		240215460		954.691	954.709	81.5440	81.5674	570	−23.08	0.00	
323		240214838		337.7152	337.7316	83.8407	83.8633	660	−27.43	0.00	
324		240217661		678.6686	678.6801	84.0112	84.0284	520	−33.14	0.00	
325		240215452		1736.9117	1736.9263	65.0688	65.0908	650	−33.64	0.00	
326		240214854		1315.2342	1315.2531	83.1146	83.1441	600	−35.93	0.00	
327		240217460		403.5894	403.6023	84.1265	84.1484	630	−41.10	0.00	
328		240216224		245.1993	245.2106	66.0757	66.0963	600	−45.15	0.00	
329		240281788	3/4"	6910.2186	6910.2311	89.1392	89.1634	620	−48.35	0.00	
330		240215385		1198.9158	1198.9250	83.6415	83.6610	630	−52.82	0.00	
331		240215404		2953.3695	2953.3787	82.8409	82.8609	540	−54.00	0.00	
332		240214605		1089.236	1089.2564	65.0659	65.1165	600	−59.68	0.00	
		332						Total	−79.46	−143.77	
								Average	−0.23933	−0.43304	

Meter Change List at Ruyenzi DMA (Big Customer)

No.	Change Date	POC No.	Diameter	Old Meter		New meter		
				Brand	Final Index (m3)	Brand	Serial No.	Start Index (m3)
1	13/12/2018	240214554	3/4"	Itron	22,754,516.2	Baylan	9804059	0
2	11/12/2018	240214438	3/4"	Itron	1,351,490.6	Baylan	9804233	0
3		240215489	3/4"	Already Replaced by Nyargenge Branch				
4	13/12/2018	240214860	3/4"	Itron	1,346,094.0	Baylan	9804292	0
5	13/12/2018	240214688	3/4"	Itron	2,377,571.4	Baylan	9804108	0
6	13/12/2018	240214494	3/4"	Itron	701,103.2	Baylan	9804114	0
7	13/12/2018	240214936	3/4"	Itron	981,002.3	Baylan	9804287	0
8	12/12/2018	240215460	3/4"	Itron	1,016,010.1	Baylan	9804115	0
9		240214490	3/4"	Already Replaced by Nyargenge Branch				
10	13/12/2018	240215684	3/4"	Itron	672,907.7	Baylan	9804277	0
11	17/12/2018	240215092	3/4"	Itron	7,491,470.0	Baylan	9804301	0
12	13/12/2018	240215404	3/4"	Itron	3,045,395.4	Baylan	9804318	0
13	14/12/2018	240214854	3/4"	Itron	1,365,057.5	Baylan	9804045	0
14	12/12/2018	240216058	3/4"	Itron	716,124.2	Baylan	9804350	0
15	12/12/2018	240215385	3/4"	Itron	1,255,940.9	Baylan	9804253	0
16	12/12/2018	240218912	3/4"	Itron	215,489.9	Baylan	9804259	0
17	11/12/2018	240214839	3/4"	Itron	1,369,344.2	Baylan	9804236	0
18	17/12/2018	240214838	3/4"	Itron	400,607.3	Baylan	9804307	0
19	11/12/2018	240217460	3/4"	Itron	440,288.5	Baylan	9804144	0
20	11/12/2018	240217661	3/4"	Itron	747,388.1	Baylan	9804250	0
21		240215085	3/4"	Already Replaced by Nyargenge Branch				
22	17/12/2018	240216397	3/4"	Itron	694,096.1	Baylan	9804222	0
23		240215173	3/4"	Already Replaced by Nyargenge Branch				
24	12/12/2018	240215912	3/4"	Itron	141,718.6	Baylan	9804345	0
25		240215898	3/4"	Reinstalled by Nyargenge Branch				
26	13/12/2018	240214572	3/4"	Itron	1,037,197.5	Baylan	9804206	0
27	13/12/2018	240214761	3/4"	Itron	771,868.4	Baylan	9804281	0
28	12/12/2018	240215908	3/4"	Itron	779,203.0	Baylan	9804278	0
29	7/1/2019	240215265	3/4"	Itron	1,023,855.5	Baylan	9804116	0
30	12/12/2018	240218477	3/4"	Itron	290,940.5	Baylan	9804228	0
31	14/12/2018	240215929	3/4"	Itron	577,355.5	Disconnected for 1 month		
32	7/1/2019	240218850	3/4"	Itron	161,878.9	Baylan	9804415	0
33	14/12/2018	240215179	3/4"	Itron	888,676.2	Baylan	9804180	0
34	17/12/2018	240218367	3/4"	Itron	282,736.2	Baylan	9804187	0
35	11/12/2018	240215933	3/4"	Itron	960,376.0	Baylan	9804180	0
36	17/12/2018	240215688	3/4"	Sensus	493,490.0	Baylan	9804265	0
37	13/12/2018	240215452	3/4"	Itron	1,779,748.1	Baylan	9804171	0
38	13/12/2018	240214605	3/4"	Itron	1,116,041.6	Baylan	9804256	0
39	12/12/2018	240214828	3/4"	Itron	1,185,083.4	Baylan	9804334	0
40	17/12/2018	240214832	3/4"	Itron	667,166.9	Baylan	9804320	0
41	12/12/2018	240216985	3/4"	Itron	414,492.5	Baylan	9804340	0
42	12/12/2018	240216224	3/4"	Itron	263,634.2	Baylan	9804272	0
43	11/12/2018	240215277	3/4"	Itron	1,389,506.0	Baylan	9804185	0
44	14/12/2018	240214795	3/4"	Itron	813,360.8	Baylan	9804293	0
45	17/12/2018	240214953	3/4"	Itron	1,358,030.6	Baylan	9804183	0
46	9/1/2019	240281788	1"	KMEI	7,027,416.5	Baylan	9790832	0
47		240214804	3/4"	Reinstalled by Nyargenge Branch				
48	14/12/2018	240215009	3/4"	Itron	427,899.4	Baylan	9804110	0
49	11/12/2018	240214715	3/4"	Itron	987,940.0	Baylan	9804295	0
50	11/12/2018	240214529	3/4"	Itron	648,461.6	Baylan	9804224	0
51	17/12/2018	240215845	3/4"	Itron	2,357,487.3	Baylan	9804296	0
52	17/12/2018	240218522	3/4"	Itron	328,917.2	Baylan	9804035	0
53	2019/11/1	240215624	3/4"	Itron	991,587.7	Baylan	9804308	0
54	2019/11/1	240217870	3/4"	Itron	390,991.2	Baylan	9804161	0
55	19/12/2018	240214553	3/4"	Itron	1,461,889.6	Baylan	9804327	0
56	19/12/2018	240217534	3/4"	Itron	668,961.9	Baylan	9804072	0
57	19/12/2018	240214491	3/4"	Itron	509,075.6	Baylan	9804119	0
58	9/1/2019	240215354	3/4"	Itron	1,676,785.3	Baylan	9804402	0
59	10/1/2019	240218123	3/4"	Itron	413,901.5	Baylan	9804410	0
60	9/1/2019	240214724	3/4"	Itron	1,321,060.4	Baylan	9804409	0
61	7/1/2019	240215235	3/4"	Itron	1,131,183.7	Baylan	9804338	0
62	10/1/2019	240217476	3/4"	Itron	1,403,513.2	Baylan	9804404	0
63	11/1/2019	240214760	3/4"	Itron	1,064,882.1	Baylan	9804038	0

Meter Change List at Ruyenzi DMA (Big Customer)

No.	Change Date	POC No.	Diameter	Old Meter		New meter		
				Brand	Final Index (m3)	Brand	Serial No.	Start Index (m3)
64	7/1/2019	240218468	3/4"	Itron	442,052.6	Baylan	9804219	0
65	7/1/2019	240215723	3/4"	Itron	990,651.2	Baylan	9804139	0
66	7/1/2019	240216223	3/4"	Itron	812,260.4	Baylan	9804117	0
67	7/1/2019	240218091	3/4"	Itron	537,307.5	Baylan	9804217	0
68	8/1/2019	240215150	3/4"	Itron	1,203,351.7	Baylan	9804413	0
69	7/1/2019	240217981	3/4"	Itron	384,783.1	Baylan	9804122	0
70	10/1/2019	240218994	3/4"	Itron	145,531.4	Baylan	9804406	0
71	8/1/2019	240214859	1"	Sensus	222,833.7	Baylan	9790836	0
72	10/1/2019	240216087	3/4"	Itron	626,413.9	Baylan	9804407	0
73	8/1/2019	240215614	3/4"	Itron	819,698.1	Baylan	9804383	0
74	8/1/2019	240214807	3/4"	Itron	943,109.3	Baylan	9804412	0
75	9/1/2019	240215399	3/4"	Itron	804,828.7	Baylan	9804401	0
76	19/12/2018	240215651	3/4"	Itron	156,084.9	Disconnected		
77	19/12/2018	240214564	3/4"	Itron	1,398,791.0	Baylan	9804095	0
78	19/12/2018	240214968	3/4"	Itron	1,270,370.0	Baylan	9804291	0
79	19/12/2018	240214901	3/4"	Itron	1,521,341.3	Baylan	9804036	0
80	7/1/2019	240216161	3/4"	Itron	597,253.3	Baylan	9804105	0
81	7/1/2019	240215340	3/4"	Itron	6,379,140.1	Baylan	9804360	0
82	19/12/2018	240215133	3/4"	Itron	356,374.4	Baylan	9804331	0
83	10/1/2019	240215897	3/4"	Itron	1,614,203.8	Baylan	9804406	0
84	8/1/2019	240215836	3/4"	Itron	277,204.3	Baylan	9804414	0
85	19/12/2018	240216310	3/4"	Itron	765,274.2	Baylan	9804220	0
86	10/1/2019	240215931	3/4"	Itron	562,338.3	Baylan	9804403	0
87	9/1/2019	240215107	3/4"	Itron	551,946.1	Baylan	9804408	0
88	11/1/2019	240217327	3/4"	Itron	785,966.1	Baylan	9804133	0
89	8/1/2019	240214962	3/4"	Itron	796,480.1	Baylan	9804382	0
90	14/1/2019	240217746	1"	Sensus	1,168,009.3	Baylan	9790838	0
91	7/1/2019	240214964	3/4"	Itron	529,632.3	Baylan	9804346	0
92		240216242	2" - 1"	Branch will decided if 2" can be removed and replace by 1"				

Summary of 92 meters(Big customer) suppose to be replaced

Diameter	Replaced by JICA	Replaced by WASAC	Desconnected	Not replaced (Factory)
3/4"	80	6	2	
1"	3	0	0	
2"				1
Total	83	6	2	1

Meter Change List at Ruyenzi DMA (Small Customer)

No.	Change Date	POC No.	Diameter	Old Meter			New meter		
				Brand	Serial No.	Final Index (m3)	Brand	Serial No.	Start Index (m3)
1	24/1/2019	240211747	3/4"	Typing error to this Poc, no need to be replaced					
2	22/1/2019	240214504	3/4"	Itron	D13UA494937	581,674.4	Baylan	9804375	0
3	22/1/2019	240214602	3/4"	Already replaced by Nyarugenge					
4	22/1/2019	240214618	3/4"	Already replaced by Nyarugenge					
5	22/1/2019	240214635	3/4"	Unreadable				9804377	0
6	22/1/2019	240214766	3/4"	KMEI		671,250.1	Baylan	9790840	0
7	15/1/2019	240214792	3/4"	Itron	D13UA596536	76,987.5	Baylan	9804313	0
8	22/1/2019	240214835	3/4"	Itron	D12CA051404	1,714,767.0	Baylan	9804372	0
9	30/1/2019	240214841	3/4"	Itron	unreadable	373,508.70	Baylan	9804378	
10	22/1/2019	240214892	3/4"	Itron	D12UA550203	207,256.6	Baylan	9804374	0
11	16/1/2019	240214914	3/4"	Already replaced by Nyarugenge					
12	22/1/2019	240214940	3/4"	Meter stolen, no meter from 2014					
13	16/1/2019	240214942	3/4"	Already replaced by Nyarugenge					
14	22/1/2019	240214948	3/4"	Itron		342,416.0	Baylan	9804376	0
15	24/1/2019	240214950	3/4"	Itron	unreadable	50,451,359.6	Baylan	9804371	0
16	16/1/2019	240214951	3/4"	Already replaced by Nyarugenge					
17	22/1/2019	240214989	3/4"	Already replaced by Nyarugenge					
18	16/1/2019	240215035	3/4"	Itron	D12CA048390	372,386.2	Baylan	9804398	0
19	24/1/2019	240215073	3/4"	Itron	D12CA048197	336,248.8	Baylan	9804373	0
20	22/1/2019	240215107	3/4"	Replaced on Big list					
21	25/1/2019	240215313	3/4"	Already replaced by Nyarugenge					
22	24/1/2019	240215410	3/4"	Branch will replace this meter, after customer pay existing one defected by him.					
23	23/1/2019	240215437	3/4"	Itron	D12UA556643	597,712.50	Baylan	9804385	
24	16/1/2019	240215494	3/4"	Itron	D12UA572810	321,164.2	Baylan	9804400	0
25	16/1/2019	240215585	3/4"	Already replaced by Nyarugenge					
26	16/1/2019	240215596	3/4"	Sensus	1194816	368,584.8	Baylan	9804397	0
27	23/1/2019	240215703	3/4"	Itron	D12UA574218	447,259.5	Baylan	9804384	0
28	22/1/2019	240215741	3/4"	Itron	D12UA565086	520,421.8	Baylan	9804379	0
29	16/1/2019	240215769	3/4"	Itron	D12UA558416	574,274.1	Baylan	9804395	0
30	23/1/2019	240215776	3/4"	Already replaced by Nyarugenge					
31	24/1/2019	240215809	3/4"	Branch will replace this meter, after customer pay existing one defected by him.					
32	23/1/2019	240215824	3/4"	Itron	D13UA596785	898,949.5	Baylan	9804389	0
33	25/1/2019	240215827	3/4"	Itron	D13UA596519	1,412,828.1	Baylan	9804381	0
34	23/1/2019	240215850	3/4"	Itron	D13UA596804	582,226.6	Baylan	9804386	0
35	31/1/2019	240215864	3/4"	No need to replace this meter, it's working well.					
36	25/1/2019	240215939	3/4"	Itron	D13UA593251	122,907.3	Baylan	9804396	0
37	29/1/2019	240216125	3/4"	No need to replace this meter, it's working well.					
38	15/1/2019	240216384	3/4"	Itron	D14UA104226	3,363,940.0	Baylan	9804359	0
39	23/1/2019	240216842	3/4"	Itron	D14UA135492	877,482.0	Baylan	9804388	0
40	23/1/2019	240217202	3/4"	Itron	D14UA132548	138,325.1	Baylan	9804390	0
41	24/1/2019	240217899	3/4"	Itron	D14UA126847	159,857.3	Baylan	9804380	0
42	31/1/2019	240217918	3/4"	No need to replace this meter, it's working well.					
43	15/1/2019	240217989	3/4"	Disconnected					
44	31/1/2019	240218012	3/4"	No need to replace this meter, it's working well.					
45	23/1/2019	240218142	3/4"	Itron	D14UA125925	186,549.3	Baylan	9804387	0
46	15/1/2019	240281787	3/4"	Not in service from 2014					
47	22/1/2019	240281800	3/4"	This Public tap has been cancelled, not exist now					

Survey of Disconnected and Zero-consumption Customers

1. Interview Survey (Disconnected Customers)

Field confirmation and interview survey of 140 out of 145 disconnected customers (9 % of all customers) were conducted from October to December 2018. The questions asked in the interviews included house ownership, POC, installation and operating state of water meters, alternative water sources and customers' requests to WASAC, as shown in Attachment 3. The survey results are summarized in the following.

1) House ownership

Since water charge is usually not included in rent in house lease contracts in Rwanda, the number of lessees who consume a large quantity of water without considering the water charges is on the increase. The interview survey revealed that a quarter of the disconnected customers were lessees, as shown in the table below. The over-consumption by lessees was a major course of the disconnection. The same problem was seen in Pilot Area 1, Kadobogo. Appealing to relevant authorities to change the condition of house lease will be an effective measure in solving this problem.

Table 6. House ownership

Subzone	Lessee	Owner	Others	No answer	Total
RY1	20	59	3	2	84
RY2	4	14	0	0	18
RY3	11	26	1	0	38
Total	35	99	4	2	140
Percentage	25.0%	70.7%	2.9%	1.4%	

2) Operating state of water meters

More than 80 % of water meters of disconnected customers worked normally. The rest included meters with unreadable indicators and mechanical failure. These defective meters have already been replaced.

Table 7. Operating state of water meters

Subzone	Inaccessible	Normal	Blocked	Unreadable	Mechanical failure	No meter	Total
RY1	1	68	3	2	0	9	83
RY2	0	16	1	0	1	0	18
RY3	1	31	2	0	1	3	38
Total	2	115	6	2	2	12	139
Percentage	1.4%	82.7%	4.3%	1.4%	1.4%	8.6%	

3) Time of disconnection

The table below shows that the number of disconnected users increased sharply in September, the month in which the survey began. The table also shows that water supply to more than 40 % of disconnected

customers was disconnected before June 2018, the month in which the full-scale implementation of the NRW reduction activities in the pilot area began. This fact indicates that the disconnection had been frequently implemented.

Table 8. Time of the beginning of the disconnection (in 2018)

Subzone	Before June	June	July	August	September	Total
RY1	34	4	3	4	39	84
RY2	7	1	0	0	10	18
RY3	16	1	1	1	18	37
Total	57	6	4	5	67	139
Percentage	41.0%	4.3%	2.9%	3.6%	48.2%	

4) State of disconnection

The table below shows that water supply to 45 % of customers disconnected before the POC survey had resumed at the time of the survey. This observation indicates that the disconnection was not always imposed for a long time. WASAC strictly imposes the disconnection against overdue of the payment of the bill for two weeks. This strict action of WASAC may make customers uneasy. This uneasiness was inferred from the customers' requests to WASAC mentioned in 6).

Table 9. State of disconnection

Subzone	Inaccessible	Water supply resumed	Disconnected (point of disconnection)			Total
			On service pipe	At meter inlet	At meter outlet	
RY1	0	39	4	3	39	85
RY2	0	8	0	0	10	18
RY3	1	16	0	3	18	38
Total	1	63	4	6	67	141
Percentage	0.7%	44.7%	2.8%	4.3%	47.5%	

5) Main alternative water sources

Many disconnected customers borrowed or purchased water from neighbors. More than 80 % of disconnected customers either borrowed or purchased water from neighbors or purchased it at public taps. In Subzone RY1, more disconnected customers borrowed water from neighbors than purchased it at public taps probably because the subzone was an old residential area where residents knew one another for a long time. Meanwhile, the opposite was the case in Subzone RY3, which was a newly developed residential area.

Table 10. Main alternative water sources (number of respondents: 70, multiple responses allowed)

Subzone	Public tap	Purchase from neighbors	Water seller	Shallow well	Bottled water	River water	Spring water	Rainwater	Total
RY1	9	26	1	0	1	4	4	2	47
RY2	6	3	0	1	0	0	2	1	13
RY3	12	3	0	0	0	0	3	1	19
Total	25	32	1	1	1	4	9	4	77
Percentage	35.7%	45.7%	1.4%	1.4%	1.4%	5.7%	12.9%	5.7%	

6) Requests to WASAC

The most requests concerned the payment of water charges. As mentioned in 4), water disconnection is imposed against overdue of the payment for two weeks. This action makes customers uneasy with WASAC's service. In many developing countries, a grace period for the payment is three months. Therefore, relaxing of the condition for the disconnection is recommended.

Table 11. Requests to WASAC (number of respondents: 74, multiple responses allowed)

Subzone	Continuous water supply	Lower rate	Water quality	Meter accuracy	Customer service	Payment	Total
RY1	21	20	1	2	6	25	75
RY2	0	3	0	0	1	10	14
RY3	8	5	0	1	0	13	27
Total	29	28	1	3	1	48	110
Percentage	39.2%	37.8%	1.4%	4.1%	1.4%	64.9%	

2. Interview Survey (Zero-Consumption Customers)

An interview survey of 56 customers (3 % of all customers) with no water consumption for the last three months was conducted simultaneously with the interview survey mentioned above. In addition to the main questions asked in the survey of the disconnected customers, a question concerning the reason of zero-consumption was asked in this survey. The result of the survey is summarized in the following. See Attachment 4 for the questionnaire and summary sheet used in the survey.

1) House ownership

Many house owners with zero water consumption live in areas to which piped water cannot be distributed because of low water pressure or have alternative water sources. Some house owners impose strict restriction on water consumption by lessees. Most of such owners lock taps of rented houses, so that lessees cannot open the taps without their permission, and make lessees use water from taps of the owners' houses.

Table 12. House ownership

Subzone	Lessee	Owner	Others	No response	Total
RY1	7	24	1	2	34
RY2	2	6			8
RY3	2	7	3	1	13
Total	11	37	4	3	55
Percentage	20.0%	67.3%	7.3%	5.5%	

2) Reasons for zero water consumption

If a customer has a solid reason for zero water consumption, such as a house being constructed, zero consumption is not a serious problem. However, it is necessary to re-visit the zero-consumption customers who did not give reasons for zero consumption, except the cases where a water meter has been removed after water supply was disconnected. (The six customers to be surveyed again are listed in Attachment 8. This second survey is scheduled for April.

Table 13. Reasons for zero water consumption

Zone	No occupant	Under construction	Not using	Others	Low water pressure	No response	Total
RY1	4	7	4	4	11	5	34
RY2	1	1	1	1	3	2	8
RY3	1	5	4	0	4	1	13
Total	6	13	9	5	18	8	55
Percentage	10.9%	23.6%	16.4%	9.1%	32.7%	14.5%	

3) Main alternative water sources

Purchase at a public tap and purchase and borrowing from neighbors accounted for more than 90 % of alternative water sources used by zero-consumption customers, as seen in the table below. Rainwater, which was used by 14.5 % of them, is assumed to have been used not for drinking or cooking, but as a supplementary source of water for cleaning and sprinkling a garden.

Table 14. Main alternative water sources (number of respondents: 24, multiple responses allowed)

Subzone	Public tap	Purchase from neighbors	Water seller	River water	Spring water	Rainwater	Total
RY1	6	8	1	1	1	3	20
RY2	3	1	1	0	1	1	7
RY3	2	2	0	0	0	0	4
Total	11	11	2	1	2	4	31
Percentage	46%	46%	8%	4%	8%	17%	

4) Payment for water purchase

Twenty-three zero-consumption customers gave valid responses. Although this number of samples is not large enough, more than half of them spend 50 F or more per day to gain access to alternative water sources. The existence of sources of inexpensive water is a reason for many zero-consumption customers not to use the piped water and to rely on other water sources.

Table 15. Water purchase cost per day (number of valid respondents: 23)

Subzone	Less than 50 F/day	50 - 100 F/day	100 - 200 F/day	200 F/day or more	Total
RY1	6	1	3	3	13
RY2	1	0	3	0	4
RY3	4	1	1	0	6
Total	11	2	7	3	23
Percentage	47.8%	8.7%	30.4%	13.0%	

5) Requests to WASAC

The table below shows that the number of no-consumption customers requesting continuous water supply was large in RY1 and RY3. Residents of RY3 receive piped water three days a week. On the other days, they cannot have piped water. Piped water does not reach high-elevation areas in RY1 because of the low water distribution pressure. This current state of the water supply is reflected in the request for continuous water supply. Meanwhile, many zero-consumption customers requested improvement of meter accuracy. It is assumed from this request that there is a discrepancy between the actual water consumption and meter readings. Although inaccuracy of meters can create this discrepancy, an obstacle to the appropriate performance of the monthly meter reading by meter readers could be another cause of the discrepancy.

Table 16. Requests to WASAC (number of respondents: 27, multiple responses allowed)

Subzone	Continuous water supply	Lower rate	Water quality	Meter accuracy	Customer service	Payment	Total
RY1	11	2	3	4	1	1	22
RY2	0	0	2	4	0	0	6
RY3	5	1	1	0	1	0	8
Total	16	3	6	8	2	1	36
Percentage	59.3%	11.1%	22.2%	29.6%	7.4%	3.7%	

6) Intention to install service pipe

Approx. 60 % of the zero-consumption customers expressed an intention to install a service pipe in their premises if the above-mentioned requests were met. However, nearly 40 % of them refused the installation. This finding suggests that quite a few zero-consumption customers are not content with the current state of

water supply, rate structure, customer service, etc.

Table 17. Intention to install service pipe (number of valid respondents: 18)

Subzone	Yes	No	Total
RY1	10	3	13
RY2	0	3	3
RY3	1	1	2
Total	11	7	18
Percentage	61.1%	38.9%	

3. Physical loss

Flow rate survey of Ruyenzi

1.RUNDA InLet 200mm	
Jan. 31 – Feb. 2, 2018	As the water distribution was artificially controlled, for example, with valve operation, data of continuous water distribution curve was not obtained.
2.RY1 (Bypass Line) RUYNYAGACA200mm	
Jan. 31 – Feb. 2, 2018	Qmnf was linked with the inlet flow and Qmnf measurements were unstable. Qmnf (including the outflow from the area) changed from approx. 40 m3/h on February 1 to approx. 26 m3/h on February 2.
Jul. 11-18, 2018	Qmnf was approx. 30 m3/h (including the outflow from the area).
Dec. 3-4, 2018	Ultrasonic flow meters installed at the inlet and outlet were used for 24-hour flow rate measurement for the measurement of Qmnf. Based on the measurement results, the Qmnf was estimated at 27.9 m3/h (Qin: 30.46 m3/h and Qout: 2.51 m3/h).
Feb. 13, 2019	The leakage step test was conducted to identify areas with large leakage. Qmnf 32.38m3/h (Qin:46.57m3/h, Qout:14.19m3/h) Large leakage was observed in Zones 1-5 and 1-6. Although Zone 1-5 is an area where water pressure was regulated by PRV1, which reduced the primary pressure of 9.0 bars to the secondary pressure of 3.50 bars, a large pressure difference of 9.0 bars was observed in the area because of the elevation difference between PRV1 and the lowest part in the subzone of 55 m. This pressure difference was assumed to be related to the large leakage. Zone 1-6 is an area where water is directly distributed from the Ruyenzi Reservoir. As the water pressure at the outlet of the reservoir was 6.0 bars in the night and the elevation difference in the zone was 35 m, the maximum pressure of 9.5 bars was applied to the water pipe in the night. Although two pressure reducing valves (PRV1, PRV3) had been installed in RY1, the zones in which PRV had not been installed including Zone 1-6 occupied 70 % of the total area of RY1. A pressure reducing measure that covered the entire RY1 was required for effective leakage reduction. When water leakage was assumed to account for almost 100 % of NRW, the water leakage per unit time in the daytime was estimated at approx. 93 % of Qmnf. Dec. 4, 2018: Qmnf 27.9 m3/h (NRW: 19,414 m3/m in November) Feb. 13, 2019: Qmnf 26.5m3/h (NRW: 19,453 m3/m in January) A x 16 + 27.9 x 8 = 19,414/30, A = 26.5, 26.5/27.9 = 0.95 A x 16 + 29.4 x 8 = 19,453/31, A = 24.5, 24.5/26.5 = 0.92
2019/4/25－26	Qmnf (including the outflow from the area) was 29.8 m3/h. Qmnf in the 63-mm distribution pipe was 10.69 m3/h. In a step test, Qmnf of 2.2 m3/h and 6.15 m3/h were observed in Zones 1-1 and 1-4 (in which a beer factory was located), respectively
2019/4/29－30	In a step test of the 200-mm distribution pipe alone, excluding the 63-mm and 50-mm distribution pipes, Qmnf was measured at 22.21 m3/h. Qmnf of the outflow to Kigese was 2.08 m3/h.
2019/5/21	Qmnf (including the outflow to Kigese) of 34.87 m3/h was observed in a step test. Qmnf in the 63-mm pipe was 12.08 m3/h and that in the 200-mm pipe was 18.73 m3/h. Large leakage from both distribution pipes was confirmed.
2019/6/27-28	Qmnf (including outflow to Kigese) was 28.0 m3/h
2019/7/22-29	The minimum Qmnf of 32 m3/h and average Qmnf of approx. 40 m3/h were observed in a 7-day continuous measurement of flow rate (including that of the outflow to Kigese)
2019/7/25-29	Pressure measurement The water pressure in the delivery pipe to Kigese was high at the lowest point of the pipe ((elevation of the reservoir: 1,505) + (excess pressure: 65) – (elevation of the lowest point of the delivery pipe to Kigese: 1,364) = 206 m). Because of the feat that the high water

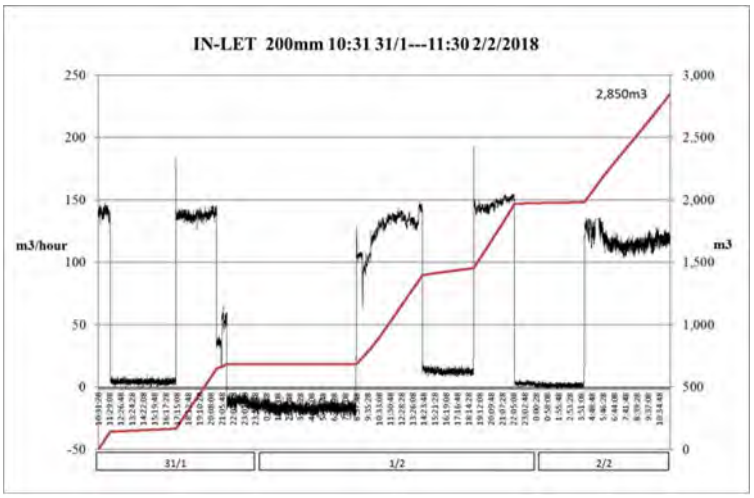
	pressure might cause water leaks, the branch delivered water to Kigese with two of the three valves on the delivery pipe to Kigese, V1 near a filling station and V2 near M5, partially closed. Therefore, water did not reach Kigese in the daytime and it was barely possible to distribute piped water in Kigese in the night. The water pressure in Kigese was 2 – 3bars at maximum in the night and it was almost zero in the daytime (the red line in Fig. 11) The pressure measurement at Nyabitare near the reservoir taken with a data logger revealed that, while pressure dropped to 1 bar in the morning, it reached 4 bars in the night (the black line in Fig. 11). The result of another measurement with manometer shows that the water pressure was 4.6 bars and 5.3 bars at 12:00 on July 22.
2019/8/07-08	Pressure measurement To test the feasibility of water delivery to Kigese in the daytime, water was delivered through the delivery pipe with V1 and V2 fully opened on August 6. Water leakage from the delivery pipe, which had been feared, was not observed The pressure measurement taken on the following day revealed that the water pressure in Kigese had increased to approx. 1.5 bar in the daytime (14:00 – 18:00) and approx. 3 bars in the night, as seen in Fig. 19. Residents of Kigese were pleased with the availability of piped water in the daytime.
2019/8/07-08	Measurement of night flow rate (Qmnf) Qmnf values of inflow into the bypass pipe and outflow to Kigese were 38.7 m3/h and 3.1 m3/h, respectively. The difference of the two values, 35.6 m3/h, was the Qmnf of the water distributed in RY1, including water leakage. Therefore, 92 % of the inflow was distributed in RY1. The maximum flow rate of water distribution in RY1, or the difference between flow rate of the inflow into the bypass pipe (99.4 m3/h) and that of the outflow to Kigese (11.3 m3/h), in the daytime was 88.3 m3/h (or 89 % of the inflow rate). On average, approx. 90 % of the water delivered through the bypass was distributed in RY1. Fluctuation of Qmnf around 39 m3/h suggested the water consumption by customers. However, as the range of fluctuation was very small, it was assumed that most of the suggested consumption was, in fact, water leakage. The water consumption increased sharply from around 05:00 and reach the morning peak between 07:00 and 08:00. The evening peak was observed between 18:30 and 19:30.
2019/8/27-28	Baseline Qmnf measured before the operation of PRV4 began PRV4, Qmnf 33.57m3/h (Qin:38.3 m3/h, Qout:4.73m3/h)
2019/9/19-20	Measurement of Qmnf after the operation of the PRV began: Qmnf 28.9m3/h (Qin:30.1 m3/h, Qout:1.3 m3/h)

Result of the step tests

Date	200-mm pipe	Other areas	63-mm pipe	Total Qin	Qout	Qmnf	Notes
Dec. 3-4, 2018				30.46	2.51	27.95	
Feb. 13, 2019				46.57	14.19	32.38	
Apr. 25, 26, 2019	19.11		10.69	29.80			Including outflow to Kigese
Apr. 29, 30, 2019	15.71	6.5	—	22.21			Excluding 63-mm and 50-mm pipes, Including outflow to Kigese
May 21, 2019	18.73	4.06	12.08	34.87			Including outflow to Kigese
Jun. 27 – 28, 2019				28.0			
Jul. 22 – 29, 2019				32.0-40.0			

Aug. 7 – 8, 2019				38.7	3.1	35.6	
Aug. 27 – 28, 2019				38.3	4.73	33.6	Before PRV4 installation
Sep. 19 – 20, 2019				30.1	1.3	28.8	After PRV4 installation

1. Reservoir Inlet



Reservoir Inflow, January 31 - February 2, 2018

2. RY1 **(pipeline that bypasses the Ruyenzi Reservoir)**

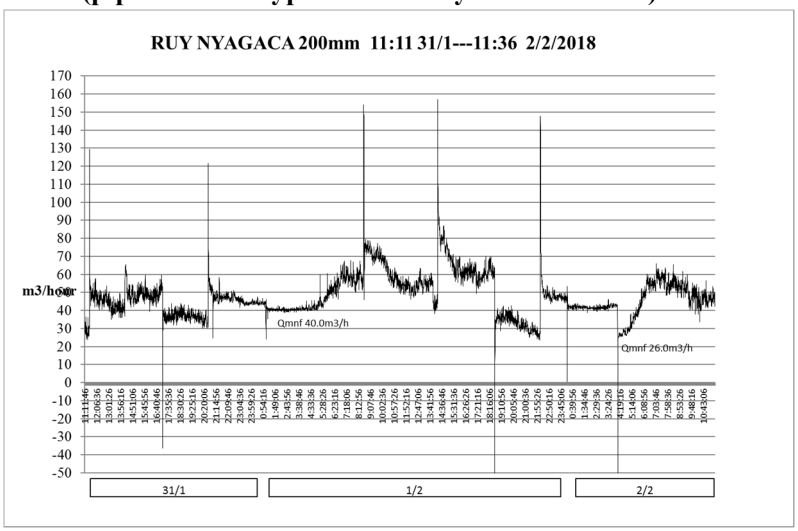
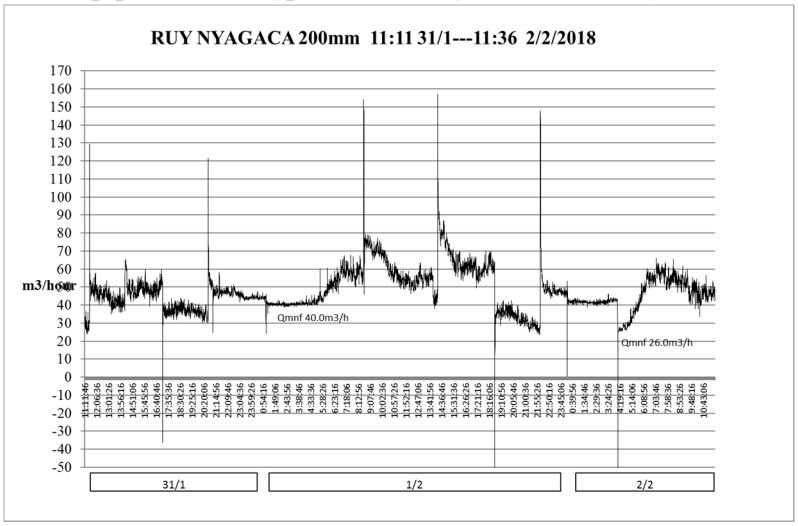


Figure 1. Qmnf in RY1, January 31 - February 2, 2018

RY1 **(pipeline that bypasses the Ruyenzi Reservoir)**



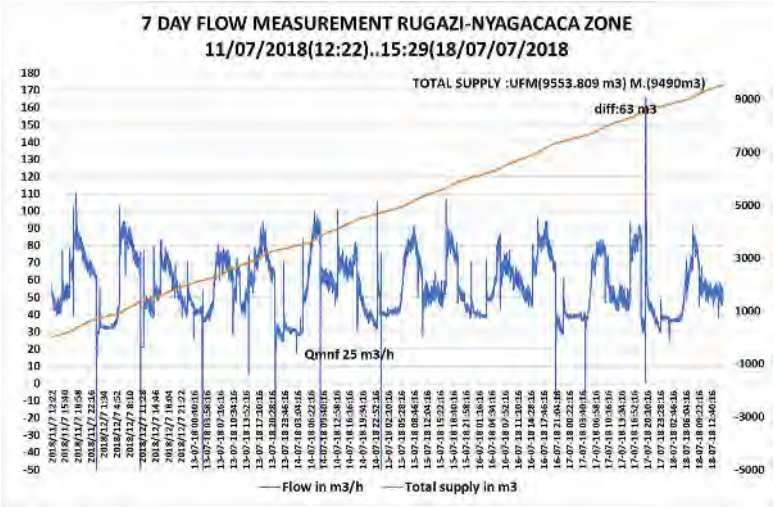


Figure 2. Qmnf in RY1, July 11 – 18, 2018

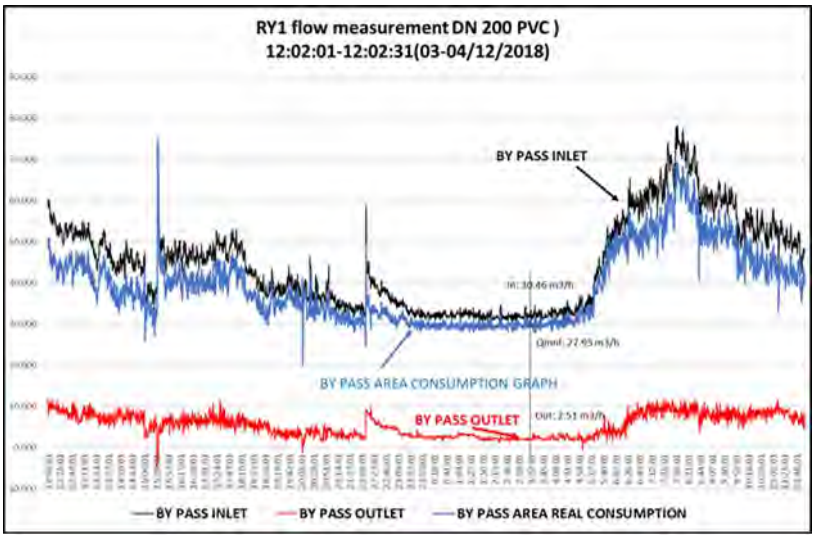


Figure 3. Measurement of Qmnf in RY1, December 3 – 4, 2018

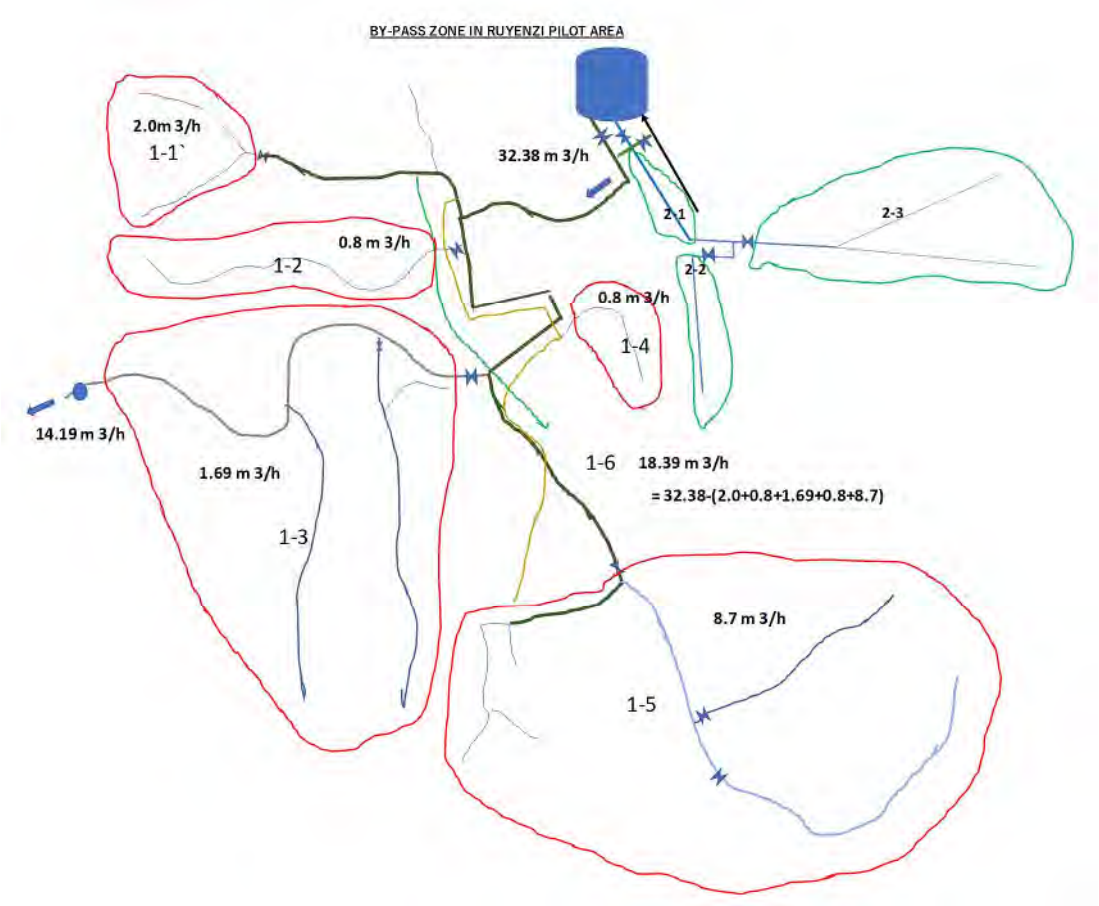


Figure 4. Step Test in RY1, February 12 -13, 2019 Qmnf

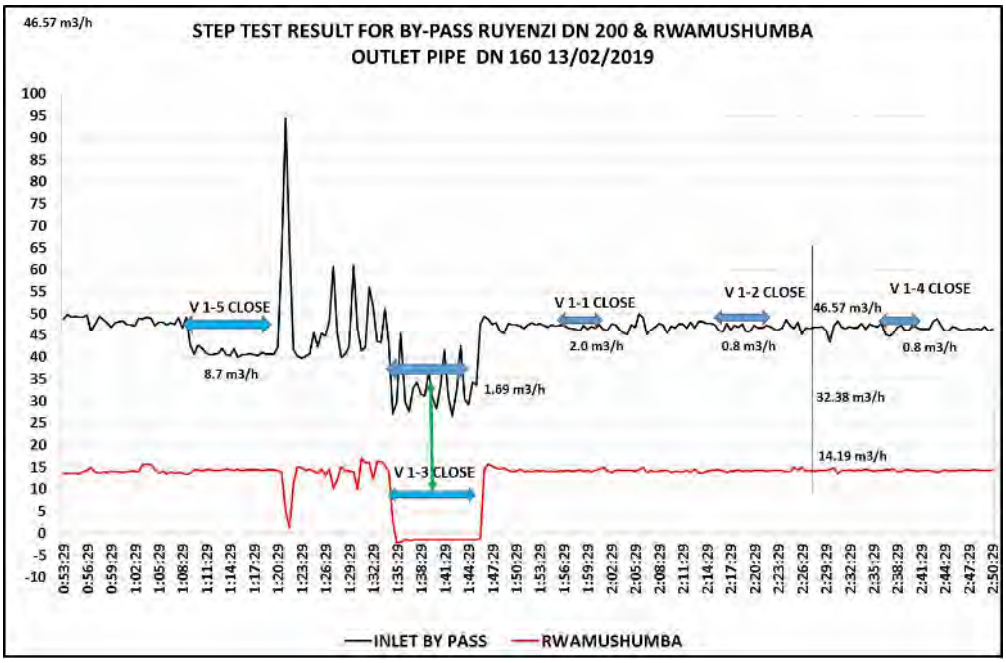
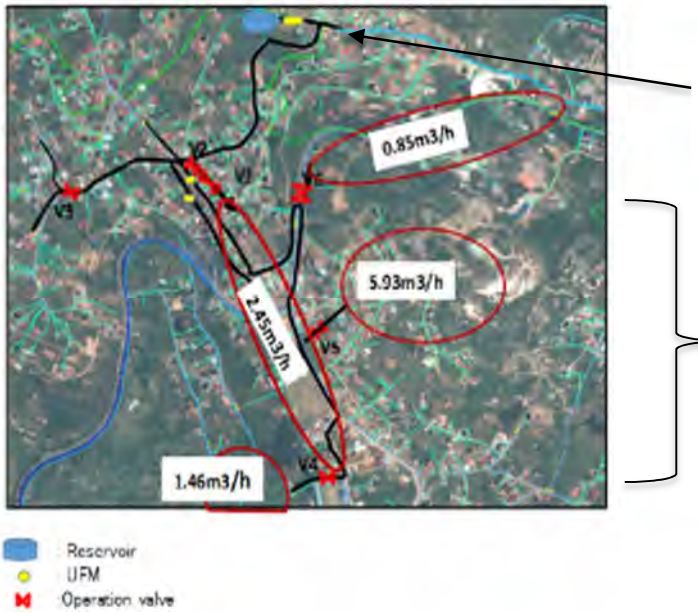


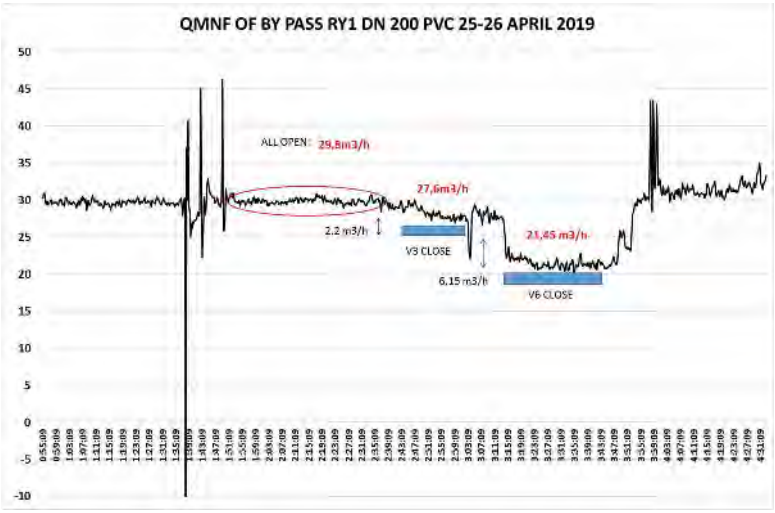
Figure 5 RY1, Step Test, February 12 -13, 2019, Qmnf

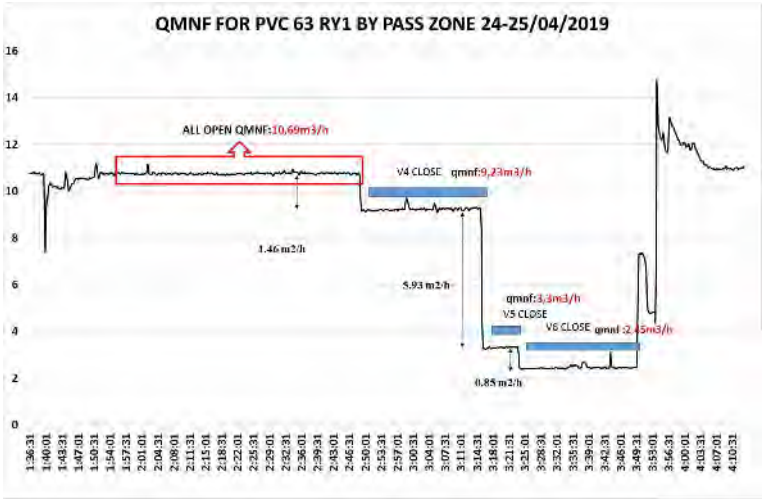
Step Test April 25 – 26, 2019, Qmnf (Figure 6)



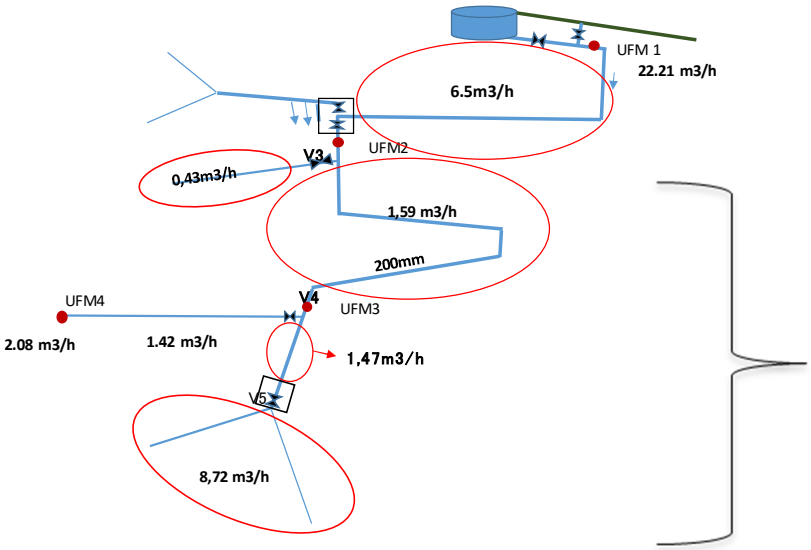
Qmnf: 29.8 m3/h
Bypass DN200

Qmnf: 10.69m3/h
PVC DN63



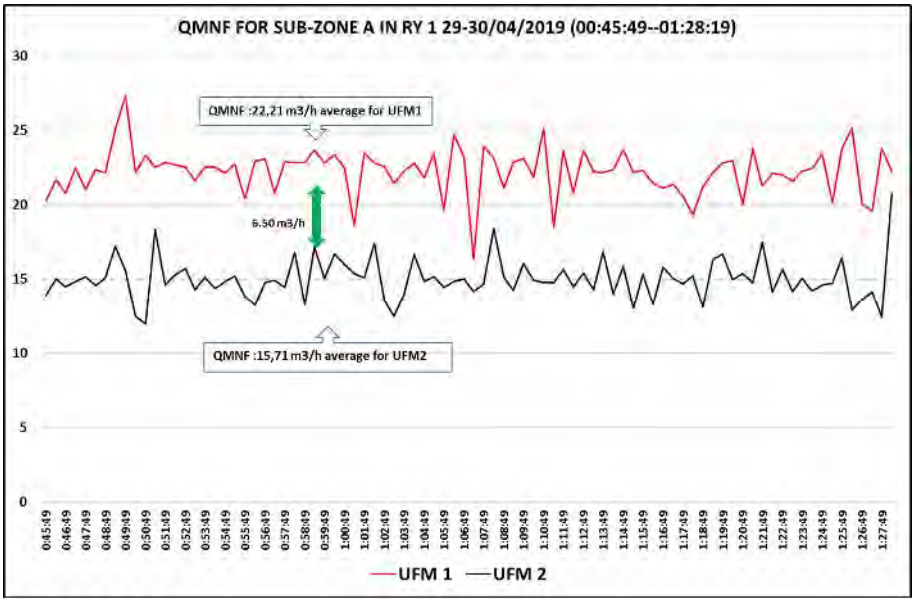


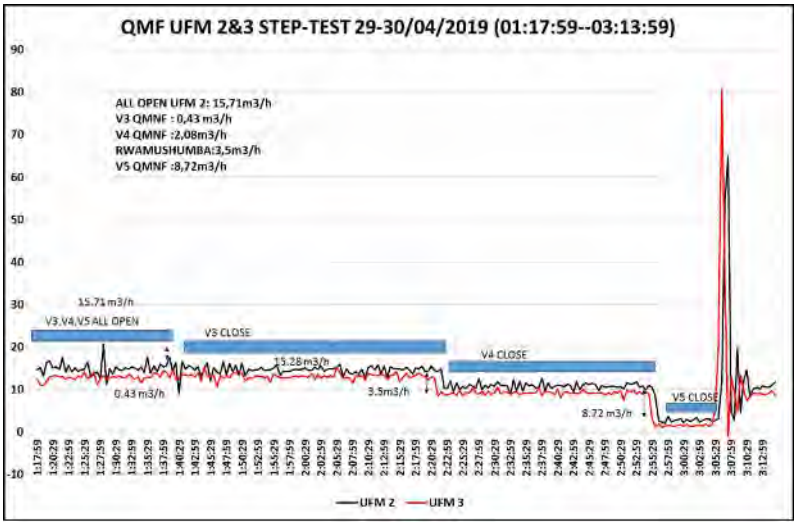
Step Test, April 29 – 30, 2019, Qmnf (Figure 7)



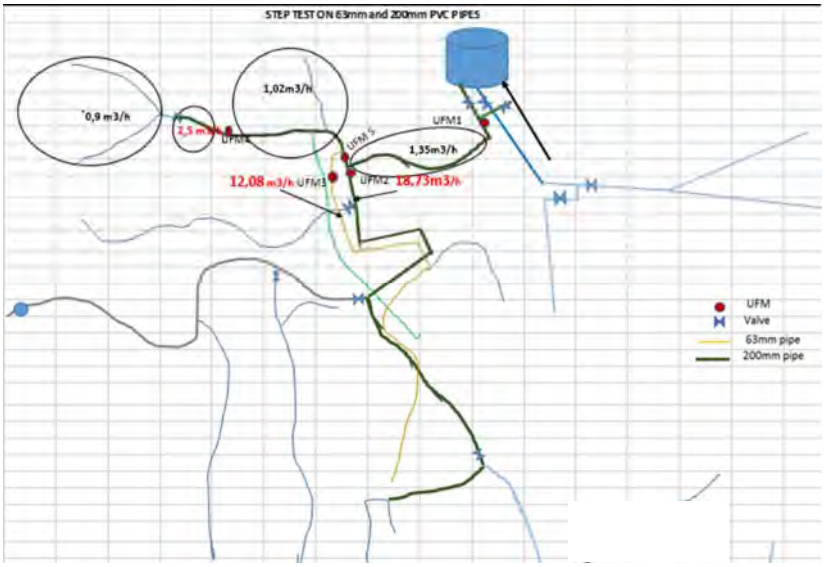
15.71 m3/h

29-30 April, 2019 200mm nain only
63mm, 50mm line not included

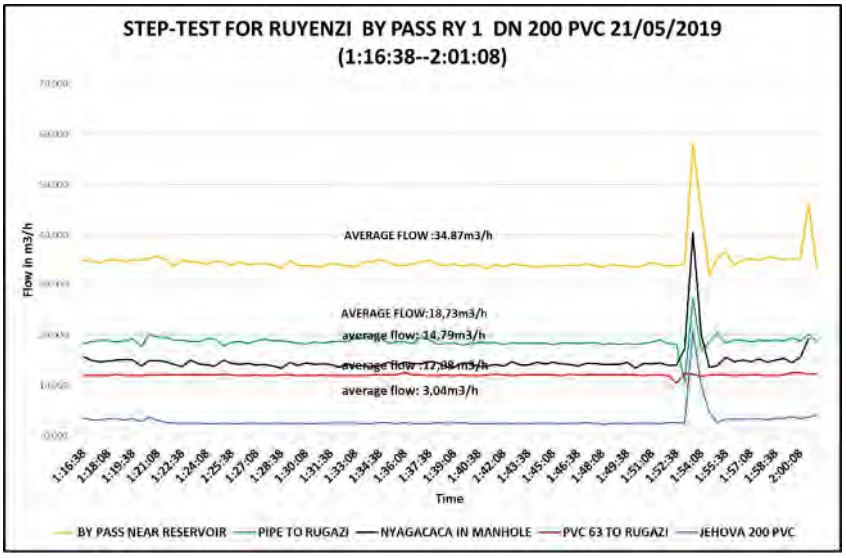


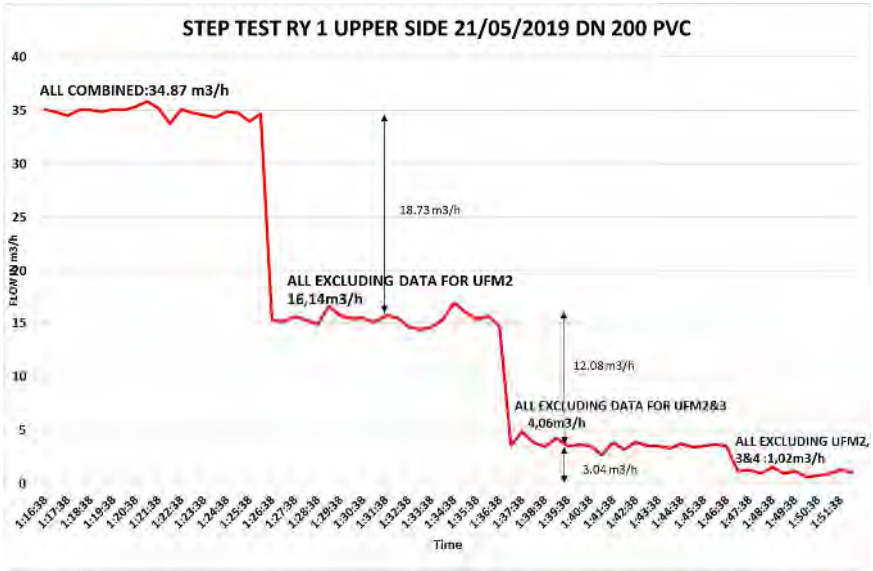


Step Test, May 21, 2019, Qmnf (Figure 8)



34.87 m3/h





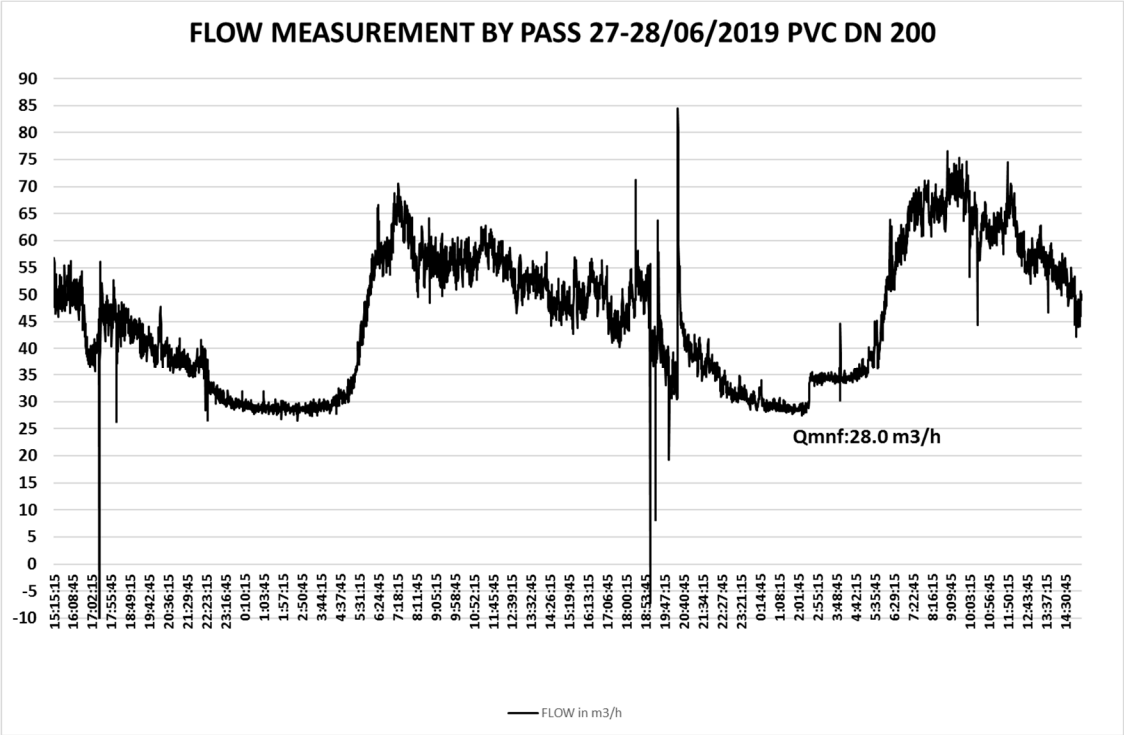


Figure 9. Measurement of Qmnf in RY1, June 27 - 28, 2019

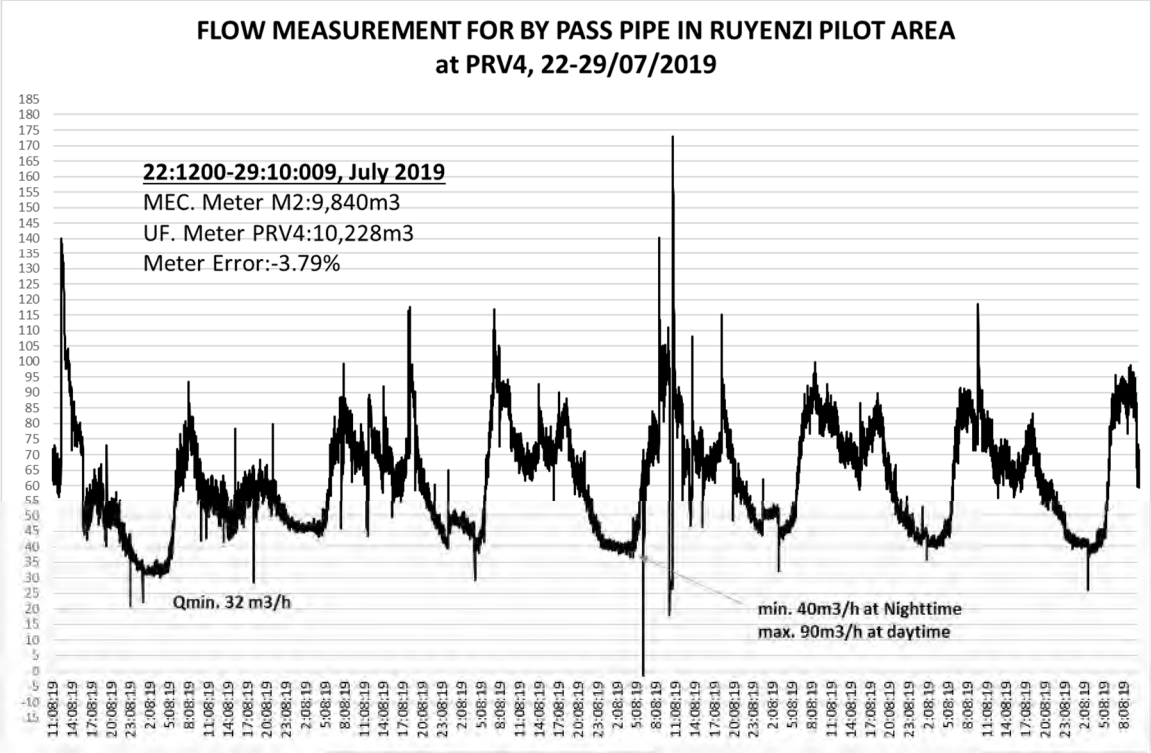


Figure 10. Measurement of Qmnf in RY1, July 22 - 29, 2019

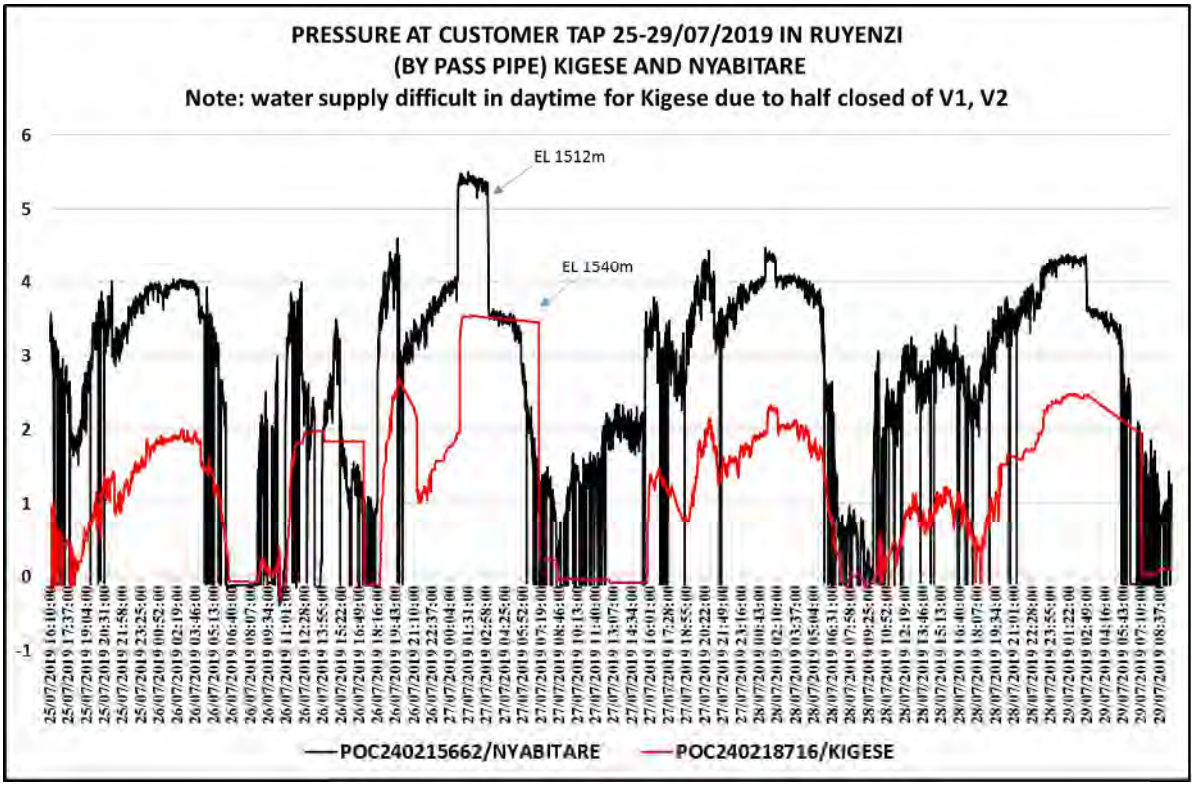


Figure 11. Measurement of Qmnf in RY1, July 25 - 29, 2019

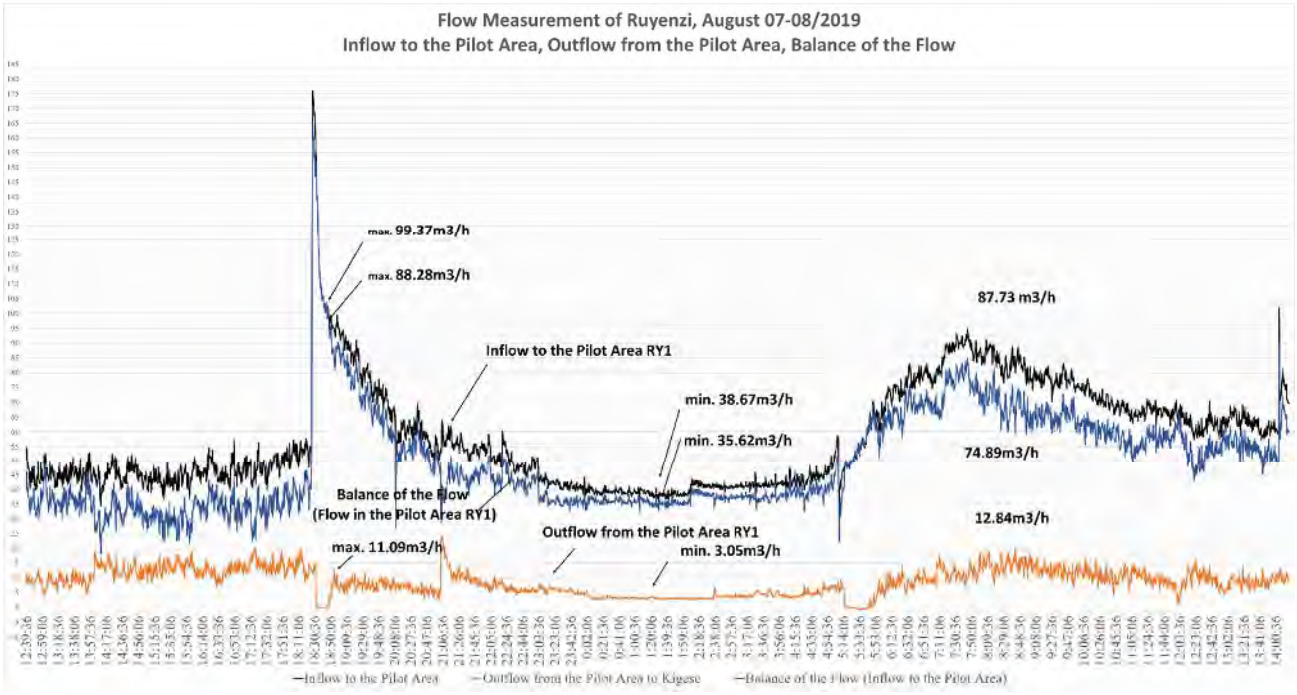


Figure 12. Measurement of Qmnf in RY1, August 7 -8, 2019

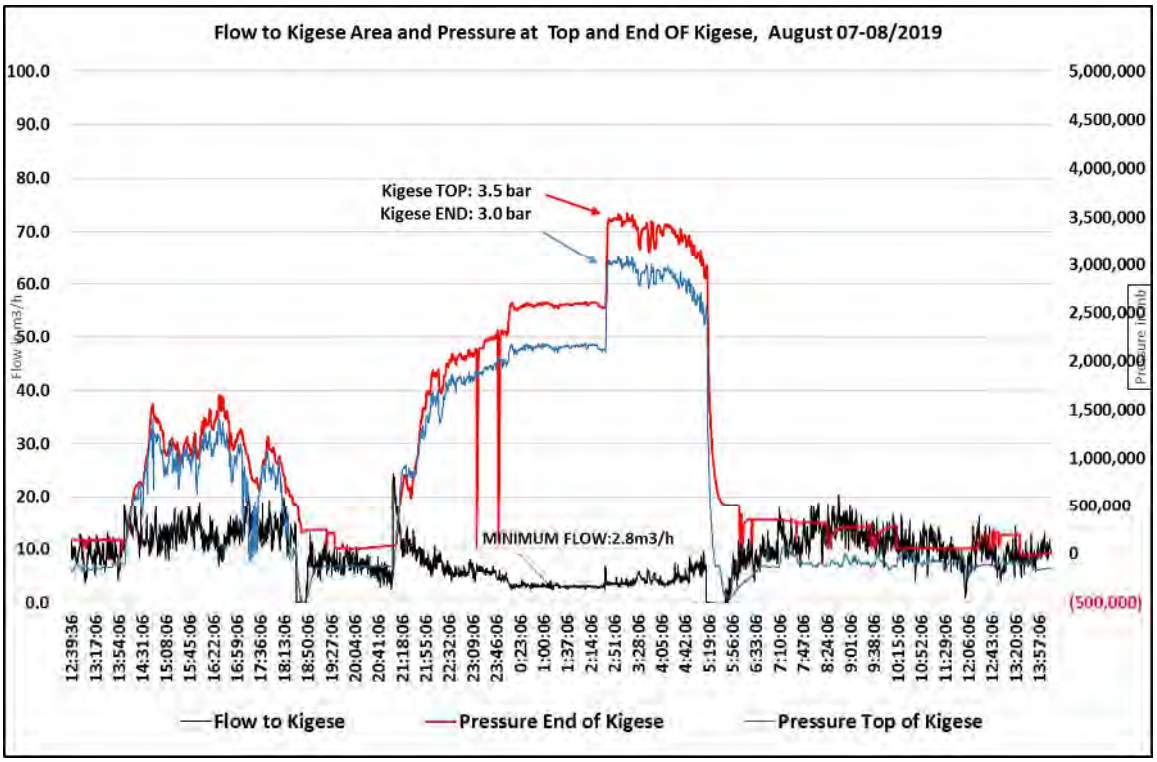


Figure 13. Measurement of Qmnf in RY1, August 7 – 8, 2019

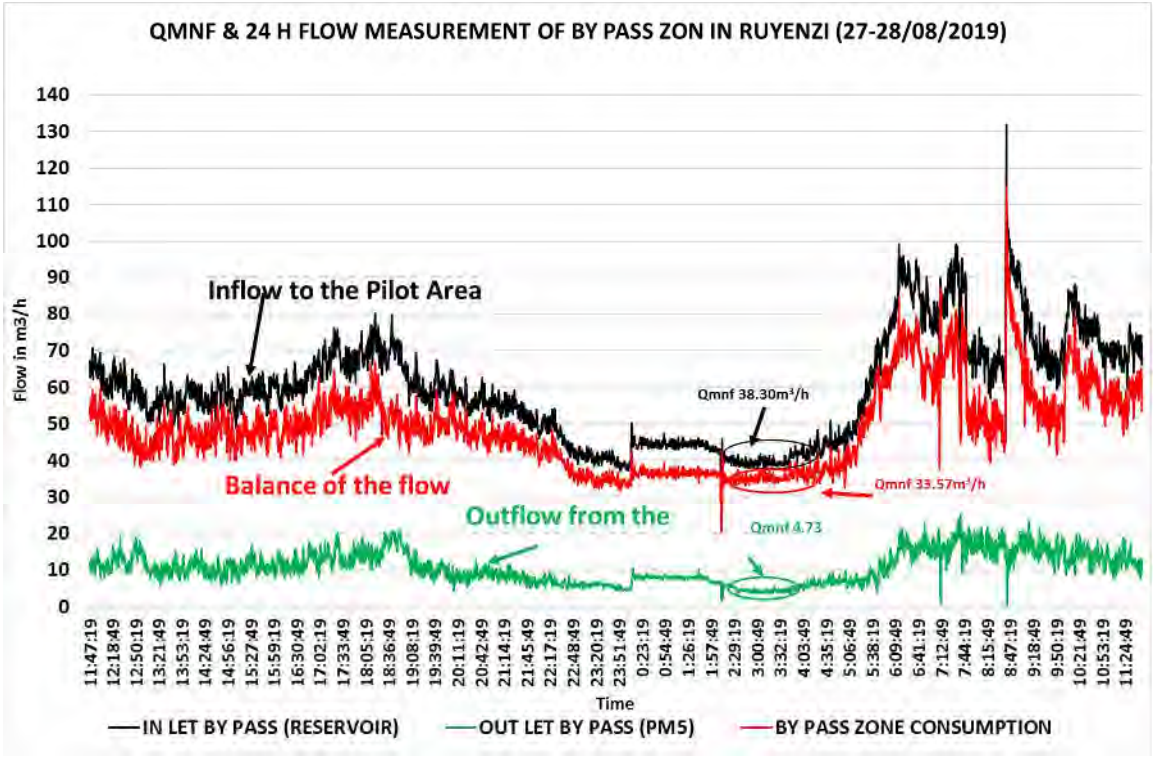


Figure 14. Measurement of Qmnf in RY1, August 27 - 28, 2019

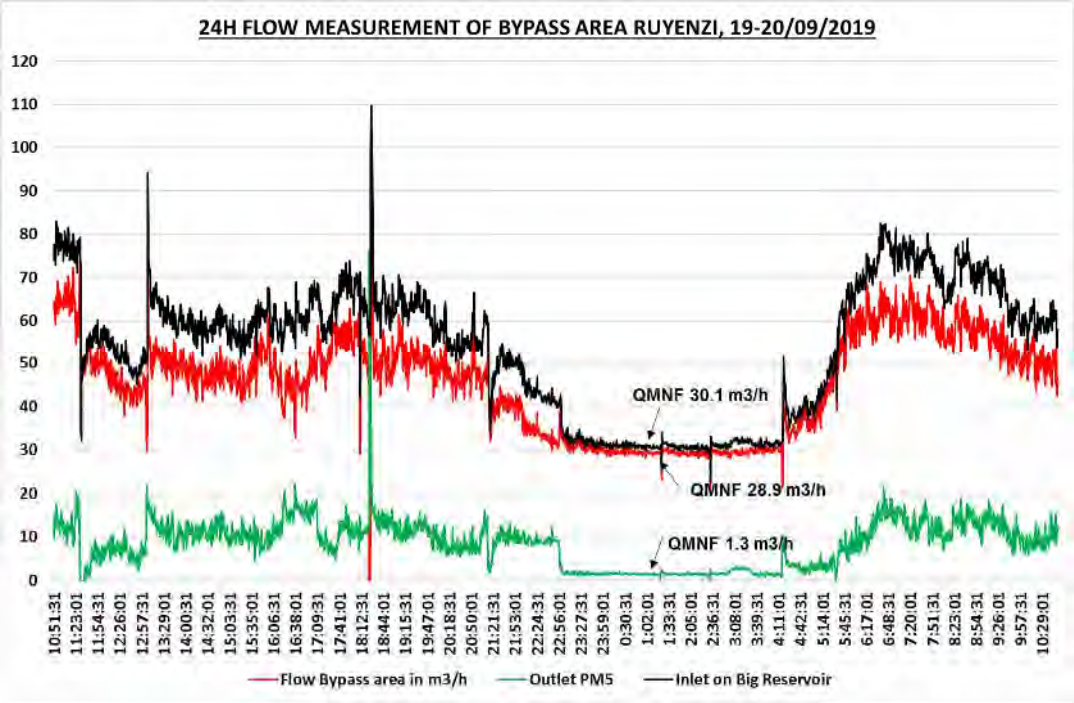


Figure 15. Measurement of Qmnf in RY1, September 19 – 20, 2019

3. RY2

3. RY2 (Gravity Line) KAMUHANDA200mm	
Jul. 11-18, 2018	7-day continuous measurement: Qmnf 4.8m3/h
Dec. 3-4, 2018	Qmnf 7.5 m3/
Feb. 19-20, 2019	The step test was conducted to identify areas with large leakage. Qmnf: 4.71m3/h As NRW in RY2 was 3,402 m3/m in February, it was assumed that the water leakage per unit time in the daytime was almost the same as Qmnf. Qmnf immediately downstream of the Ruyenzi Reservoir: Dec. 4, 2019: Qmnf 7.3 m3/h (NRW: 6,881 m3/m in November) Feb. 19, 2019: Qmnf 4.71m3/h (NRW: 2,665m3/m in January) A x 16 + 7.3 x 8 = 6,881/30, A = 10.7, 10.7/7.3 = 1.46 A x 16 + 4.71 x 8 = 2,665/31, A = 3.0, 3.0/4.71 = 0.64 Qmnf at PRV2: Nov. 15, 2018: 2.70 m3/h Feb. 19, 2019: 2.84 m3/h (2,045 m3/m)
2019/4/10	Qmnf 2.88m3/h
2019/6/27-29	Qmnf 4.5m3/h
2019/8/27-28	Qmnf 5.05m3/h

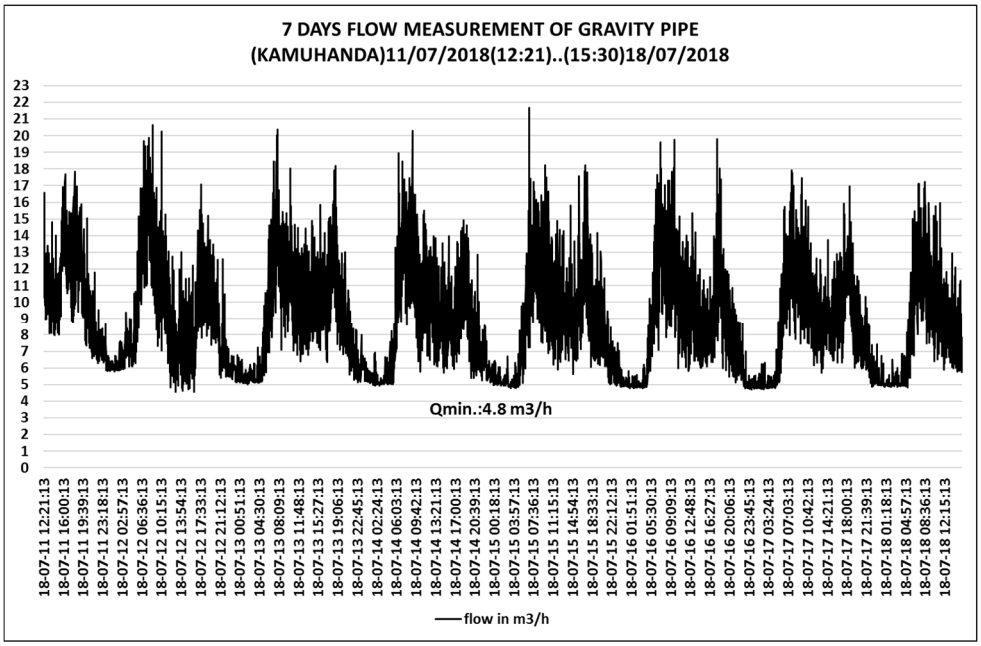


Figure 16. Measurement of Qmnf in RY2 (July 11-18, 2018)

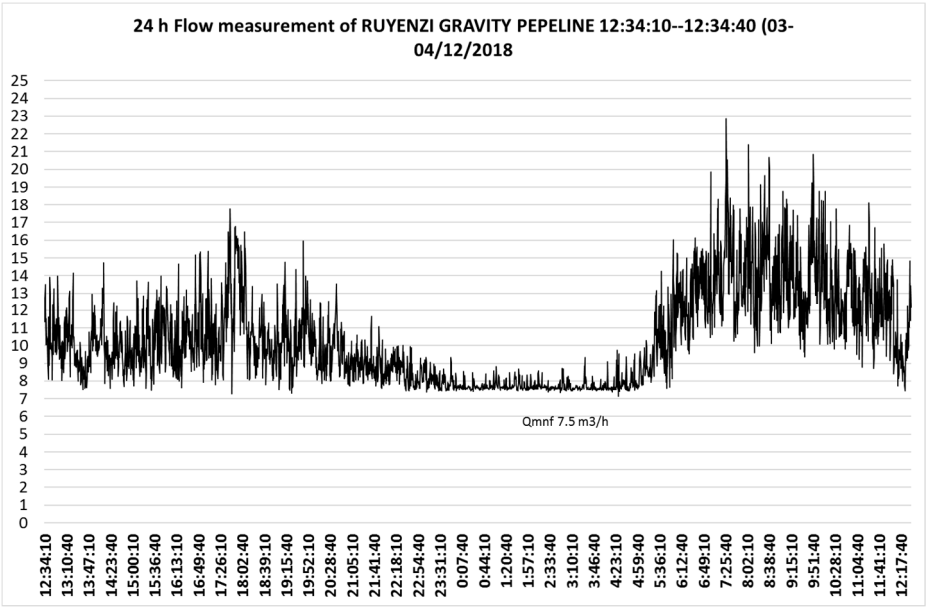
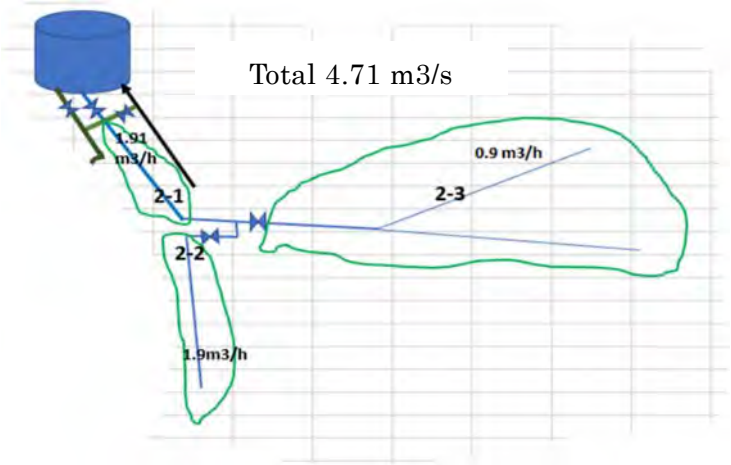
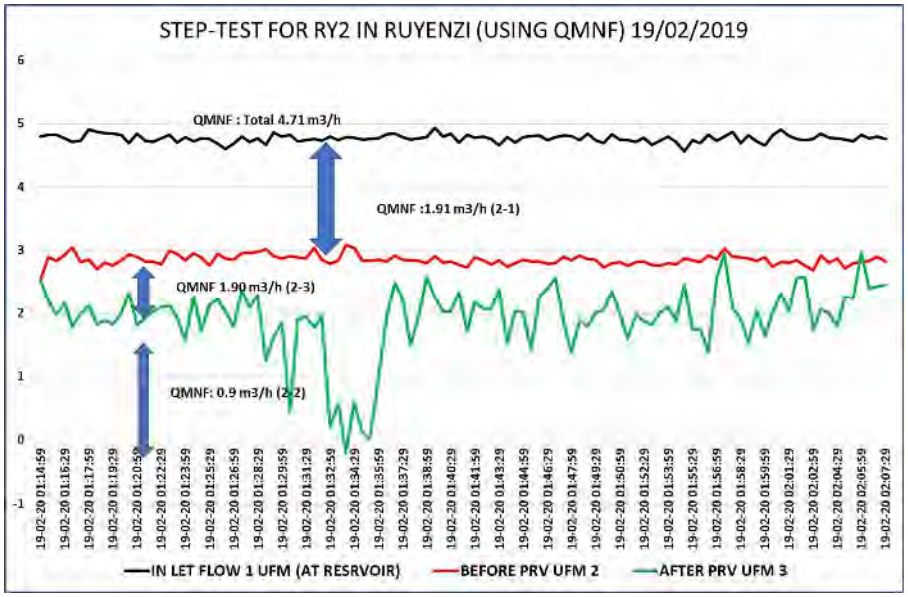


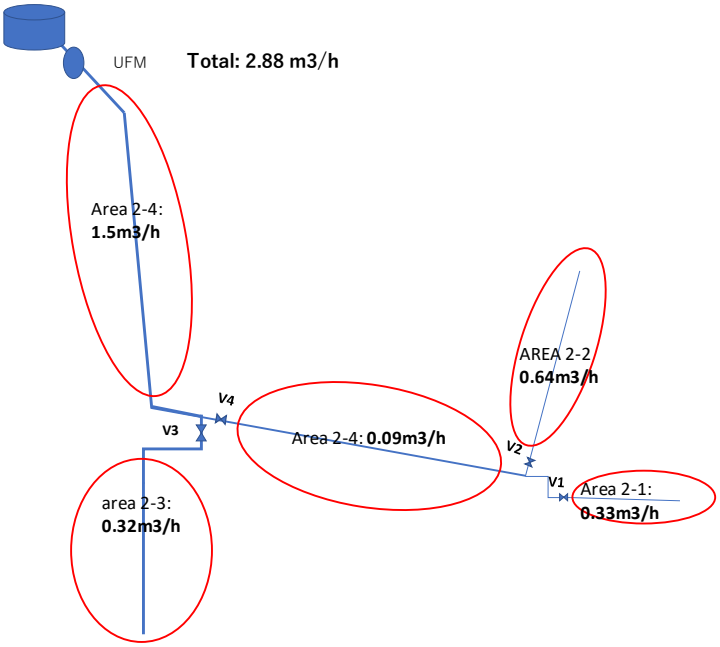
Figure 17. Measurement of Qmnf in RY2 (December 3 - 4, 2018)

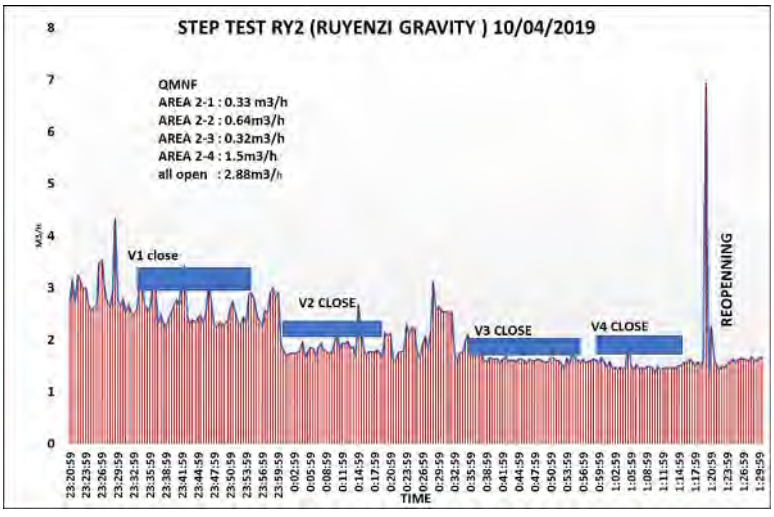
Step Test RY2, February 19, Figure 18





Step Test, RY2, April 10, Figure 19





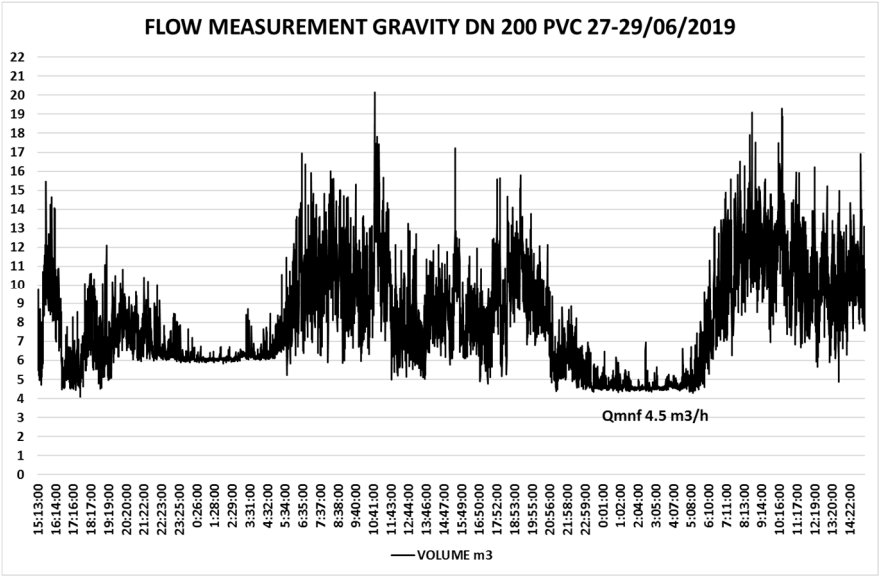


Figure 20. Measurement of Qmnf in RY2 (June 27-29, 2019)

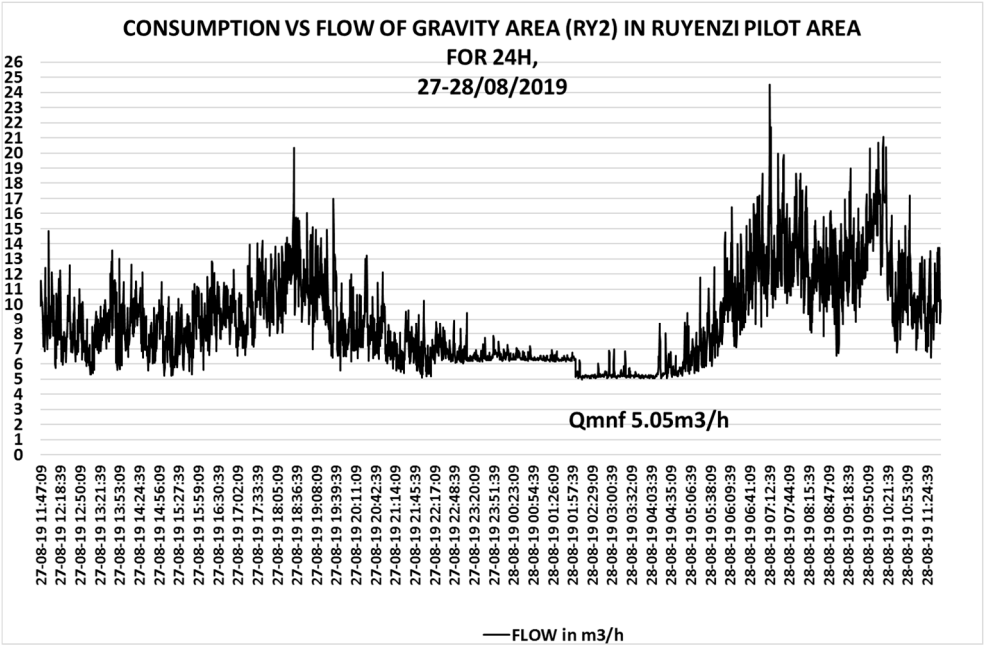


Figure 21. Measurement of Qmnf in RY2 (August 27 - 28, 2019)

4． RY3

4. RY3	PM4(Pilot Manhole)160mm
2018/1/31～1/31	At around 14:00, the minimum flow rate of 8.0 m3/h was observed. The flow rate increased till very late at night.
2018/7/11-18	Simple measurement of Qmnf was conducted. As the water supply was rationed, flow rate was low in the daytime (around 6 m3/h) and high in the night. The flow rate changed irregularly.
2018/12/3-4	There were three sharp falls of flow rate in 24 hours. These falls were assumed to have been caused by distribution of water from the Gihara Distribution Reservoir to other distribution areas. This distribution in the daytime caused shortage of water distribution in RY3 and the shortage caused frequent suspension of water supply in the daytime in RY3, which led to large water consumption in the night. The measurement of flow rate revealed that the rate was around 28 m3/h late at night. Therefore, it was not possible to measure Qmnf. The highest priority in RY3 is to establish stable water supply.
2019/6/26-28	Water supply was suspended at 19:00 on 26th. The flow rate began to increase late at night. However, it fell in the daytime.
2019/9/02-03	Change in the flow rate similar to that observed on December 3 was observed. Flow rate decreased to very low levels in the evening and early morning and increased in the night and around the noon.

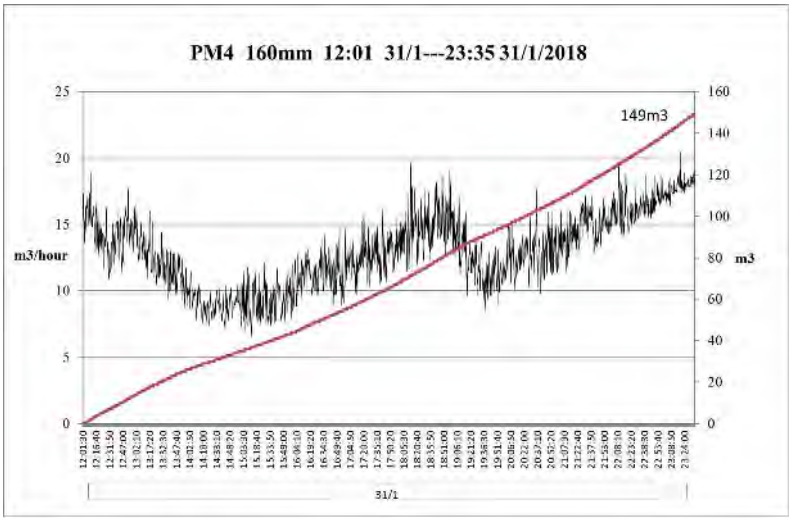


Figure 22. Measurement of flow rate in RY3 (January 31, 2018)

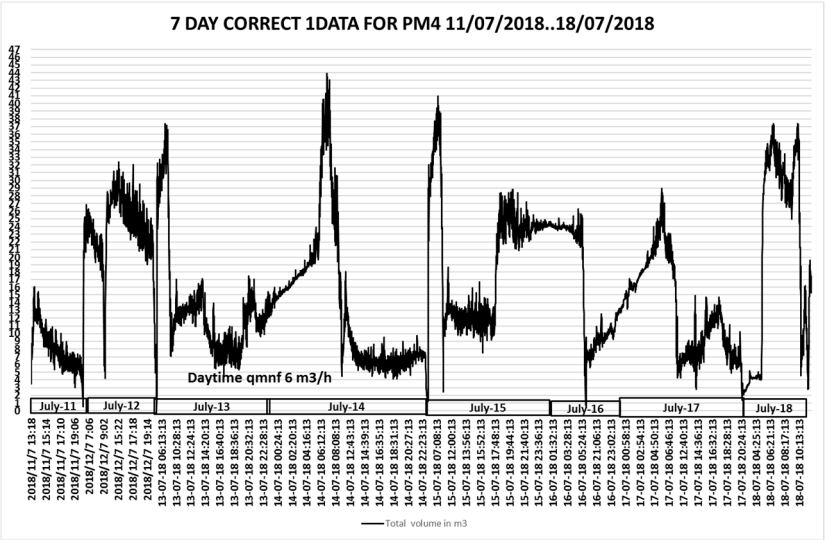


Figure 23. Measurement of flow rate in RY3 (July 11 - 18, 2018)

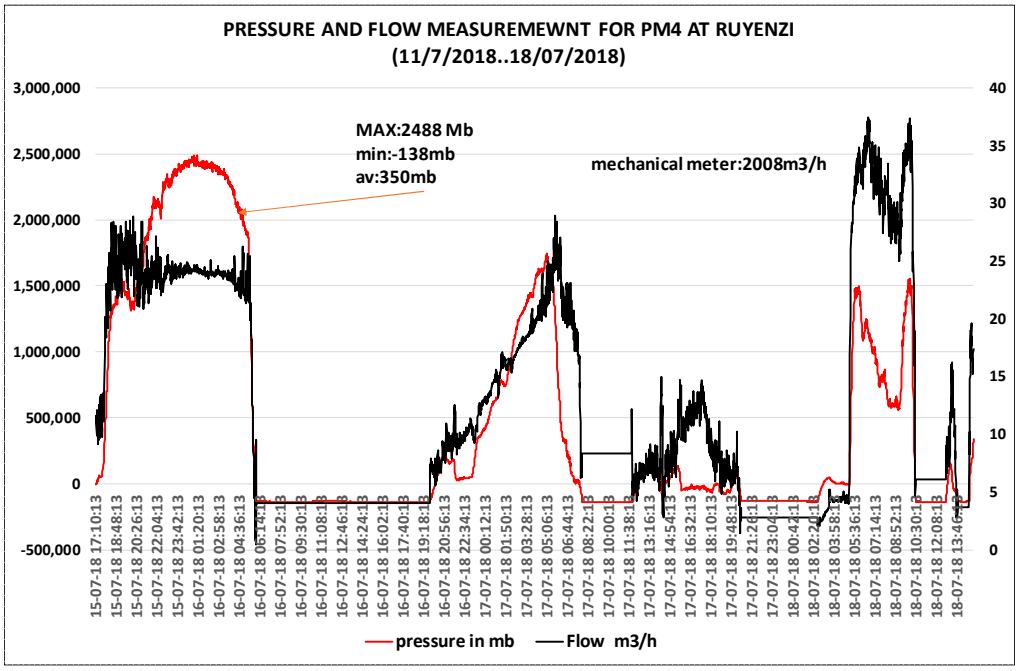


Figure 24. Measurement of water pressure in RY3 (July 15 – 18, 2018)

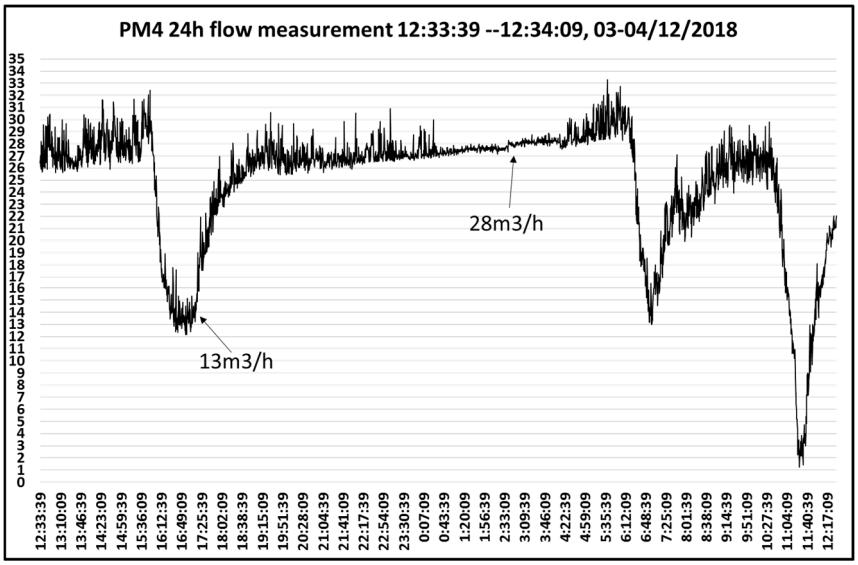


Figure 25. Measurement of flow rate in RY3 (December 3 - 4, 2018)

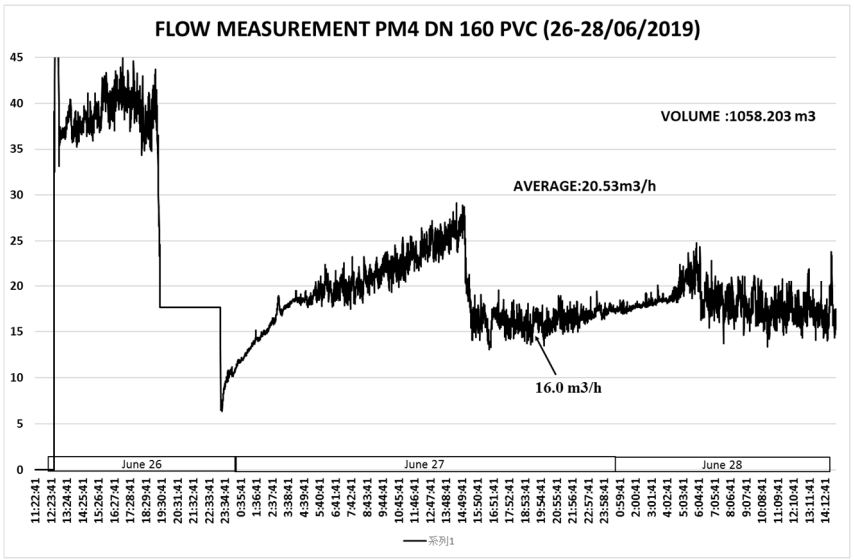


Figure 26. Measurement of flow rate in RY3 (June 26 – 28, 2019)

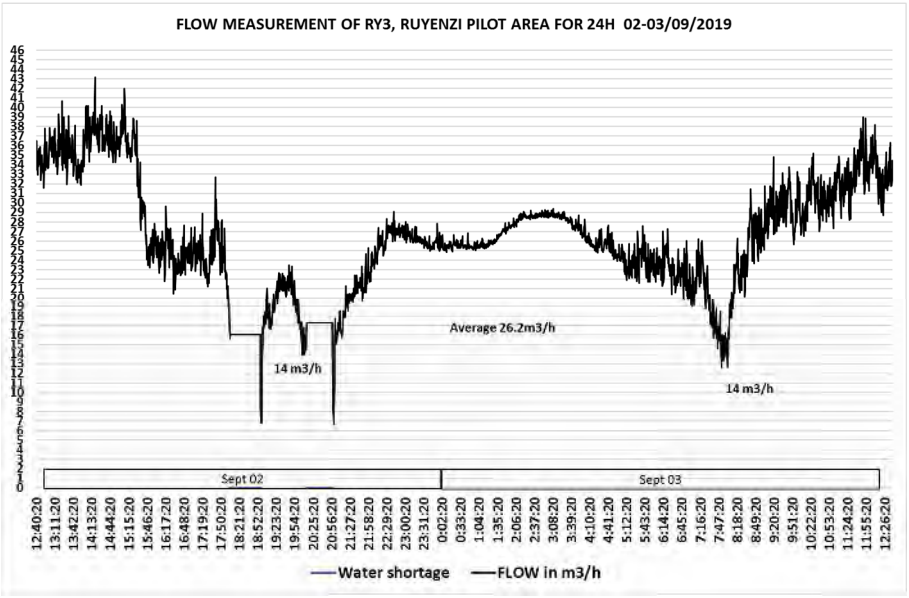
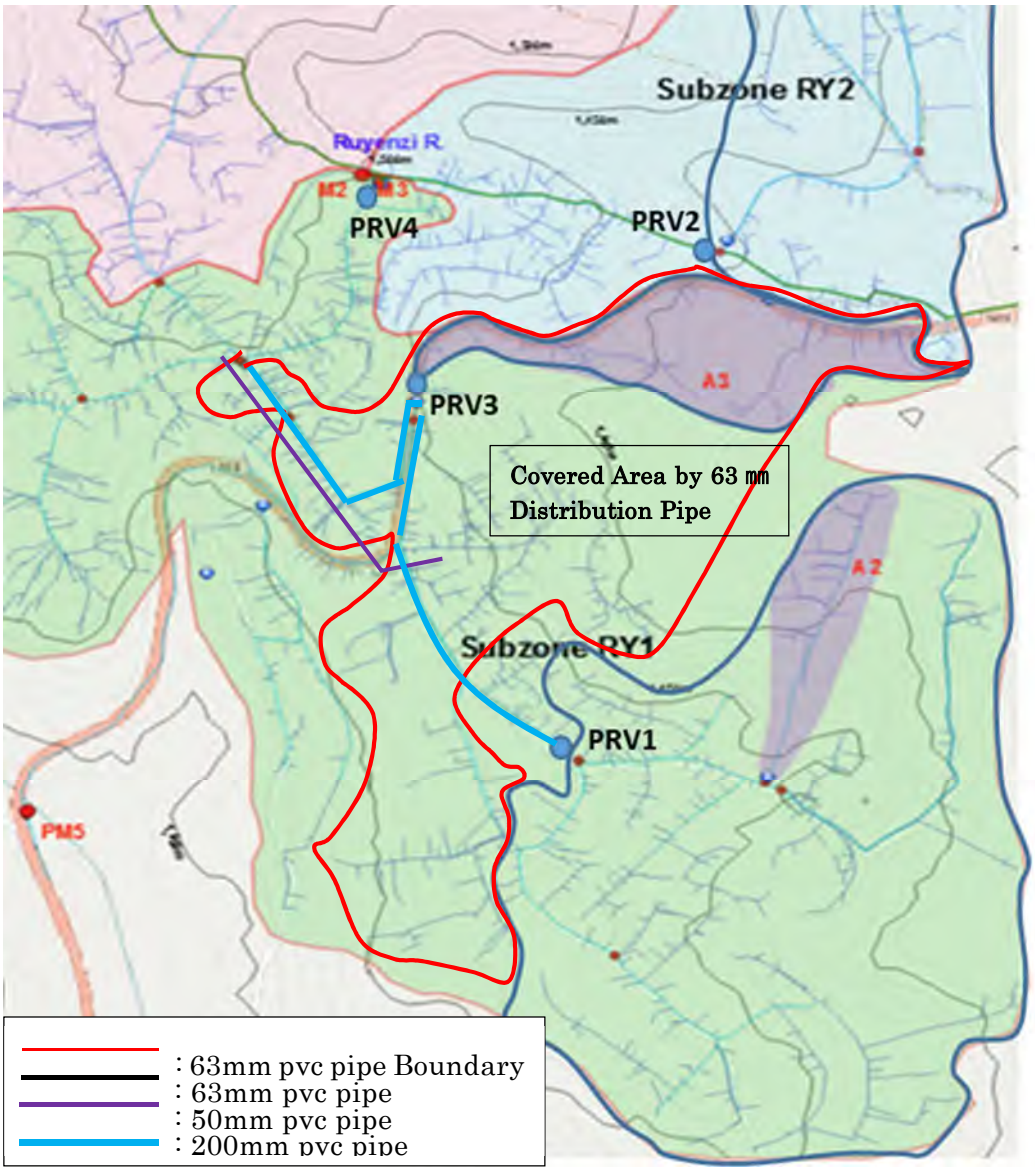


Figure 27. Measurement of flow rate in RY3 (September 2 - 3, 2019)

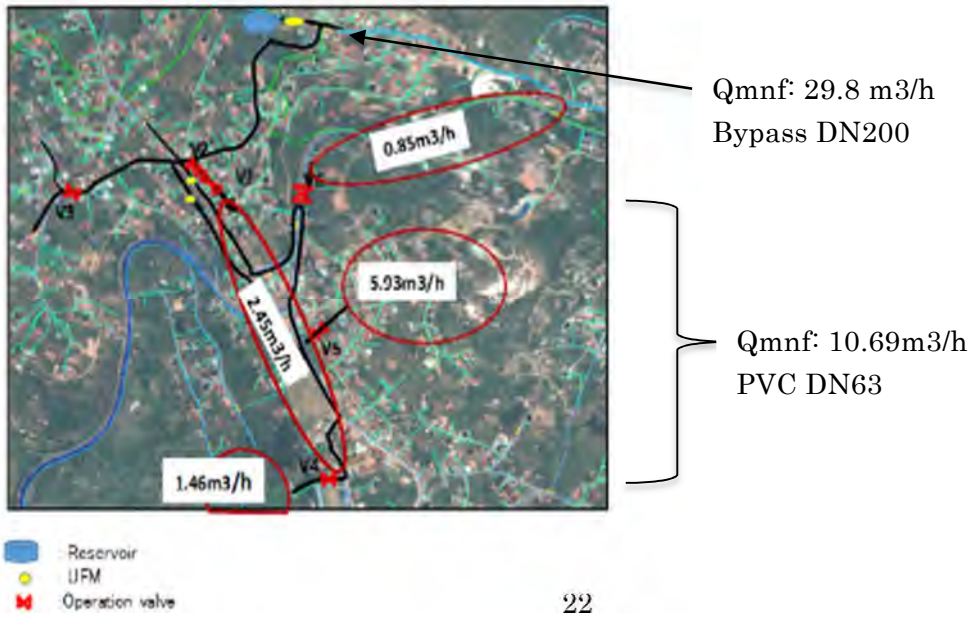
4. 63mm

2019/4/24-26	Qmnf Step Test, Qmnf: 10.69m3/h, large water leakage at V5
2019/6/13	The minimum flow rate, Qmf, observed in this flow rate measurement in the daytime was 10.84 m3/h.
2019/6/20	Qmf observed in a step test conducted in the daytime was 10.55 m3/h.
2019/7/31	Areas with many leaks were identified by conducting step tests in the daytime. Leak detection revealed water leaks at eight locations on August 8 and two locations on August 20.
2019/8/27	Qmnf was low, 5.5 m3/h.
2019/9/19	Qmnf: 9.2 m3/h
2019/9/27	Measurement of baseline Qmnf before the installation of a ball valve on the 63-mm pipe. Qmnf: 6.7m3/h

PRV4: Operation began on August 29, 2019. Operation of the ball valve on the 63-mm pipe began on October 3.



Step Test, April 25 – 25, 2019, Qmnf, Figure 28



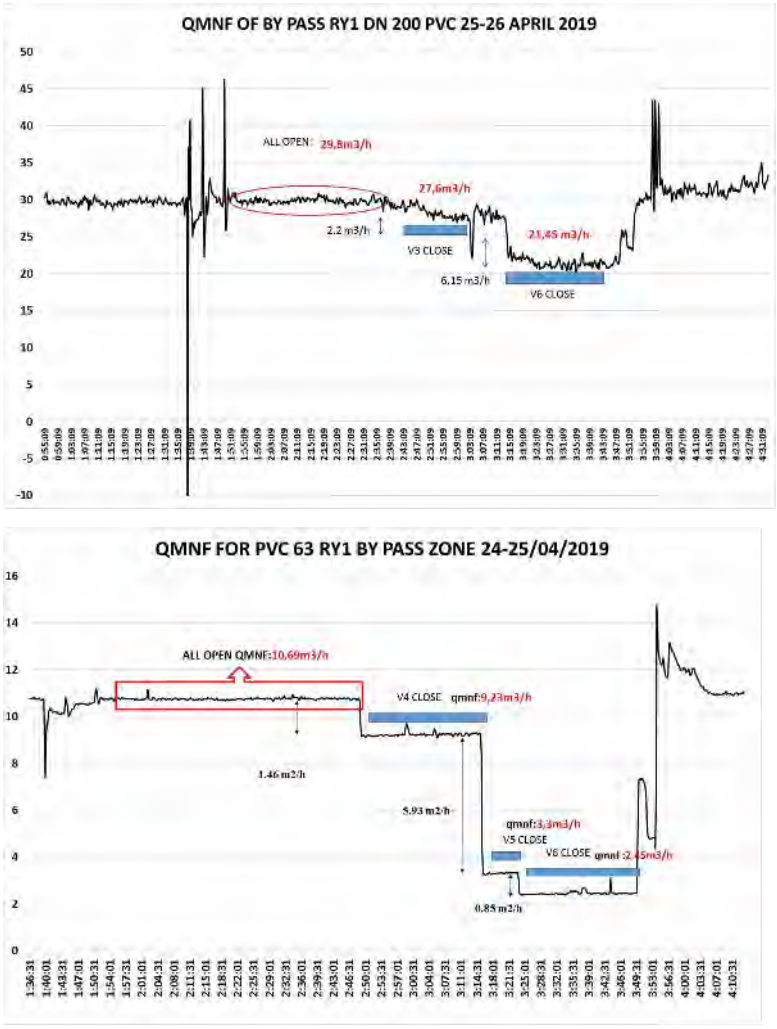


Figure 29. Measurement of flow rate in 63-mm distribution pipe, Step Test, April 24 – 25, 2019

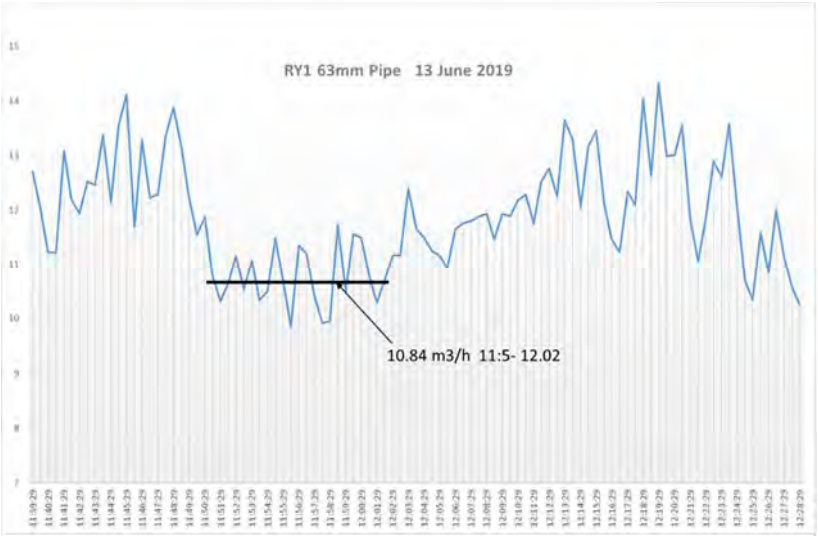
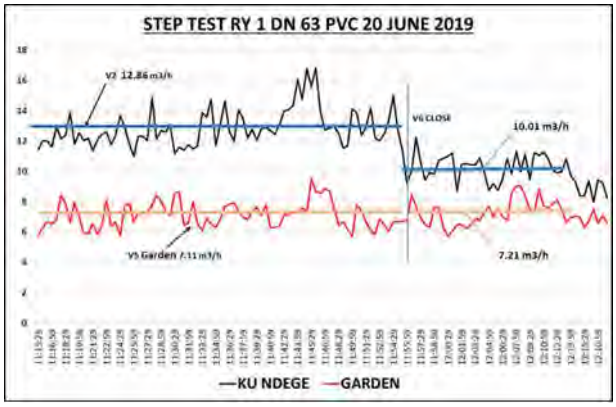


Figure 30. Measurement of flow rate in 63-mm distribution pipe, June 13, 2019



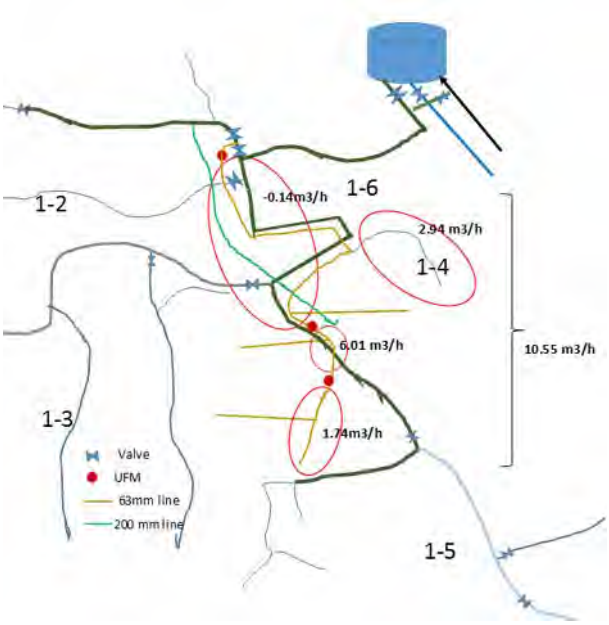


Figure 31. Measurement of flow rate in 63-mm distribution pipe,
Step Test, June 20, 2019

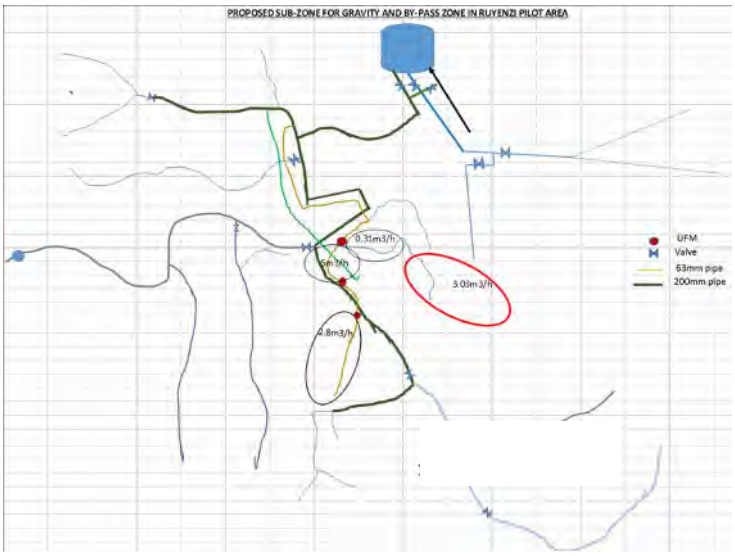


Figure 32. Measurement of flow rate in 63-mm distribution pipe, Step Test, July 31, 2019

Water leaks detected at 8 locations on August 7

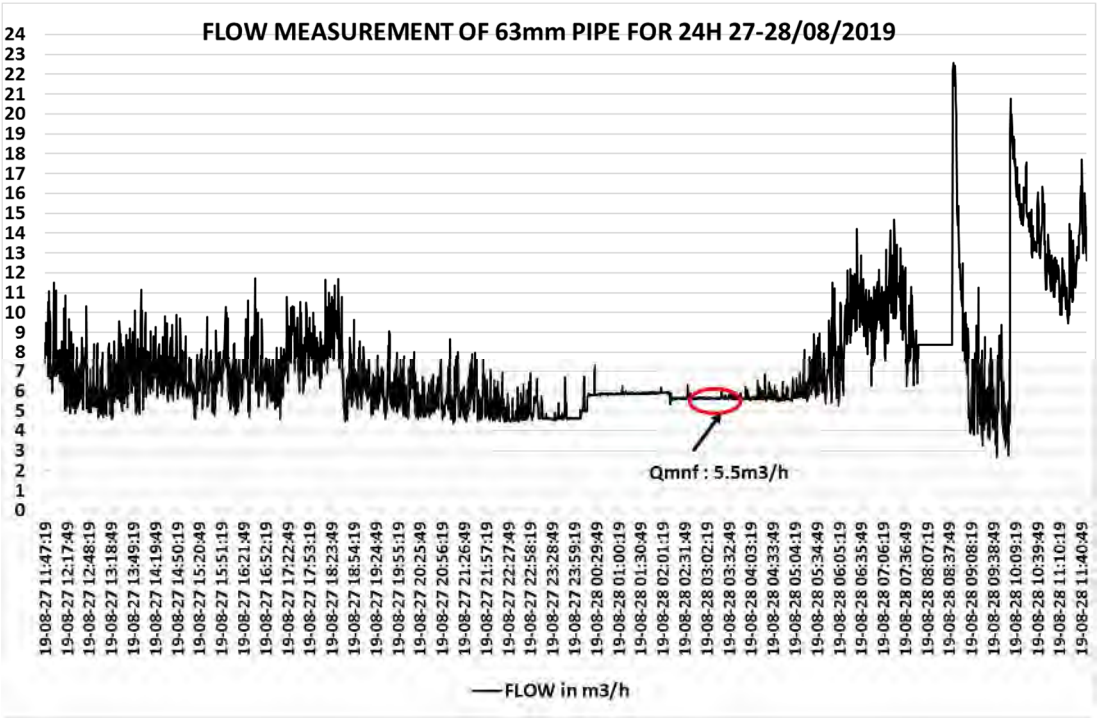


Figure 33. Measurement of flow rate in 63-mm distribution pipe, August 27 – 28, 2019

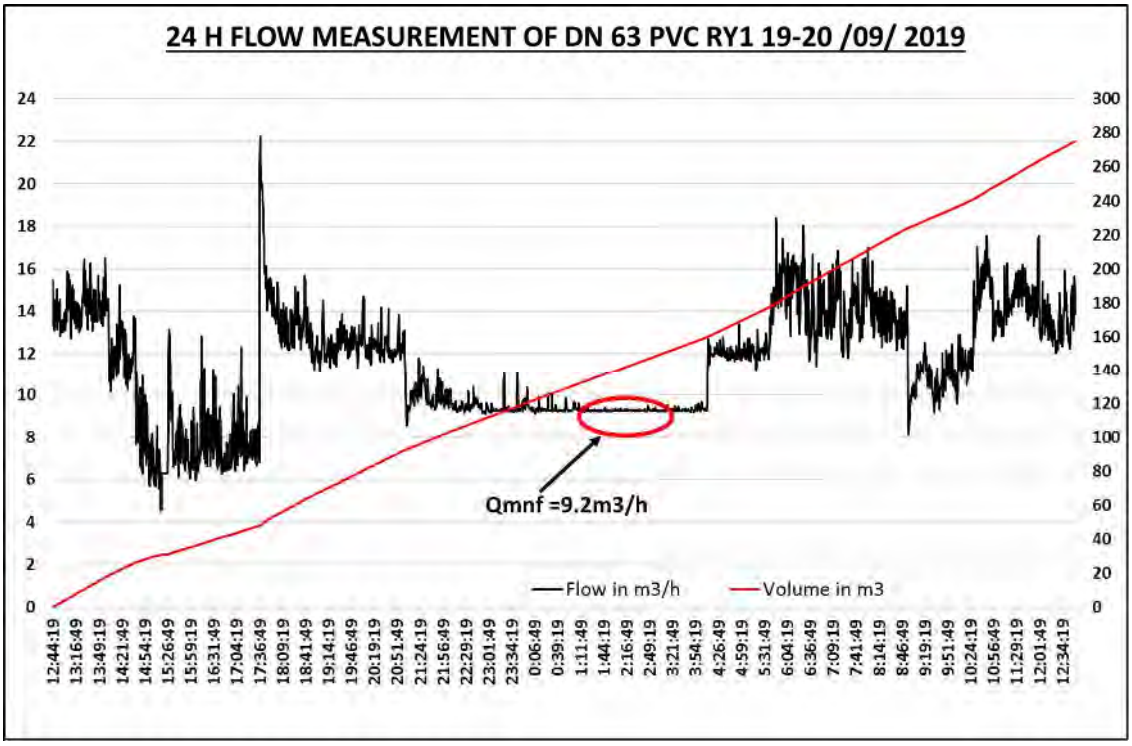


Figure 34. Measurement of flow rate in 63-mm distribution pipe, September 19 – 20, 2019

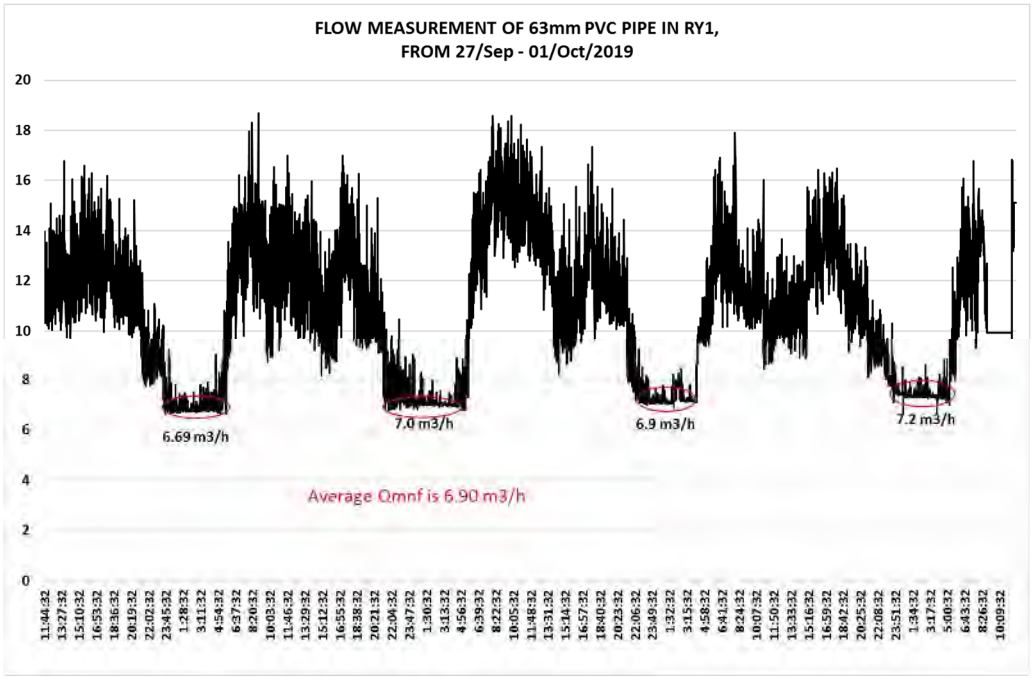


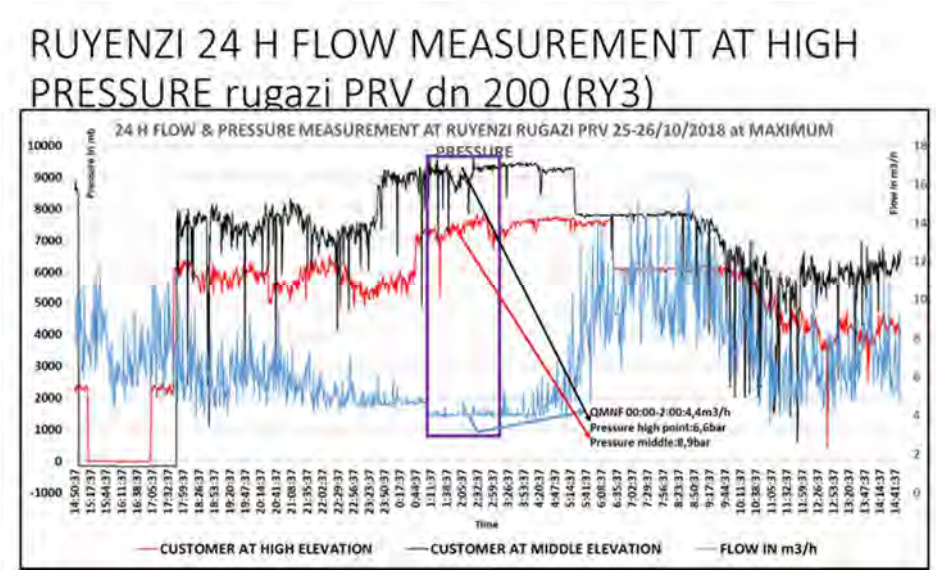
Figure 35. Measurement of flow rate in 63-mm distribution pipe, September 27 – October 1, 2019

Measurement of the effect of PRVs

1) PRV1

Measurement of the effect of PRV1 (in Ruyenzi)

Date	Activity	Description and result
Oct. 25-26, 2018	Measurement of baseline Qmnf	As there was not an appropriate location to install an ultrasonic flow meter just downstream of PRV1, one of the two diverging pipelines (HDPE 110) further downstream was excavated and the meter was installed on the pipeline. Qmnf was measured at 4.4. m3/h (P2: 6.6 bars). (These values of P2 and Qmnf were almost the same as those measured in the staged measurement conducted on the 31st.) However, because the valve could not be opened fully in the measurement conducted on the 26th, Qmnf of 7.48 m3/h recorded in the beginning of the measurement on the 31st with PRV1 fully open (P2: 9.1 bars) was adopted as the baseline Qmnf.
Oct. 31, 2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was fully open (the condition simulating that without PRV) to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. The final pressure setting: P2 at 2.5 bars (Qmnf: 2.4 m3/h)
Nov. 7-8, 2018	Measurement of Qmnf reduction effect	Qmnf was measured on the 8th. The measurement revealed a decrease of Qmnf from 7.48 m3/h in the case without PRV (P2: 9.1 bar) to 1.5 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 2.2 bars) measured on the 8th, or a Qmnf reduction effect of 5.98 m3/h (or 80 %) (with the pressure reduction of 6.9 bars). The final pressure setting of P2 at 2.5 bars was adopted temporarily. Because the water pressure at water taps near PRV1 was low with this pressure setting, the setting was modified to P2 at 3.5 bars on Feb. 6, 2019.



Qmnf:4.4m3/

Ryenzi

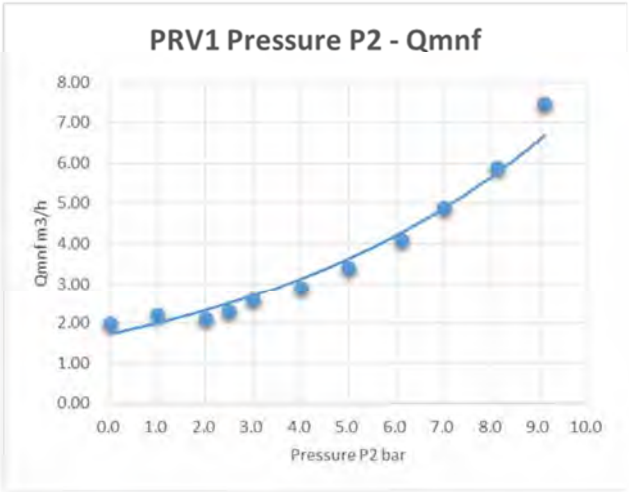
Pressre-Qmnf Measurement

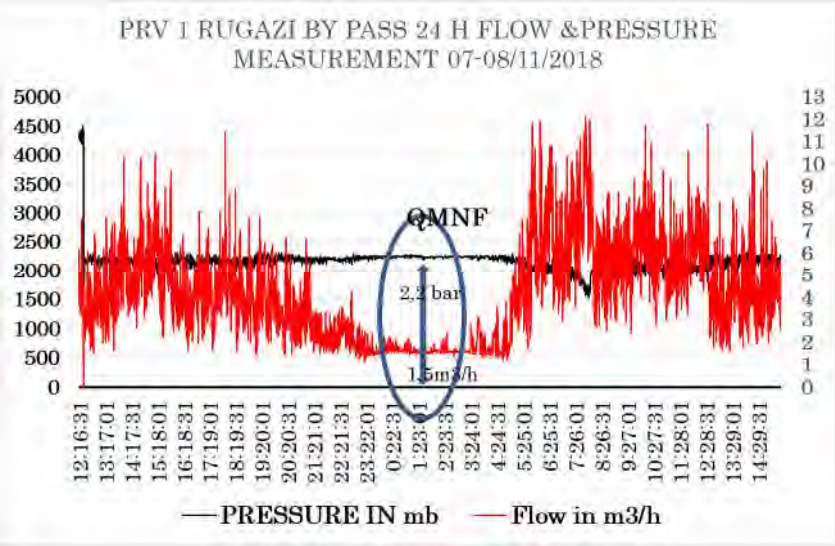
Oct. 31, 2018 01:17-2:25

Bypass PRV1 200mm

Measurement Record

No	Time	P1	P2	Qmnf
		bar	bar	m3/h
	1:05			2.20
1	1:17	9.9	9.1	7.48
2	1:22	10.0	8.1	5.90
3	1:31	10.1	7.0	4.90
4	1:37	10.1	6.1	4.10
5	1:45	10.2	5.0	3.40
6	1:52	10.3	4.0	2.90
7	2:00	10.4	3.0	2.60
8	2:06	10.4	2.0	2.10
9	2:15	11.0	1.0	2.20
10	2:21	11.5	0.0	2.00
11	2:25	11.0	2.5	2.30





Result of the Qmnf measurement downstream PRV1 (November 7-8)

Water pressure measurement at PRV1 (October 25))

PRV Survey
Date 25th October, 2018
Place Ruyenzi
PRV1: 200mm 1475

Pressure Reading (bar)

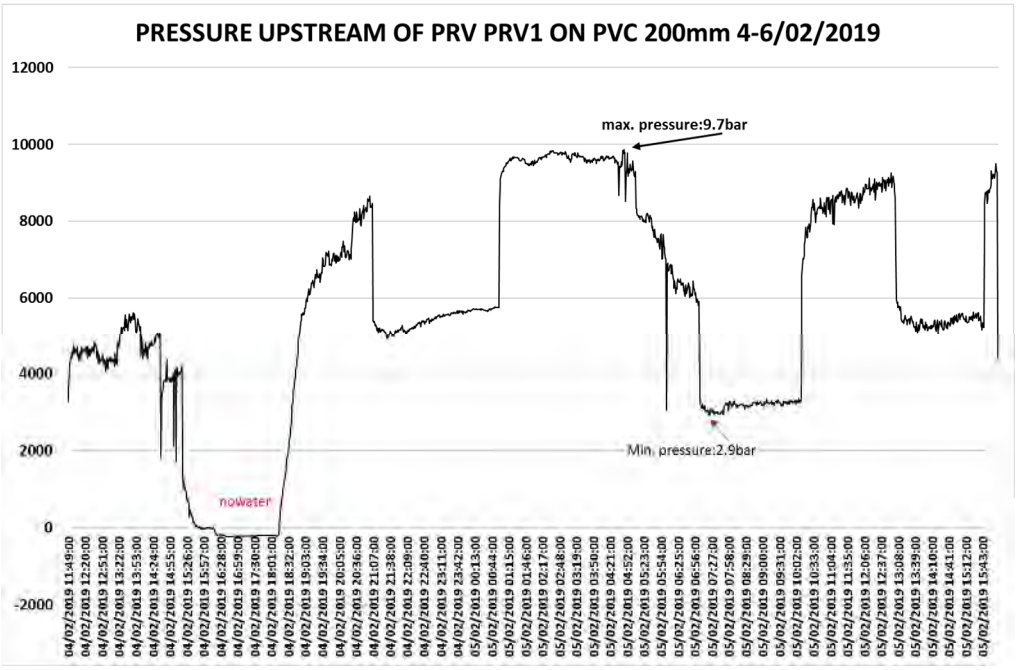
Day	Time	Flow Rate	P1	P2	Difference	Opening
		m3/h	bar	bar		
25	10:05	6.4	7.5	2.5	5.0	No touch
25	12:20	8.3	8.0	5.0	3.0	Full Open （Fail)
26	15:26	5.5	8.0	2.0	6.0	
26	15:40		8.0	8.0	0.0	Full Open （Success)
26	15:47		8.0	2.0	6.0	Adjusted to 15:26

Flowmeter (m3/h)

Day	Time		Flow Rate	For		Place
			m3/h			
25	12:10		6.4	Setting Up		Down S of PRV
25	12:05		8.3	Full Open		Down S of PRV
26	14:53		5.5	Removed		Down S of PRV

POC Pressure measurement (bar)

Day	Time		Pressure	Device		POC No
			bar			
25	11:17		–	–		~~240215084~~
25	11:33		2.5	Manometer	Data Logger	240214522
25	13:03	解放後	~~3.4~~	~~Manometer~~		~~240215065~~
25	13:36	解放後	6.9	Manometer	Data Logger	240219069
25	13:45	解放後	–	–		~~240216735~~
25	14:21	解放後	16.0	Manometer		240216098
26	14:50	解放後			Data Logger	240214522
26	13:36	解放後			Data Logger	240219069

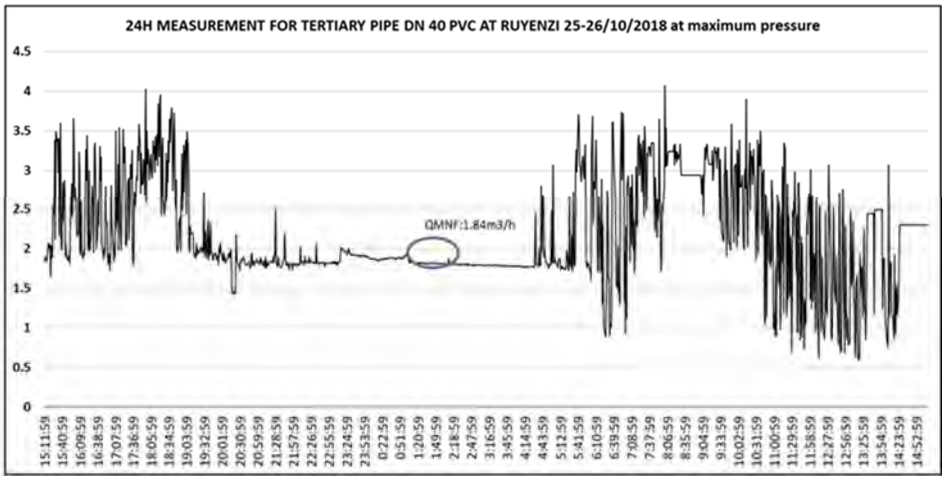


2) PRV3

Measurement of the effect of PRV3 (in Ruyenzi)

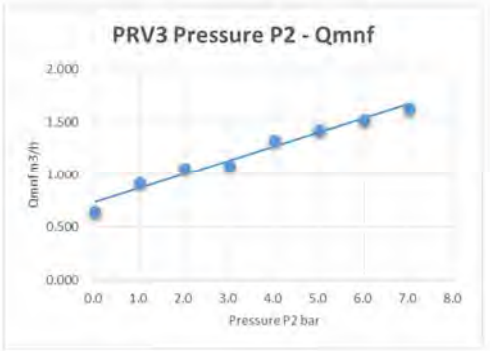
Date	Activity	Description and result
Oct. 25-26, 2018	Measurement of baseline Qmnf	The baseline Qmnf was measured with PRV installed on the bypass pipeline fully open (P1:4.0 bars, P2: 4.0 bars). Qmnf was 1.84 m3/h.
Oct. 31, 2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was fully open (the condition simulating that without PRV) to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. The final pressure setting: P2: 1.0 bar (Qmnf: 0.92 m3/h)
Nov. 15-16, 2018 (The measurement attempted on the 7th and 8th failed.)	Measurement of Qmnf reduction effect	Qmnf measurement was conducted. The measurement revealed a decrease of Qmnf from 1.84 m3/h in the case without PRV (P2: 4.0 bars) to 0.78 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 1.0 bar), or a Qmnf reduction effect of 1.06 m3/h (or 58 %) (with the pressure reduction of 3.0 bars).

RUYENZI TRRTIARY PIPE DN 40 (RY1)

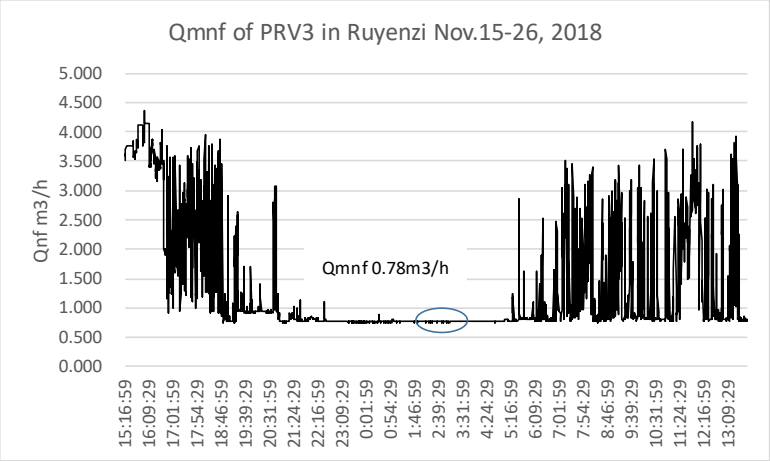


Ryenzi
Pressre-Qmnf Measurement
Oct. 31, 2018 01:13-1:47
Bypass PRV3 40mm
Measurement Record

No	Time	P1	P2	Qmnf
		bar	bar	m3/h
1	1:13		7.0	1.637
2	1:19		6.0	1.528
3	1:23		5.0	1.430
4	1:27		4.0	1.332
5	1:31		3.0	1.096
6	1:40		2.0	1.063
7	1:43		1.0	0.920
8	1:47		0.0	0.647



Result of the Qmnf measurement downstream of PRV1 (November 7-8)



Result of the Qmnf measurement downstream of PRV3 (November 15-16)

Water pressure measurement at PRV3 (October 25-26, 2018)

PRV Survey
Date 25th October, 2018
Place Ruyenzi
PRV3: 40mm 1462

Pressure Reading (bar)

Day	Time		P1	P2	Difference	Opening
			bar	bar	bar	
25	9:55		5.0	4.0-2.0	1.0-3.0	No touch
25	13:20		5.5	4.9	0.6	No touch
25	13:25		4.0	4.0	0.0	Bypass Full Open
26	16:00		-	-	-	
26	17:30		-	-	-	Bypass Full Close

Flowmeter (m3/h)

Day	Time		Flow Rate	For		Place
			m3/h			
25	15:22		1.8	Setting Up		Down S PRV3
26	16:00		2.3	Removed		Down S PRV3

POC Pressure measurement (bar)

Day	Time		Pressure	Device		POC No
			bar			
25	14:50		12.5	Manometer		240215008

3) PRV2

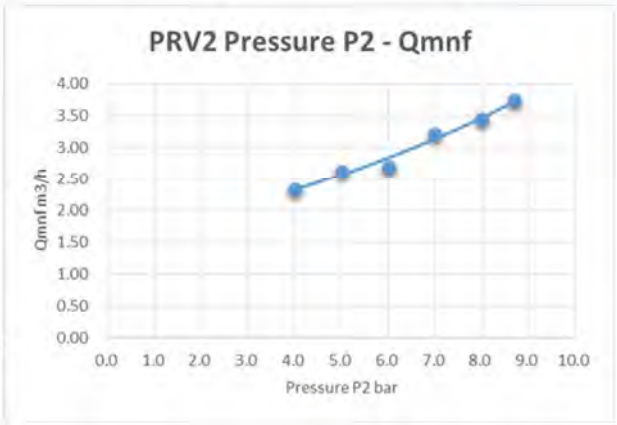
Measurement of the effect of PRV2 (in Ruyenzi)

Date	Activity	Description and result
Nov. 15, 2018	Measurement of baseline Qmnf	An ultrasonic flow meter was installed just upstream of the PRV. The Qmnf measurement of 3.74 m3/h taken at the beginning of the staged measurement on the 15th while PRV was kept as open as possible (P2: 8.7 bars) was used as the baseline Qmnf.
Nov. 15, /2018	Staged measurement	Qmnf was measured while P2 was reduced stepwise from the condition that the valve was as open as possible to measure the Qmnf reduction effect of the valve. The measurement revealed a correlation between P2 and Qmnf: Whenever the pressure was reduced by a step, Qmnf clearly decreased. A sharp drop of Qmnf

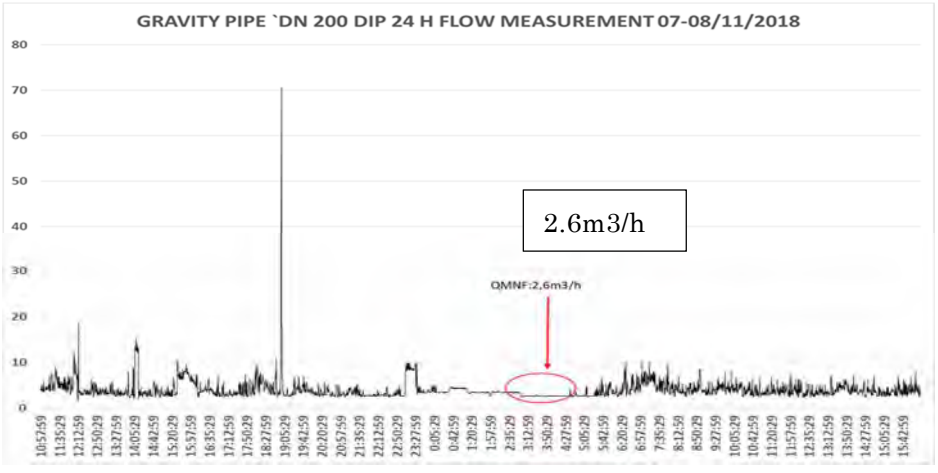
		was observed when the pressure was reduced below 4 bars. However, the water flow from water taps in the high elevation area was reduced when P2 was reduced below 6.0 bars. For these reasons, the final pressure setting of P2 = 6.0 bars (Qmnf = 2.70 m3/h) was adopted.
Nov. 7, 2018	Measurement of Qmnf reduction effect	There is an area above the elevation of PRV2, EL 1,410 m, downstream of the valve. The highest point in this area is at EL 1,460 m. The measurement of the water pressure at water taps of customers in the highest area revealed that water barely reached the tap in this area (water pressure of 0.2 - 1.0 bar) when P2 was set at 5.5 bars. Therefore, P2 could only be reduced to around 6.0 bars. The Qmnf measurement taken in November 7 and 8 with P2 set at 6.0 bars was 2.6 m3/h Qmnf decreased from 3.74 m3/h in the case without PRV (P2: 8.7 bars) to 2.6 m3/h in the case that the water pressure was reduced by the installed PRV (P2: 6.0 bars), or a Qmnf reduction effect of 1.14 m3/h (or 30 %) (with the pressure reduction of 2.7 bars).

Ryenzi
Pressre-Qmnf Measurement
Nov. 15, 2018 01:10-01:54
Gravity PRV2 200mm
Measurement Record

No	Time	P1	P2	Qmnf	Qmnf-1	Qmnf-2	
		bar	bar	m3/h	m3/h	m3/h	
1	1:10	9.5	8.7	3.74	3.64	0.1	Full Open
3	1:18	9.5	8.0	3.45	3.30	−0.5～0.8	
4	1:25	9.5	7.0	3.21	3.21	−1.4～0.3	
5	1:32	9.5	6.0	2.70	2.70	−0.2～0.10	
6	1:40	9.5	5.0	2.63	2.63	−0.6～0.5	
7	1:48	9.5	4.0	2.33	2.33	−0.1～0.0	
8	1:54	9.5	3.5	0.95	0.95	−0.3	Full Close



Result of the measurement of the effect of PRV2 (staged measurement of P2-Qmnf)



Result of the measurement of Qmnf downstream of PRV2 (in Ruyenzi) (November 7-8)

4. High water pressure management

PRV 4 INSTALLATION AND MANHOLE CONSTRUCTION

THE SCHEDULE OF INSTALLATION AND CONSTRUCTION THE MANHOLE OF PRV 4		
DATE		ACTIVITIES
From	to	
15/05/2019	21/05/2109	Excavation
22/05/2019	29/05/2019	Installation of PRV and fittings
03/06/2019	05/06/2019	Trust bloc concrete
06/06/2019	07/06/2109	Support pipe concrete
10/06/2019	11/06/2019	Excavation full opening for manhole
12/06/2019	13/06/2019	Steel bars preparation for Slab
14/06/2019	14/06/2019	Slab concrete
17/06/2019	19/06/2019	Elevation wall by bricks blocs
20/06/2019	20/06/2109	Steel bars and form work for chaining & Beam
21/06/2019	21/06/2019	Concrete of chaining and Beam
24/06/2019	27/06/2019	Finishing by mortar coating to the wall and finishing of pavment
28/06/2019	29/06/2019	Back filling
28/06/2019	30/06/2019	Manhole cover by welding metal tubes & metal sheet
29/06/2019	29/06/2019	Top finishing after manhole covering
30/06/2019	30/06/2019	Application of paint

Excavation , Transport materials and procurement photos

Installation of PRV and fittings photos

Trust bloc concrete photos

Support pipe concrete photos

Excavation full opening for manhole photos

Steel bars preparation for Slab and form work photos


Slab concrete photos


Elevation wall by bricks blocs photos


Steel bars, form work and Concrete for chaining & Beam


Finishing by mortar coating to the wall and finishing of pavement photos


Manhole cover by welding metal tubes & metal sheet photos


Top finishing after manhole covering and Application of paint photos

Photos

5. NRW measurement effect

Plan to Develop a New Water Delivery Network for Delivery to Ruyenzi

Flooding of the Nyabugogo River caused by heavy rain in the early May 2018 washed away the delivery pipe from the Nzove 2 Pumping Station to Ruyenzi and protective concrete. To maintain water delivery to Ruyenzi, WASAC delivered water from New Nzove 1 Pumping Station to Ruyenzi through the Mt Kigali Distribution Reservoir and the Old Karama Distribution Reservoir. However, the water delivery to Ruyenzi was unstable and water was not distributed to certain areas in Ruyenzi.

WASAC is reviewing the existing delivery and distribution area in the entire Kigali City as the operation of the newly constructed New Nzove 1 Purification Station began. WASAC plans to deliver water to Ruyenzi from the New Karama Distribution Reservoir by gravity.

The schematic diagrams of the current and planned water delivery networks are shown in Figs. 1 and 2, respectively. In a grant aid project planned to be implemented, a new delivery pipe between the Nzove 2 Pumping Station to the Ntora Distribution Reservoir will not have a delivery pipe to Ruyenzi branching off from it.

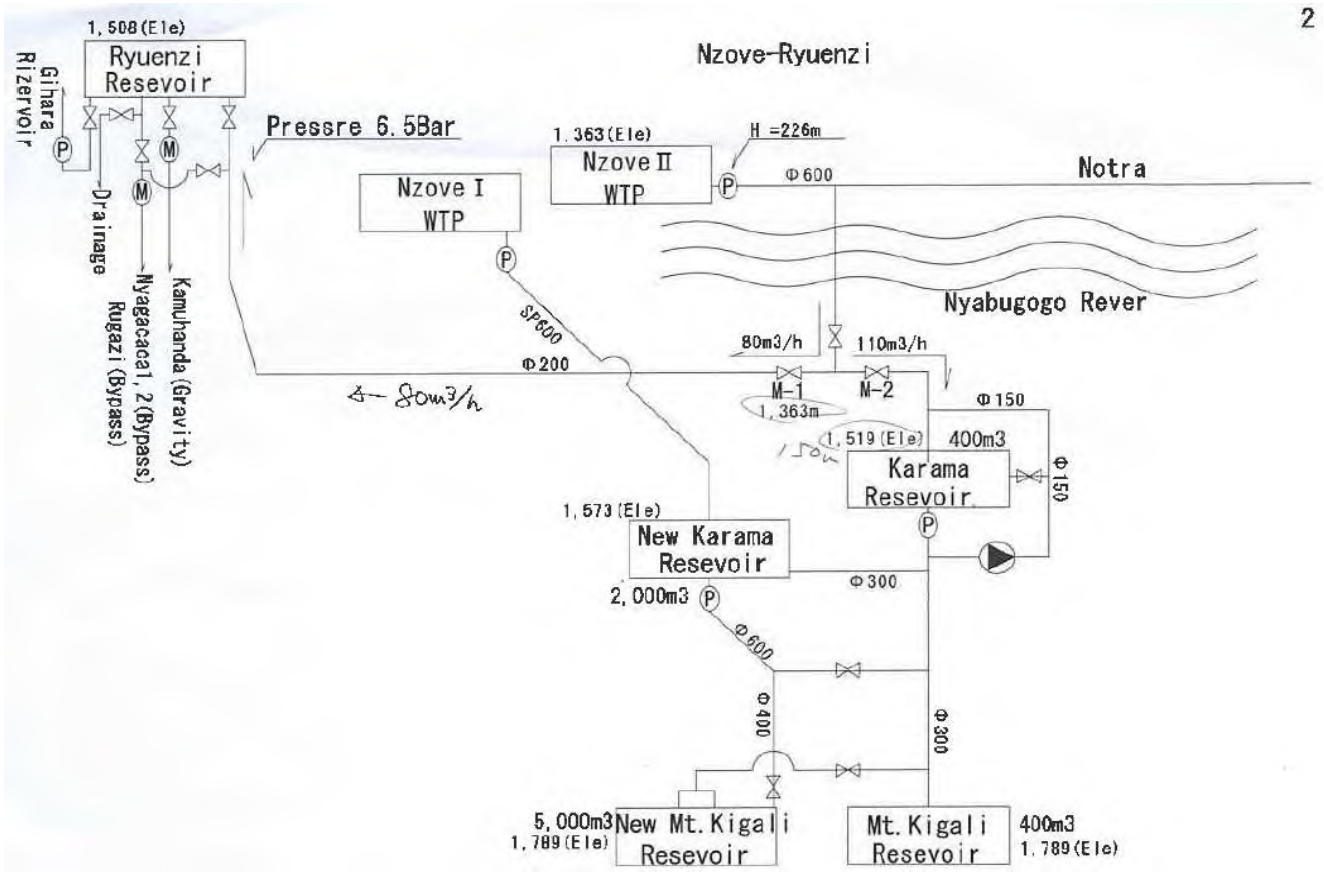


Figure 1. Current water delivery network and water pressure at the inlet to RY1

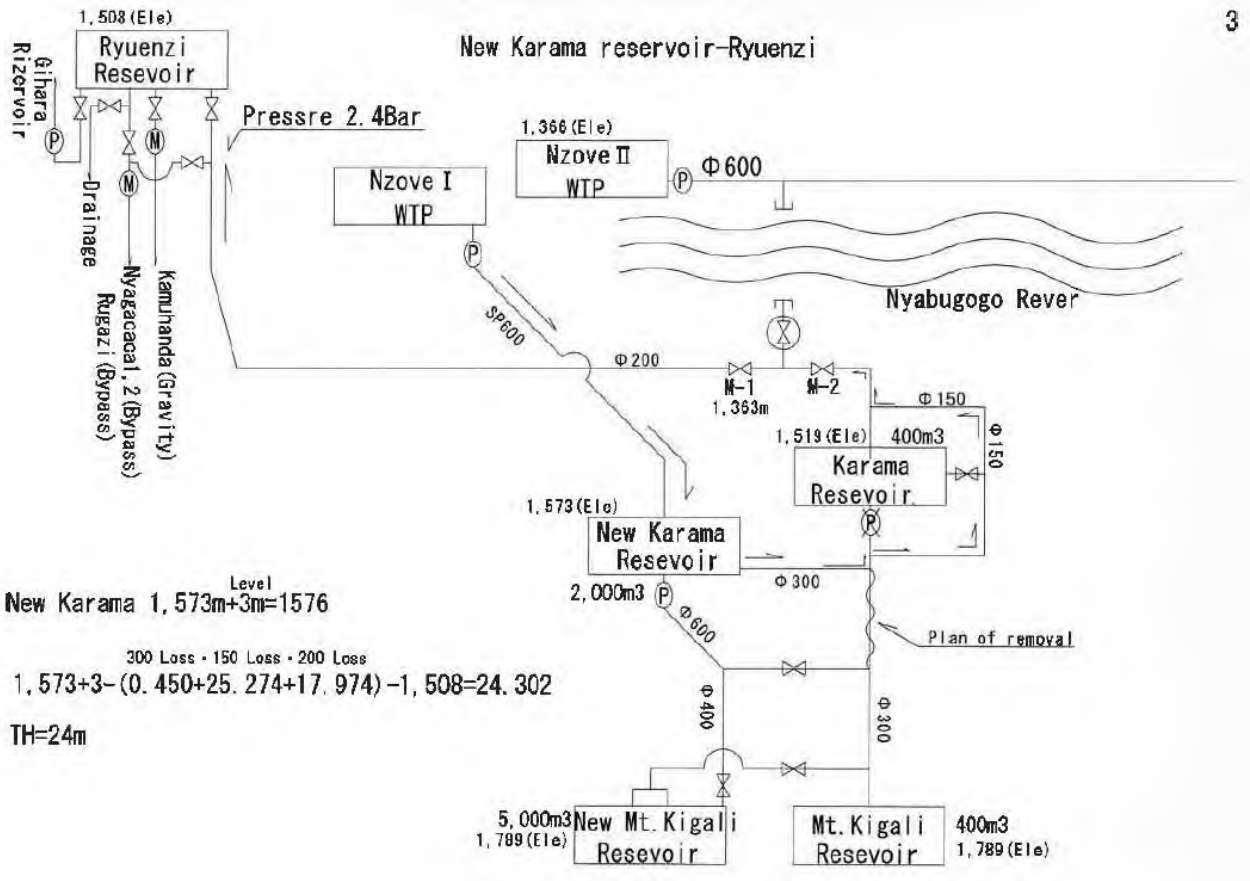
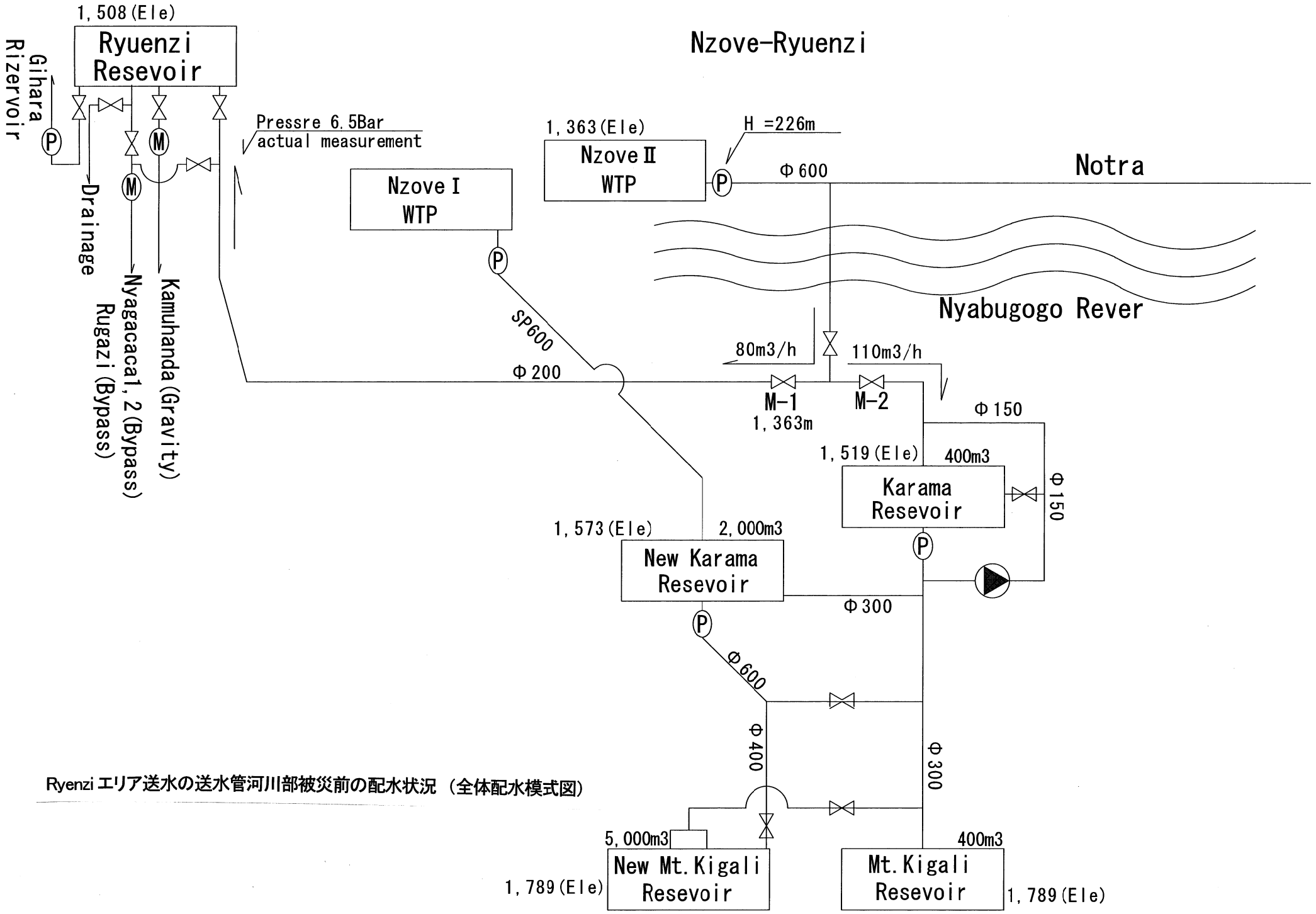
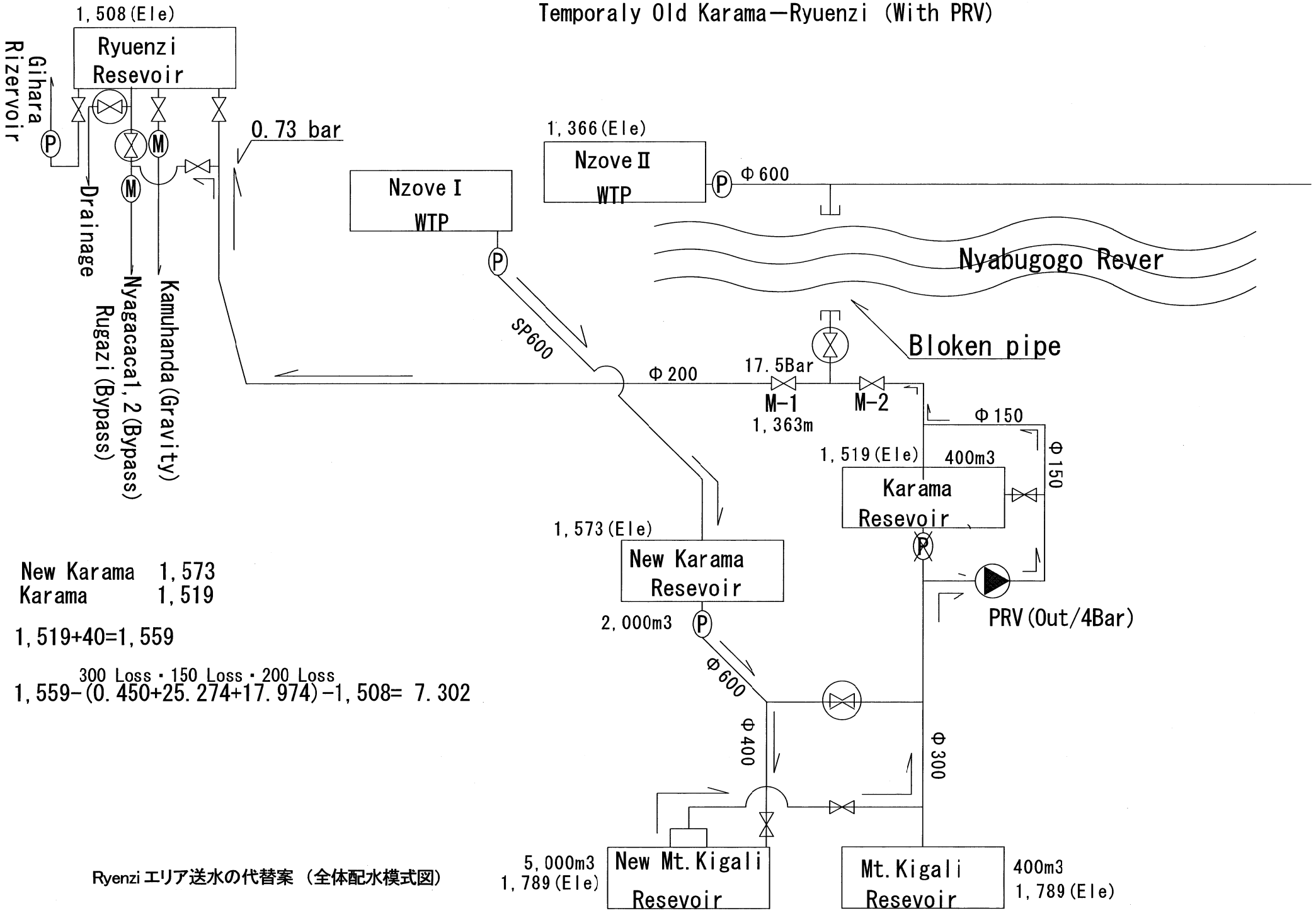


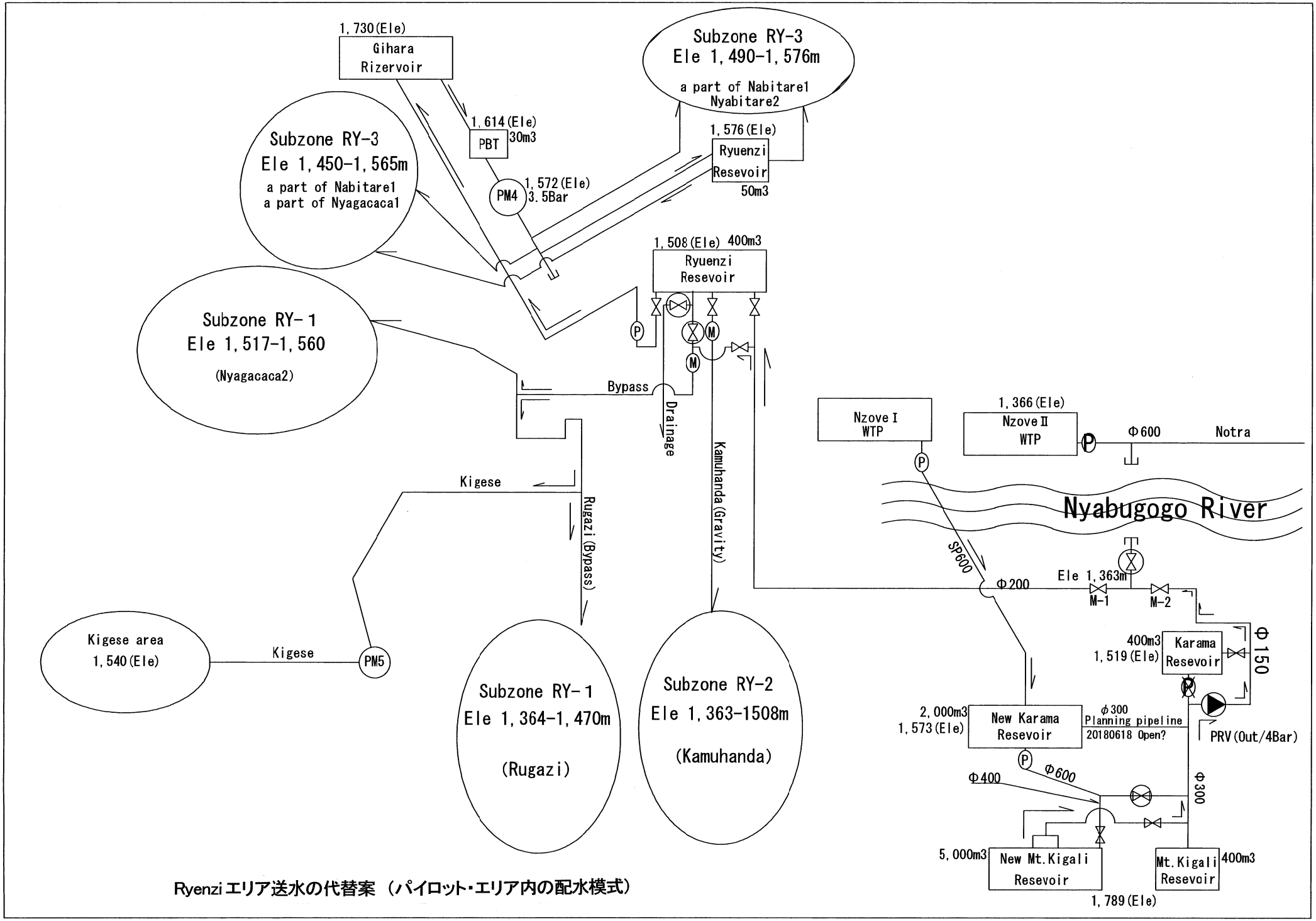
Figure 2. Planned water delivery network and water pressure at the inlet to RY1

This modification of the delivery network is expected to reduce the water distribution pressure at the inlet to RY1 from 6.5 bars to 2.4 bars. If this pressure reduction has been realized, it will be impossible to deliver water from the Ruyenzi Reservoir to Kigese, outside of Ruyenzi, and Kigese will need to have its own water source for water distribution.



Ryenzi エリア送水の送水管河川部被災前の配水状況 （全体配水模式図）


Temporaly Old Karama—Ryuenzi (With PRV)
1,508(Ele)
Ryuenzi Resevoir
Gihara Rizervoir
Drainage
Rugazi (Bypass)
Nyagacaca1,2 (Bypass)
Kamuhanda (Gravity)
0.73 bar
1,366(Ele)
Nzove Ⅱ WTP
Φ600
Nzove I WTP
SP600
Nyabugogo Rever
Bloken pipe
Φ200
17.5Bar
M-1
1,363m
M-2
Φ150
1,519(Ele)
400m3
Karama Resevoir
Φ150
1,573(Ele)
New Karama Resevoir
2,000m3
PRV(Out/4Bar)
Φ600
Φ400
Φ300
5,000m3
1,789(Ele)
New Mt.Kigali Resevoir
Mt.Kigali Resevoir
400m3
1,789(Ele)
New Karama 1,573
Karama 1,519
1,519+40=1,559
300 Loss・150 Loss・200 Loss
1,559-(0.450+25.274+17.974)-1,508= 7.302
Ryenzi エリア送水の代替案 （全体配水模式図）



Ryenzi エリア送水の代替案 （パイロット・エリア内の配水模式）

6. Cost-benefit

Cost Benefit Analysis
Ruyenzi Pilot Project

Without Project (WoP) **NRW rate 2% decrease per year**

	Year	Distribution		Billing		NRW		
	Month	Volume ①	Production Cost①	Volume	Billing Price	Volume	Rate	
		m3	RWF	m3	RWF		%	
			319		592			
	2018/3	54,812	17,485,028	19,486	11,535,712	35,326	64.4%	Baseline
	2018/4	63,327	20,201,313	17,540	10,383,680	45,787	72.3%	Baseline 68.4%
	2018/5	50,826	16,213,494	14,753	8,733,776	36,073	71.0%	
	2018/6	37,437	11,942,403	17,520	10,371,840	19,917	53.2%	
	2018/7	40,226	12,832,094	20,910	12,378,720	19,316	48.0%	
	2018/8	47,153	15,041,807	23,820	14,101,440	23,333	49.5%	
	2018/9	47,161	15,044,359	20,543	12,161,456	26,618	56.4%	
	2018/10	51,242	16,346,198	20,588	12,188,096	30,654	59.8%	
1	2018/11	48,539	15,483,941	16,427	9,724,784	32,112	66.2%	Starting Activities
2	2018/12	59,701	19,044,577	20,304	12,019,968	39,397	66.0%	
3	2019/1	68,091	21,721,093	23,271	13,776,432	44,820	65.8%	
4	2019/2	61,308	19,557,309	21,055	12,464,560	40,253	65.7%	
5	2019/3	52,432	16,725,761	18,094	10,711,648	34,338	65.5%	
6	2019/4	59,585	19,007,774	20,662	12,231,904	38,923	65.3%	
7	2019/5	56,603	18,056,247	19,722	11,675,424	36,881	65.2%	
8	2019/6	52,169	16,641,788	18,264	10,812,288	33,905	65.0%	
9	2019/7	69,700	22,234,457	24,518	14,514,656	45,182	64.8%	
10	2019/8	69,029	22,020,393	24,397	14,443,024	44,632	64.7%	
11	2019/9	63,563	20,276,652	22,571	13,362,032	40,992	64.5%	
12	2019/10	56,144	17,909,884	20,030	11,857,760	36,114	64.3%	147,594,480
1	2019/11	53,863	17,182,248	19,306	11,429,152	34,557	64.2%	
2	2019/12	53,852	17,178,907	19,392	11,480,064	34,460	64.0%	
3	2020/1	64,479	20,568,742	23,326	13,808,992	41,153	63.8%	

Note: NRW Baseline 68.4% 466,499

With Project (WP)

	Year/ Month	Distribution		Billing		NRW		Project Effect		
		Volume ②	Production Cost②	Volume	Billing Price	Volume	Rate	Volume ③	Reduction of Production Cost	Selling of Surplus Water
								①−②	Volume③x319	Volume③ x592
		m3	RWF	m3	RWF		%	m3	RWF	RWF
			319		592				319	592
	2018/3	54,812	17,485,028	19,486	11,535,712	35,326	64.4%	0	0	0
	2018/4	63,327	20,201,313	17,540	10,383,680	45,787	72.3%	0	0	0
	2018/5	50,826	16,213,494	14,753	8,733,776	36,073	71.0%	0	0	0
	2018/6	37,437	11,942,403	17,520	10,371,840	19,917	53.2%	0	0	0
	2018/7	40,226	12,832,094	20,910	12,378,720	19,316	48.0%	0	0	0
	2018/8	47,153	15,041,807	23,820	14,101,440	23,333	49.5%	0	0	0
	2018/9	47,161	15,044,359	20,543	12,161,456	26,618	56.4%	0	0	0
	2018/10	51,242	16,346,198	20,588	12,188,096	30,654	59.8%	0	0	0
1	2018/11	48,539	15,483,941	16,427	9,724,784	32,112	66.2%	0	0	0
2	2018/12	47,923	15,287,437	20,304	12,019,968	27,619	57.6%	11,778	3,757,140	6,972,498
3	2019/1	49,026	15,639,294	23,271	13,776,432	25,755	52.5%	19,065	6,081,799	11,286,598
4	2019/2	47,189	15,053,291	21,055	12,464,560	26,134	55.4%	14,119	4,504,018	8,358,554
5	2019/3	38,875	12,401,125	18,094	10,711,648	20,781	53.5%	13,557	4,324,636	8,025,658
6	2019/4	49,156	15,680,764	20,662	12,231,904	28,494	58.0%	10,429	3,327,010	6,174,263
7	2019/5	43,285	13,807,915	19,722	11,675,424	23,563	54.4%	13,318	4,248,332	7,884,051
8	2019/6	42,917	13,690,523	18,264	10,812,288	24,653	57.4%	9,252	2,951,265	5,476,955
9	2019/7	48,084	15,338,796	24,518	14,514,656	23,566	49.0%	21,616	6,895,661	12,796,963
10	2019/8	51,863	16,544,297	24,397	14,443,024	27,466	53.0%	17,166	5,476,096	10,162,535
11	2019/9	51,135	16,312,065	22,571	13,362,032	28,564	55.9%	12,428	3,964,587	7,357,478
12	2019/10	47,168	15,046,592	20,030	11,857,760	27,138	57.5%	8,976	2,863,292	5,313,695
1	2019/11	46,755	14,914,845	19,306	11,429,152	27,449	58.7%	7,108	2,267,403	4,207,844
2	2019/12	50,999	16,268,681	19,392	11,480,064	31,607	62.0%	2,853	910,226	1,689,196
3	2020/1	48,312	15,411,528	23,326	13,808,992	24,986	51.7%	16,167	5,157,214	9,570,755

Note：Cost 319 RWF: Monthly average production cost of Nzove Treatment Plant

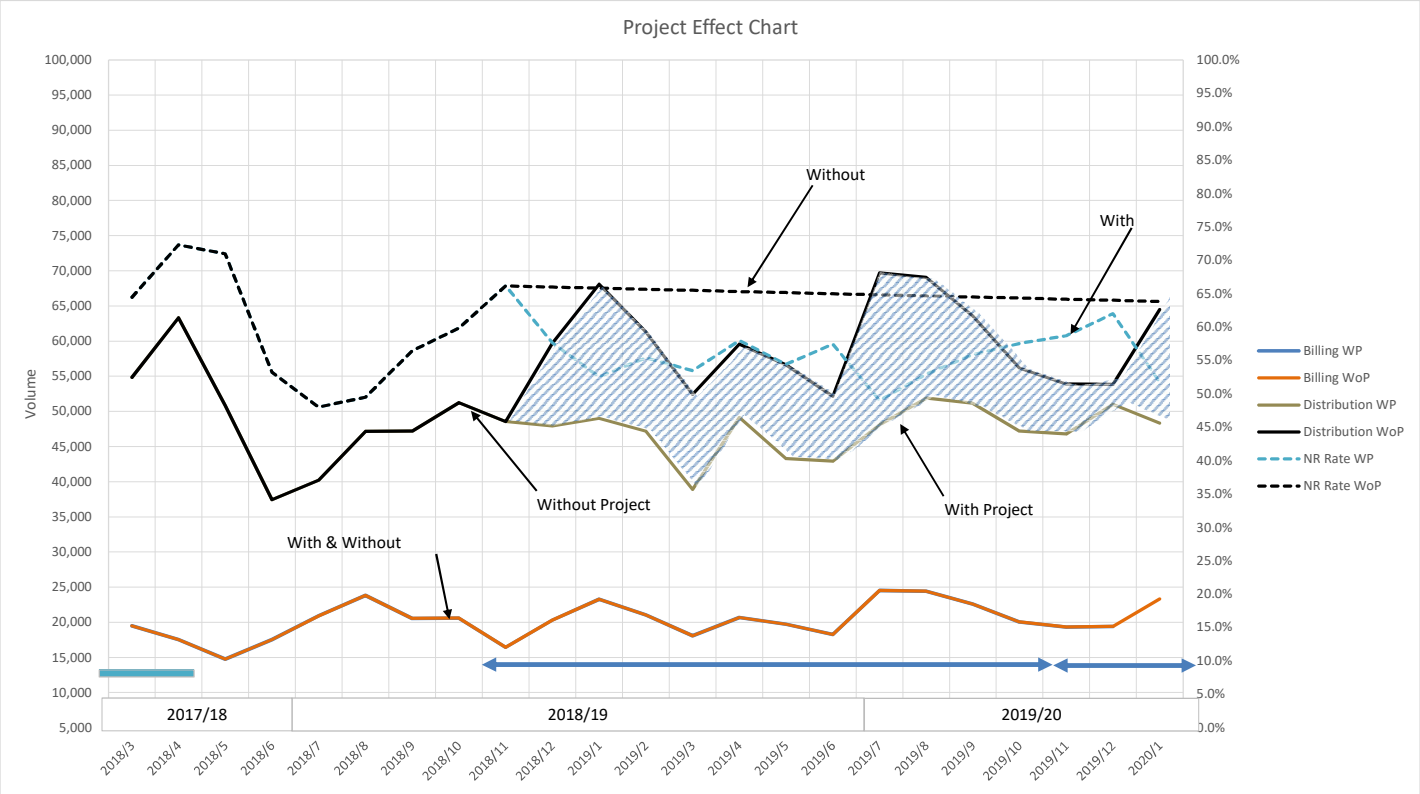
Price 592 RWF: Monthly average water billing of New Nyarugenge Branch

2018/11-19/10	**48,393,835**	**89,809,248**
2019/11-20/1	**8,334,843**	**15,467,796**

Water Volume (m3/month)

	Year/Month	Billing WP	Billing WoP	Distribution WP	Distribution WoP	NR Rate WP	NR Rate WoP
	2018/3	19,486	19,486	54,812	54,812	64.4%	64.4%
	2018/4	17,540	17,540	63,327	63,327	72.3%	72.3%
	2018/5	14,753	14,753	50,826	50,826	71.0%	71.0%
	2018/6	17,520	17,520	37,437	37,437	53.2%	53.2%
	2018/7	20,910	20,910	40,226	40,226	48.0%	48.0%
	2018/8	23,820	23,820	47,153	47,153	49.5%	49.5%
	2018/9	20,543	20,543	47,161	47,161	56.4%	56.4%
	2018/10	20,588	20,588	51,242	51,242	59.8%	59.8%
1	2018/11	16,427	16,427	48,539	48,539	66.2%	66.2%
2	2018/12	20,304	20,304	47,923	59,701	57.6%	66.0%
3	2019/1	23,271	23,271	49,026	68,091	52.5%	65.8%
4	2019/2	21,055	21,055	47,189	61,308	55.4%	65.7%
5	2019/3	18,094	18,094	38,875	52,432	53.5%	65.5%
6	2019/4	20,662	20,662	49,156	59,585	58.0%	65.3%
7	2019/5	19,722	19,722	43,285	56,603	54.4%	65.2%
8	2019/6	18,264	18,264	42,917	52,169	57.4%	65.0%
9	2019/7	24,518	24,518	48,084	69,700	49.0%	64.8%
10	2019/8	24,397	24,397	51,863	69,029	53.0%	64.7%
11	2019/9	22,571	22,571	51,135	63,563	55.9%	64.5%
12	2019/10	20,030	20,030	47,168	56,144	57.5%	64.3%
1	2019/11	19,306	19,306	46,755	53,863	58.7%	64.2%
2	2019/12	19,392	19,392	50,999	53,852	62.0%	64.0%
3	2020/1	23,326	23,326	48,312	64,479	51.7%	63.8%

Note, WP: With Project, WoP: Without Project



Because the PRV Setting that is a substantial activity of a NRW reduction was started from November, 2018,
NRW will be compared after November between "with Project" and "without Project".

Project Effect of Ruyenzi

A: Selling of Surplus Water

Case 1

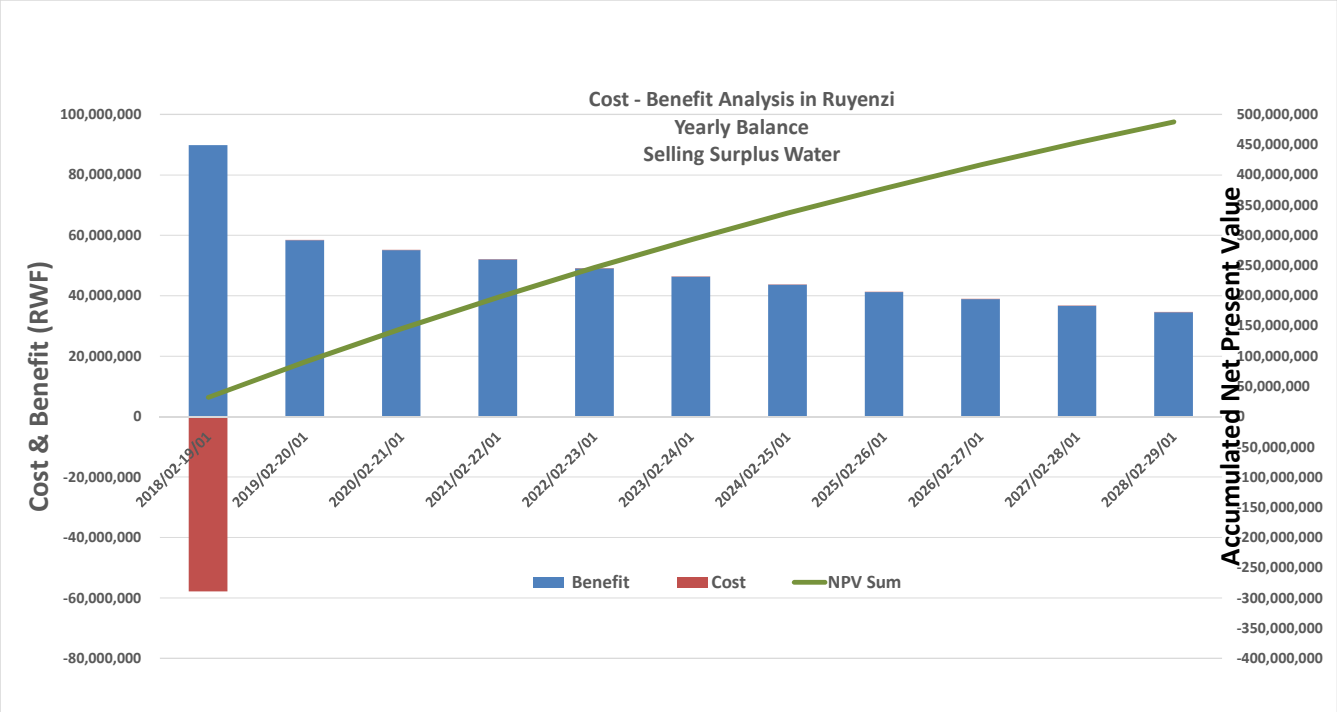
Full Cost (DMA Formation, Meter Replacement, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

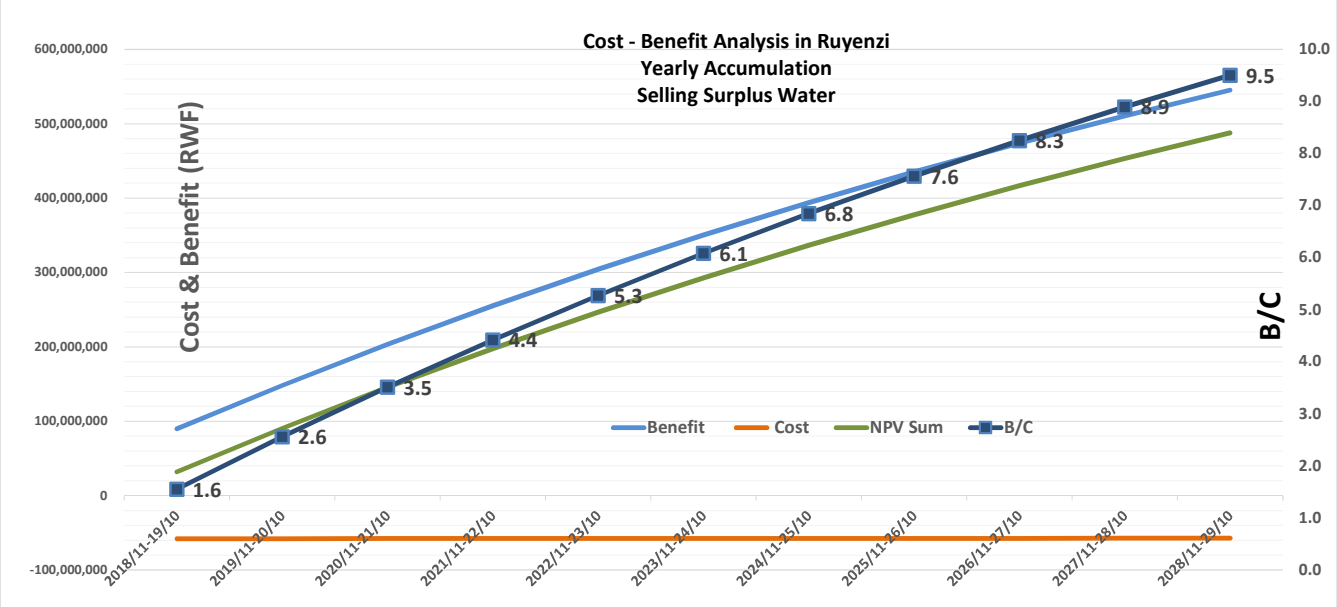
	Year	Benefit			Cost			NPV (Benefit-Cost)	Effect of the Project (Accumulation)				Discount Rate %	6.0
		WP	WoP	WP	WP	WoP	Balance		Benefit	Cost	NPV Sum	B/C	Conversion Factor	1/(1+i)^n
1	2018/11-19/10	89,809,248	0	89,809,248	65,864,450	7,937,280	-57,927,170	31,882,078	89,809,248	-57,927,170	31,882,078	1.6	0	1.000
2	2019/11-20/10	58,369,041	0	58,369,041	7,416,453	7,488,000	71,547	58,440,588	148,178,289	-57,855,623	90,322,666	2.6	1	0.943
3	2020/11-21/10	55,065,133	0	55,065,133	6,996,654	7,064,151	67,497	55,132,630	203,243,421	-57,788,126	145,455,296	3.5	2	0.890
4	2021/11-22/10	51,948,238	0	51,948,238	6,600,617	6,664,293	63,677	52,011,915	255,191,660	-57,724,449	197,467,211	4.4	3	0.840
5	2022/11-23/10	49,007,772	0	49,007,772	6,226,997	6,287,069	60,072	49,067,845	304,199,432	-57,664,376	246,535,056	5.3	4	0.792
6	2023/11-24/10	46,233,747	0	46,233,747	5,874,525	5,931,197	56,672	46,290,419	350,433,179	-57,607,704	292,825,475	6.1	5	0.747
7	2024/11-25/10	43,616,743	0	43,616,743	5,542,005	5,595,469	53,464	43,670,207	394,049,922	-57,554,240	336,495,682	6.8	6	0.705
8	2025/11-26/10	41,147,871	0	41,147,871	5,228,307	5,278,745	50,438	41,198,308	435,197,793	-57,503,802	377,693,990	7.6	7	0.665
9	2026/11-27/10	38,818,746	0	38,818,746	4,932,365	4,979,948	47,583	38,866,329	474,016,538	-57,456,219	416,560,319	8.3	8	0.627
10	2027/11-28/10	36,621,458	0	36,621,458	4,653,174	4,698,064	44,890	36,666,348	510,637,997	-57,411,330	453,226,667	8.9	9	0.592
11	2028/11-29/10	34,548,546	0	34,548,546	4,389,787	4,432,136	42,349	34,590,894	545,186,542	-57,368,981	487,817,561	9.5	10	0.558
								0.30	NPV/Billing					

NRW Reduction Activity Cost

Repair 25,440 RWF/Place

WP: Repair 23 places/year x 25,440=		7,021,440
Qmnf, Step Test 4 times/year x 210,000=		840,000
	Total	7,861,440
WoP: Repair 26x12 places/year x 25,440 =		7,937,280





Project Effect of Ruyenzi

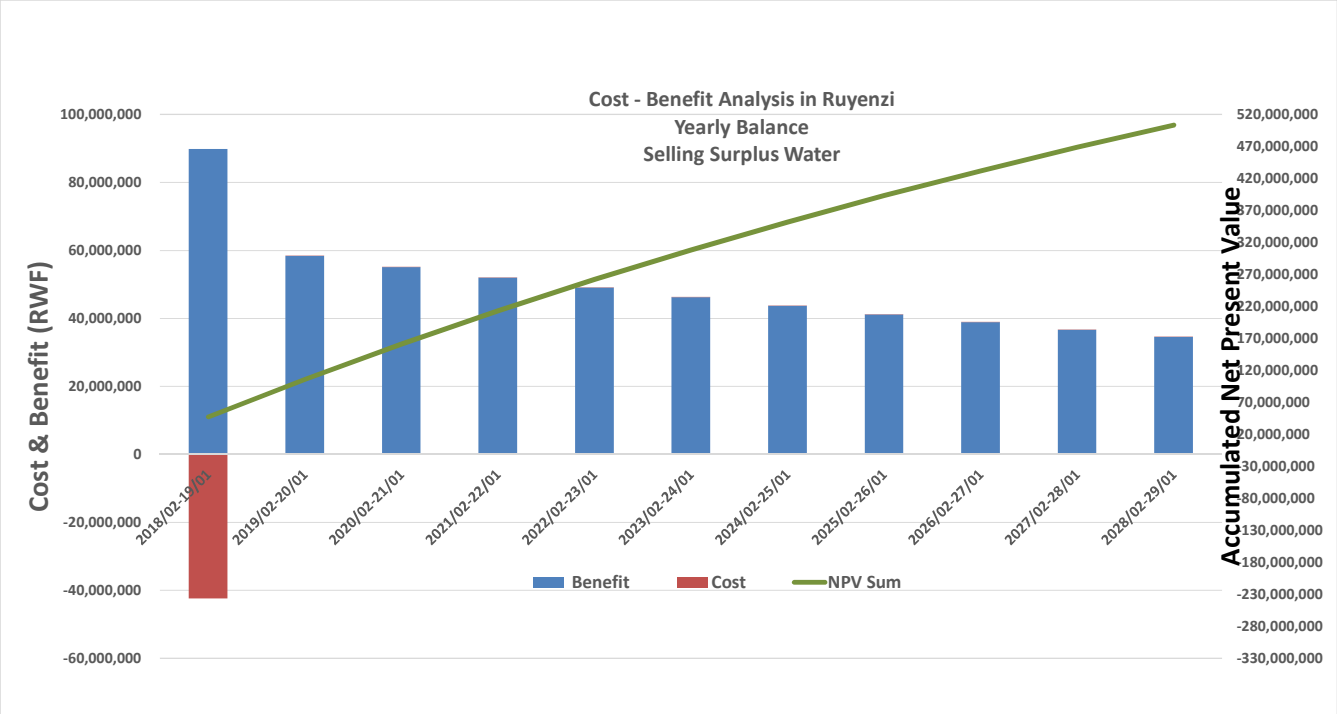
A: Selling of Surplus Water

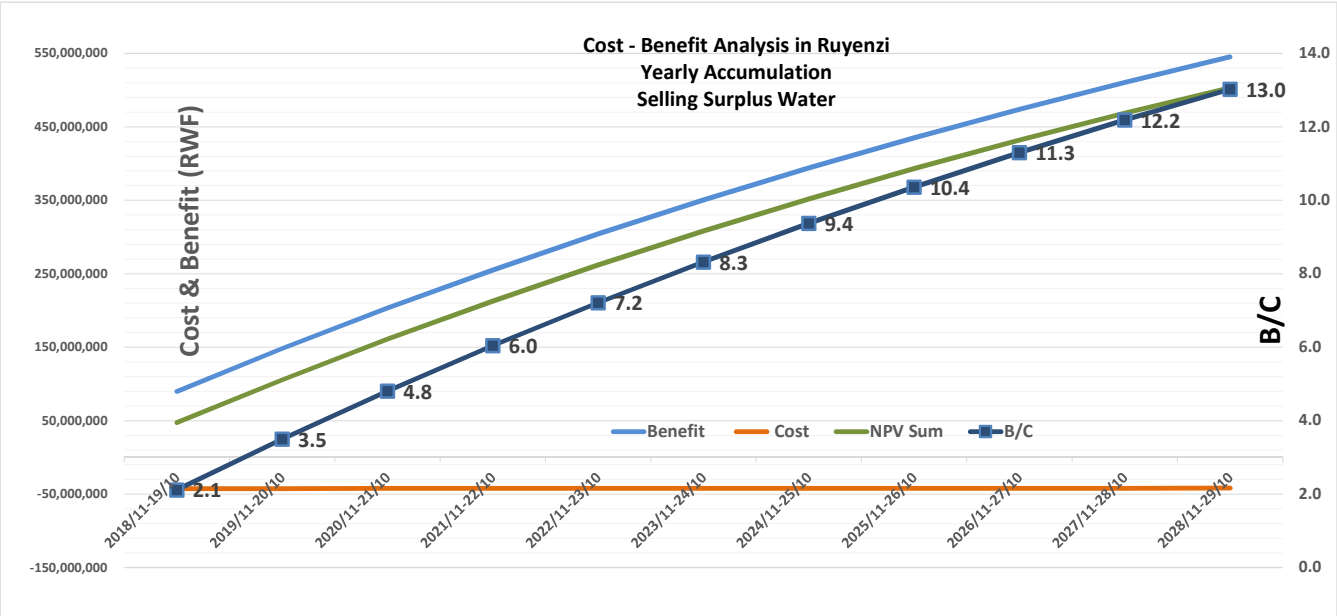
Case 2

Full Cost (DMA Formation, Meter Replacement, 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	2018/11-19/10	89,809,248	0	89,809,248	50,356,400	7,937,280	-42,419,120	47,390,128	89,809,248	-42,419,120	47,390,128	2.1	0	1.000
2	2019/11-20/10	58,369,041	0	58,369,041	7,416,453	7,488,000	71,547	58,440,588	148,178,289	-42,347,573	105,830,716	3.5	1	0.943
3	2020/11-21/10	55,065,133	0	55,065,133	6,996,654	7,064,151	67,497	55,132,630	203,243,421	-42,280,076	160,963,346	4.8	2	0.890
4	2021/11-22/10	51,948,238	0	51,948,238	6,600,617	6,664,293	63,677	52,011,915	255,191,660	-42,216,399	212,975,261	6.0	3	0.840
5	2022/11-23/10	49,007,772	0	49,007,772	6,226,997	6,287,069	60,072	49,067,845	304,199,432	-42,156,326	262,043,106	7.2	4	0.792
6	2023/11-24/10	46,233,747	0	46,233,747	5,874,525	5,931,197	56,672	46,290,419	350,433,179	-42,099,654	308,333,525	8.3	5	0.747
7	2024/11-25/10	43,616,743	0	43,616,743	5,542,005	5,595,469	53,464	43,670,207	394,049,922	-42,046,190	352,003,732	9.4	6	0.705
8	2025/11-26/10	41,147,871	0	41,147,871	5,228,307	5,278,745	50,438	41,198,308	435,197,793	-41,995,752	393,202,040	10.4	7	0.665
9	2026/11-27/10	38,818,746	0	38,818,746	4,932,365	4,979,948	47,583	38,866,329	474,016,538	-41,948,169	432,068,369	11.3	8	0.627
10	2027/11-28/10	36,621,458	0	36,621,458	4,653,174	4,698,064	44,890	36,666,348	510,637,997	-41,903,280	468,734,717	12.2	9	0.592
11	2028/11-29/10	34,548,546	0	34,548,546	4,389,787	4,432,136	42,349	34,590,894	545,186,542	-41,860,931	503,325,611	13.0	10	0.558
								0.31	NPV/Billing					

NRW Reduction Activity Cost
Repair 25,440 RWF/Place
WP: Repair 23 places/year x 25,440= 7,021,440
Qmnf, Step Test 4 times/year x 210,000= 840,000
Total 7,861,440
WoP: Repair 26x12 places/year x 25,440 = 7,937,280





Project Effect of Ruyenzi

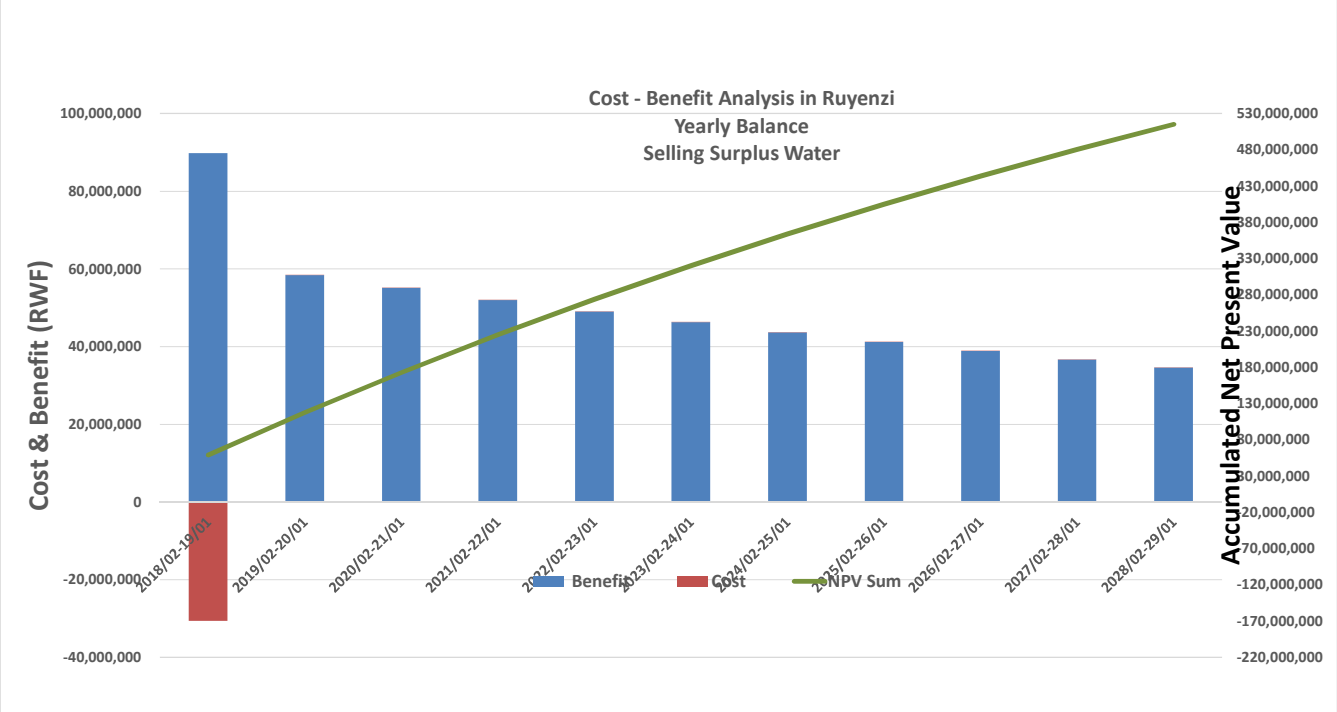
A: Selling of Surplus Water

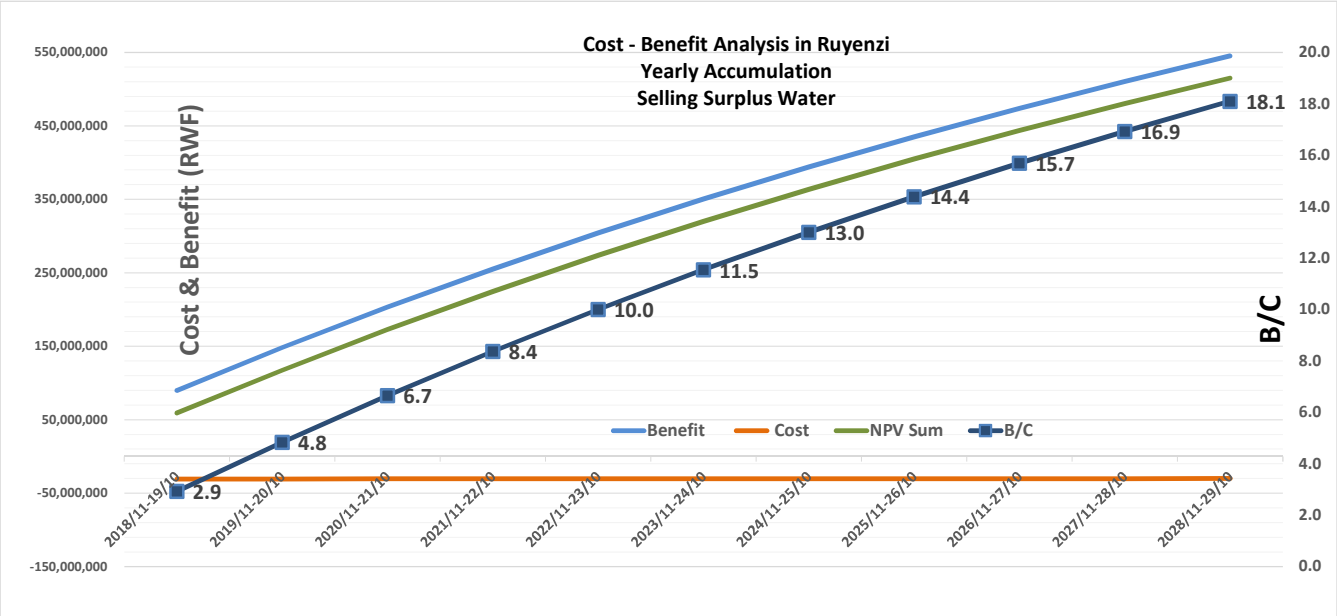
Case 3

Full Cost (DMA Formation, Meter Replacement, 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	2018/11-19/10	89,809,248	0	89,809,248	38,609,400	7,937,280	-30,672,120	59,137,128	89,809,248	-30,672,120	59,137,128	2.9	0	1.000
2	2019/11-20/10	58,369,041	0	58,369,041	7,416,453	7,488,000	71,547	58,440,588	148,178,289	-30,600,573	117,577,716	4.8	1	0.943
3	2020/11-21/10	55,065,133	0	55,065,133	6,996,654	7,064,151	67,497	55,132,630	203,243,421	-30,533,076	172,710,346	6.7	2	0.890
4	2021/11-22/10	51,948,238	0	51,948,238	6,600,617	6,664,293	63,677	52,011,915	255,191,660	-30,469,399	224,722,261	8.4	3	0.840
5	2022/11-23/10	49,007,772	0	49,007,772	6,226,997	6,287,069	60,072	49,067,845	304,199,432	-30,409,326	273,790,106	10.0	4	0.792
6	2023/11-24/10	46,233,747	0	46,233,747	5,874,525	5,931,197	56,672	46,290,419	350,433,179	-30,352,654	320,080,525	11.5	5	0.747
7	2024/11-25/10	43,616,743	0	43,616,743	5,542,005	5,595,469	53,464	43,670,207	394,049,922	-30,299,190	363,750,732	13.0	6	0.705
8	2025/11-26/10	41,147,871	0	41,147,871	5,228,307	5,278,745	50,438	41,198,308	435,197,793	-30,248,752	404,949,040	14.4	7	0.665
9	2026/11-27/10	38,818,746	0	38,818,746	4,932,365	4,979,948	47,583	38,866,329	474,016,538	-30,201,169	443,815,369	15.7	8	0.627
10	2027/11-28/10	36,621,458	0	36,621,458	4,653,174	4,698,064	44,890	36,666,348	510,637,997	-30,156,280	480,481,717	16.9	9	0.592
11	2028/11-29/10	34,548,546	0	34,548,546	4,389,787	4,432,136	42,349	34,590,894	545,186,542	-30,113,931	515,072,611	18.1	10	0.558
								0.32	NPV/Billing					

NRW Reduction Activity Cost
Repair 25,440 RWF/Place
WP: Repair 23 places/year x 25,440= 7,021,440
Qmnf, Step Test 4 times/year x 210,000= 840,000
Total 7,861,440
WoP: Repair 26x12 places/year x 25,440 = 7,937,280





Project Effect of Ruyenzi

B: Reduction of Production Cost

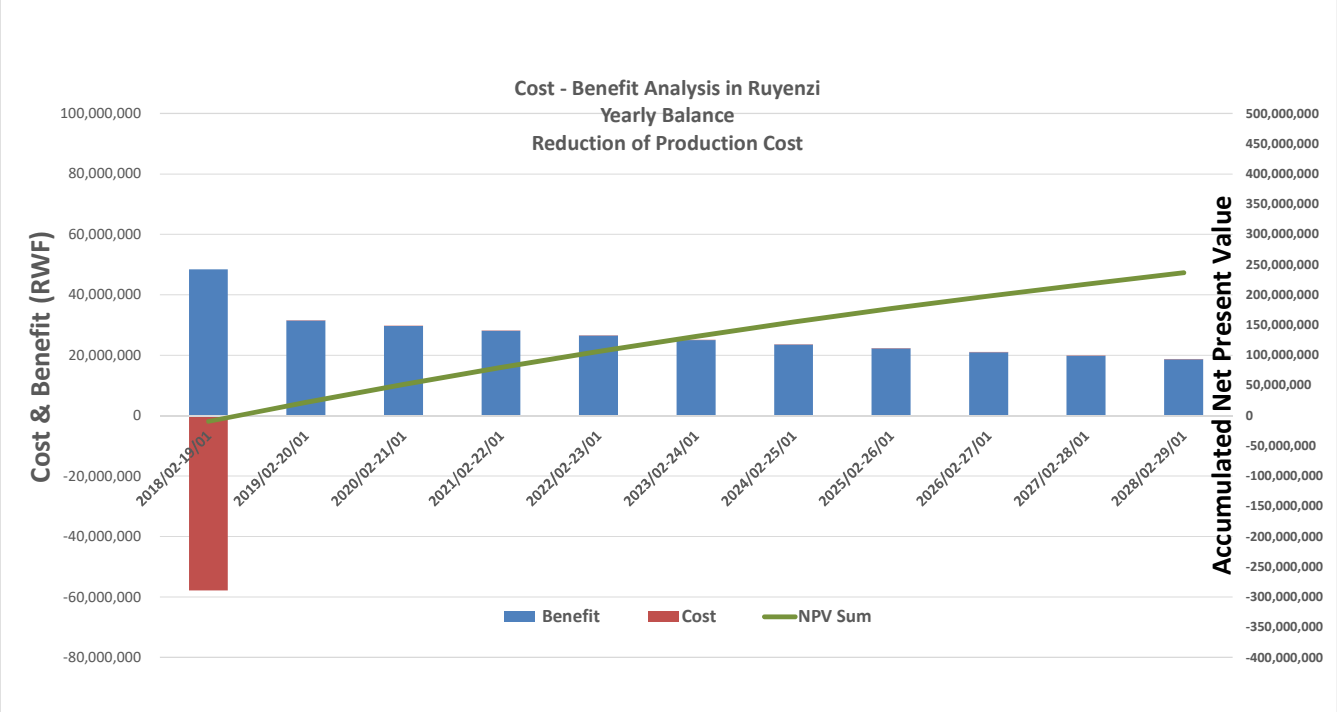
Case 1

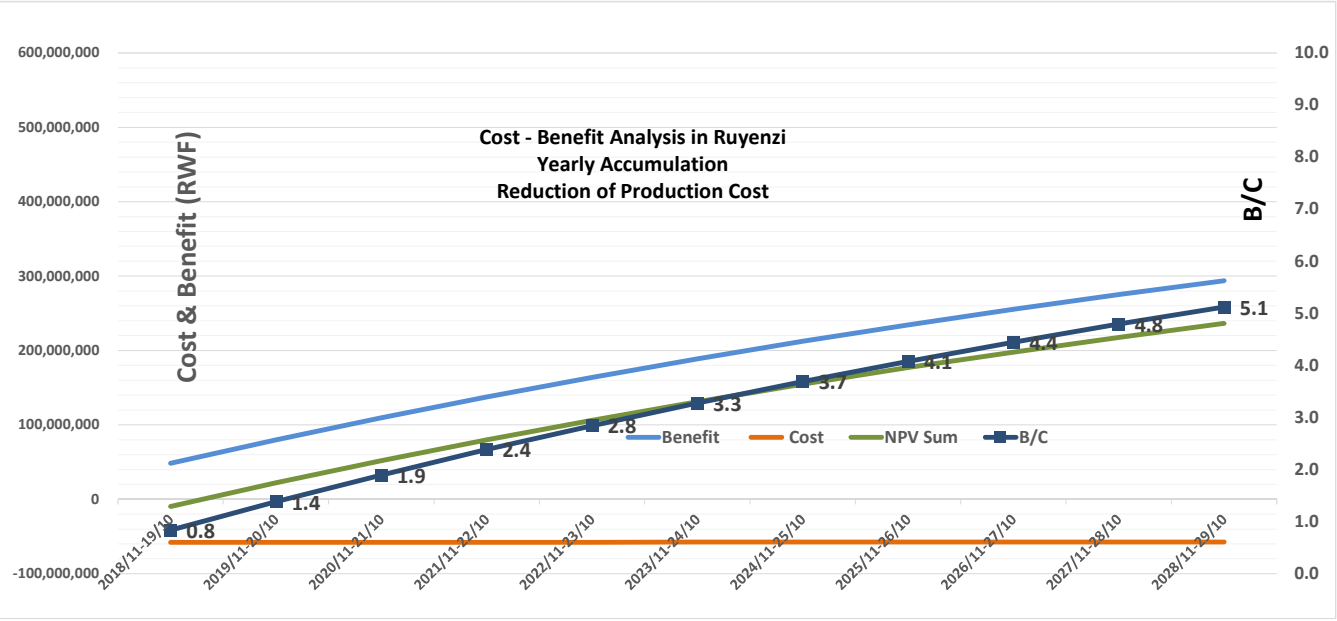
Full Cost (DMA Formation, Meter Replacement, PRV installation, Pipe replacement, Leakage repair) Unit:RWF

	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	2018/11-19/10	48,393,835	0	48,393,835	65,864,450	7,937,280	-57,927,170	-9,533,335	48,393,835	-57,927,170	-9,533,335	0.8	0	1.000
2	2019/11-20/10	31,452,236	0	31,452,236	7,416,453	7,488,000	71,547	31,523,784	79,846,071	-57,855,623	21,990,448	1.4	1	0.943
3	2020/11-21/10	29,671,921	0	29,671,921	6,996,654	7,064,151	67,497	29,739,419	109,517,992	-57,788,126	51,729,867	1.9	2	0.890
4	2021/11-22/10	27,992,379	0	27,992,379	6,600,617	6,664,293	63,677	28,056,055	137,510,371	-57,724,449	79,785,922	2.4	3	0.840
5	2022/11-23/10	26,407,904	0	26,407,904	6,226,997	6,287,069	60,072	26,467,977	163,918,275	-57,664,376	106,253,899	2.8	4	0.792
6	2023/11-24/10	24,913,117	0	24,913,117	5,874,525	5,931,197	56,672	24,969,789	188,831,392	-57,607,704	131,223,688	3.3	5	0.747
7	2024/11-25/10	23,502,941	0	23,502,941	5,542,005	5,595,469	53,464	23,556,405	212,334,333	-57,554,240	154,780,093	3.7	6	0.705
8	2025/11-26/10	22,172,586	0	22,172,586	5,228,307	5,278,745	50,438	22,223,024	234,506,919	-57,503,802	177,003,116	4.1	7	0.665
9	2026/11-27/10	20,917,534	0	20,917,534	4,932,365	4,979,948	47,583	20,965,117	255,424,452	-57,456,219	197,968,233	4.4	8	0.627
10	2027/11-28/10	19,733,522	0	19,733,522	4,653,174	4,698,064	44,890	19,778,412	275,157,975	-57,411,330	217,746,645	4.8	9	0.592
11	2028/11-29/10	18,616,530	0	18,616,530	4,389,787	4,432,136	42,349	18,658,879	293,774,505	-57,368,981	236,405,524	5.1	10	0.558

0.15 NPV/Billing

NRW Reduction Activity Cost
Repair 25,440 RWF/Place
WP: Repair 23 places/year x 25,440= 7,021,440
Qmnf, Step Test 4 times/year x 210,000= 840,000
Total 7,861,440
WoP: Repair 26x12 places/year x 25,440 = 7,937,280





Project Effect of Ruyenzi

B: Reduction of Production Cost

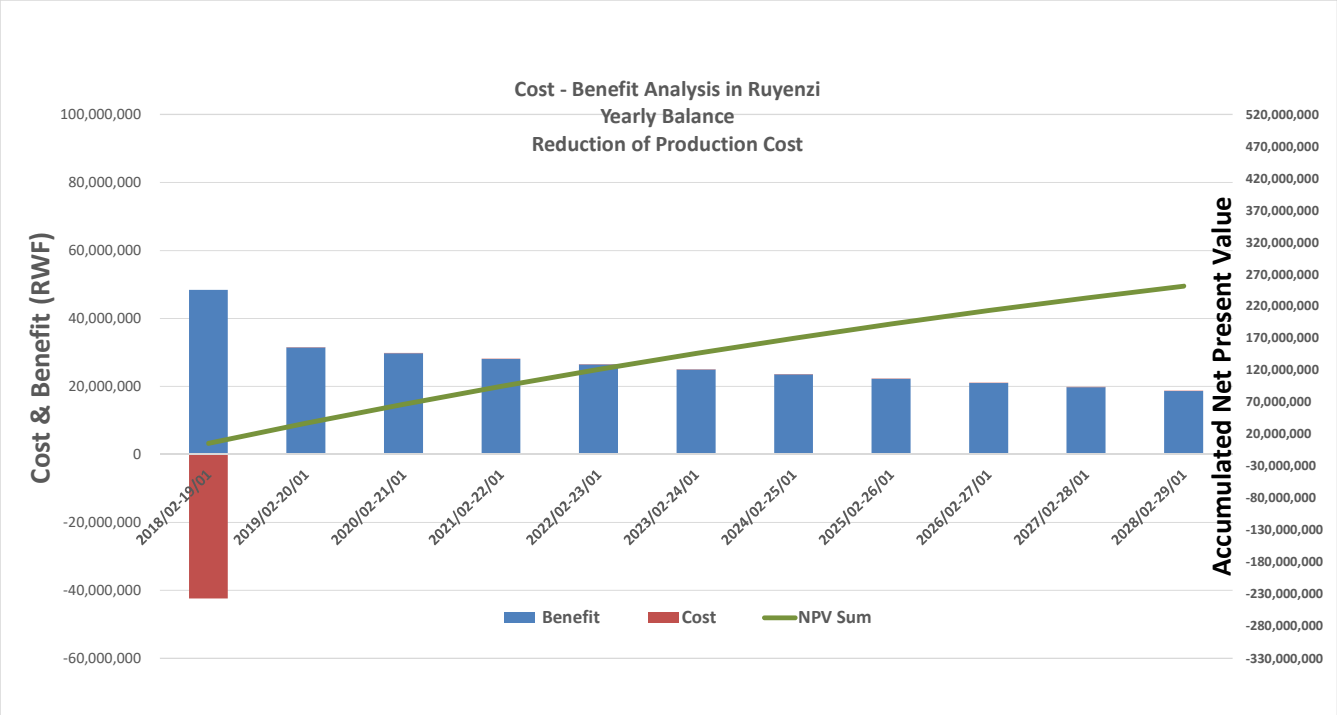
Case 2

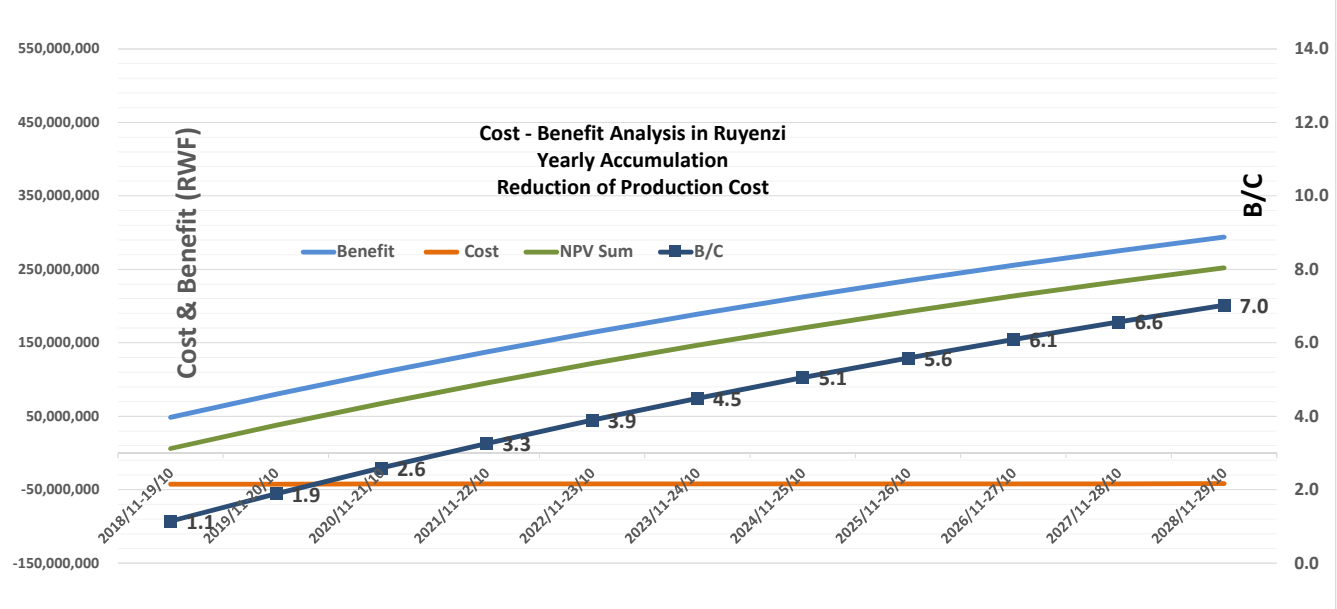
Full Cost (DMA Formation, Meter Replacement, PRV installation, Pipe replacement, Leakage repair)

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	2018/11-19/10	48,393,835	0	48,393,835	50,356,400	7,937,280	-42,419,120	5,974,715	48,393,835	-42,419,120	5,974,715	1.1	0	1.000
2	2019/11-20/10	31,452,236	0	31,452,236	7,416,453	7,488,000	71,547	31,523,784	79,846,071	-42,347,573	37,498,498	1.9	1	0.943
3	2020/11-21/10	29,671,921	0	29,671,921	6,996,654	7,064,151	67,497	29,739,419	109,517,992	-42,280,076	67,237,917	2.6	2	0.890
4	2021/11-22/10	27,992,379	0	27,992,379	6,600,617	6,664,293	63,677	28,056,055	137,510,371	-42,216,399	95,293,972	3.3	3	0.840
5	2022/11-23/10	26,407,904	0	26,407,904	6,226,997	6,287,069	60,072	26,467,977	163,918,275	-42,156,326	121,761,949	3.9	4	0.792
6	2023/11-24/10	24,913,117	0	24,913,117	5,874,525	5,931,197	56,672	24,969,789	188,831,392	-42,099,654	146,731,738	4.5	5	0.747
7	2024/11-25/10	23,502,941	0	23,502,941	5,542,005	5,595,469	53,464	23,556,405	212,334,333	-42,046,190	170,288,143	5.1	6	0.705
8	2025/11-26/10	22,172,586	0	22,172,586	5,228,307	5,278,745	50,438	22,223,024	234,506,919	-41,995,752	192,511,166	5.6	7	0.665
9	2026/11-27/10	20,917,534	0	20,917,534	4,932,365	4,979,948	47,583	20,965,117	255,424,452	-41,948,169	213,476,283	6.1	8	0.627
10	2027/11-28/10	19,733,522	0	19,733,522	4,653,174	4,698,064	44,890	19,778,412	275,157,975	-41,903,280	233,254,695	6.6	9	0.592
11	2028/11-29/10	18,616,530	0	18,616,530	4,389,787	4,432,136	42,349	18,658,879	293,774,505	-41,860,931	251,913,574	7.0	10	0.558
								0.16	NPV/Billing					

NRW Reduction Activity Cost
Repair 25,440 RWF/Place
WP: Repair 23 places/year x 25,440= 7,021,440
Qmnf, Step Test 4 times/year x 210,000= 840,000
Total 7,861,440
WoP: Repair 26x12 places/year x 25,440 = 7,937,280





Project Effect of Ruyenzi

B: Reduction of Production Cost

Case 3

Full Cost (DMA Formation, Meter Replacement, 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	2018/11-19/10	48,393,835	0	48,393,835	38,609,400	7,937,280	-30,672,120	17,721,715	48,393,835	-30,672,120	17,721,715	1.6	0	1.000
2	2019/11-20/10	31,452,236	0	31,452,236	7,416,453	7,488,000	71,547	31,523,784	79,846,071	-30,600,573	49,245,498	2.6	1	0.943
3	2020/11-21/10	29,671,921	0	29,671,921	6,996,654	7,064,151	67,497	29,739,419	109,517,992	-30,533,076	78,984,917	3.6	2	0.890
4	2021/11-22/10	27,992,379	0	27,992,379	6,600,617	6,664,293	63,677	28,056,055	137,510,371	-30,469,399	107,040,972	4.5	3	0.840
5	2022/11-23/10	26,407,904	0	26,407,904	6,226,997	6,287,069	60,072	26,467,977	163,918,275	-30,409,326	133,508,949	5.4	4	0.792
6	2023/11-24/10	24,913,117	0	24,913,117	5,874,525	5,931,197	56,672	24,969,789	188,831,392	-30,352,654	158,478,738	6.2	5	0.747
7	2024/11-25/10	23,502,941	0	23,502,941	5,542,005	5,595,469	53,464	23,556,405	212,334,333	-30,299,190	182,035,143	7.0	6	0.705
8	2025/11-26/10	22,172,586	0	22,172,586	5,228,307	5,278,745	50,438	22,223,024	234,506,919	-30,248,752	204,258,166	7.8	7	0.665
9	2026/11-27/10	20,917,534	0	20,917,534	4,932,365	4,979,948	47,583	20,965,117	255,424,452	-30,201,169	225,223,283	8.5	8	0.627
10	2027/11-28/10	19,733,522	0	19,733,522	4,653,174	4,698,064	44,890	19,778,412	275,157,975	-30,156,280	245,001,695	9.1	9	0.592
11	2028/11-29/10	18,616,530	0	18,616,530	4,389,787	4,432,136	42,349	18,658,879	293,774,505	-30,113,931	263,660,574	9.8	10	0.558
								0.16	NPV/Billing					

NRW Reduction Activity Cost
Repair 25,440 RWF/Place
WP: Repair 23 places/year x 25,440= 7,021,440
Qmnf, Step Test 4 times/year x 210,000= 840,000
Total 7,861,440
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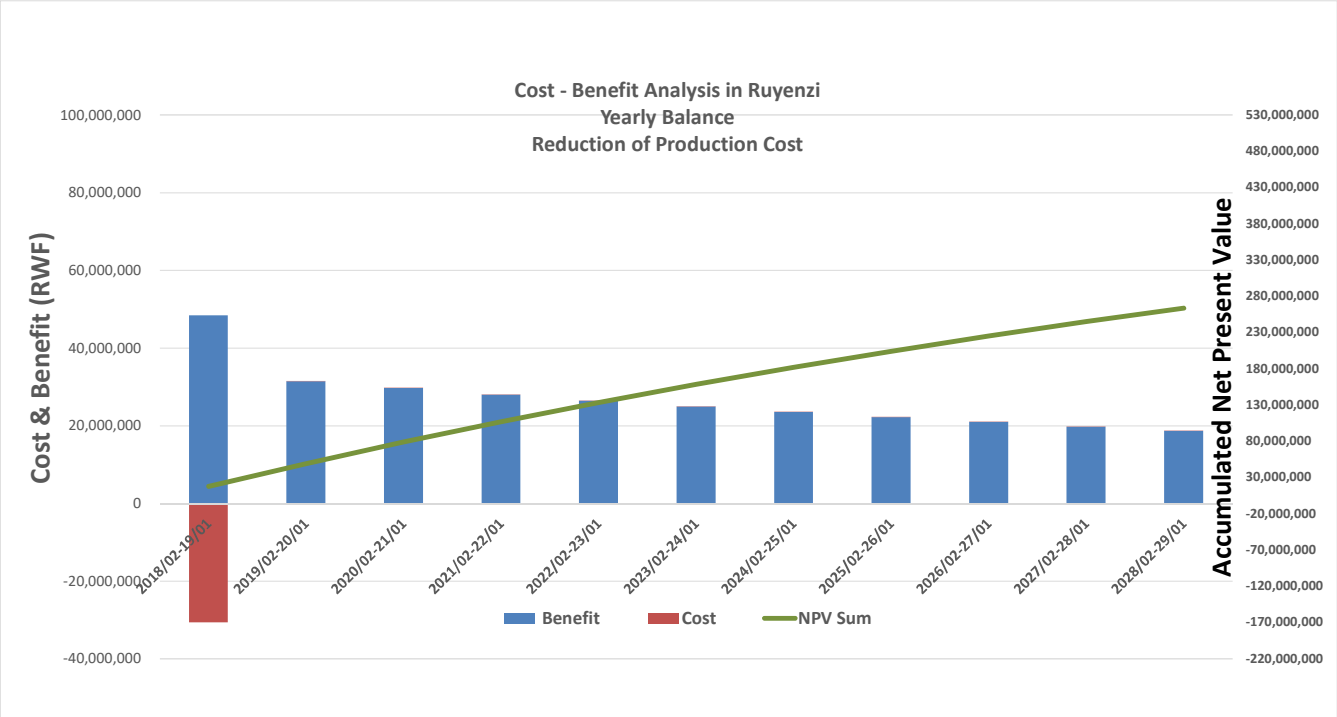

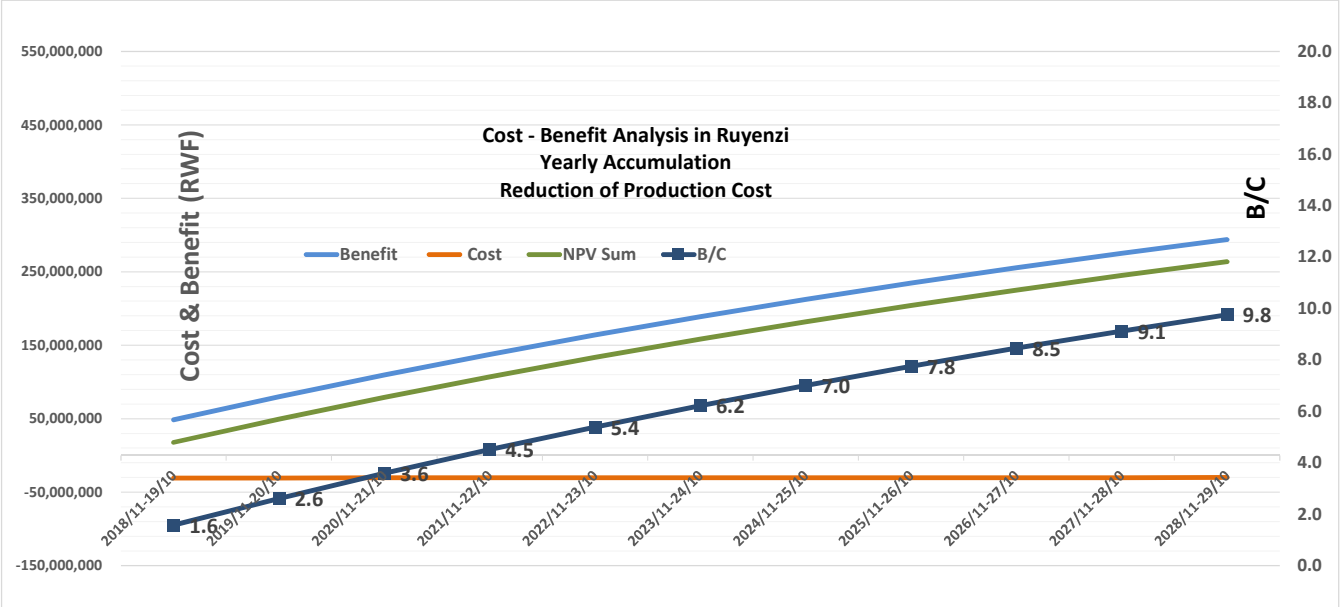

Cost of NRW Reduction Activity for Ruyenzi Pilot Area Case 1

RWF

		WASAC activity				Project Activity				WASAC COST			TOTAL WASAC	PROJECT COST			TOTAL JICA	TOTAL COST	
		Emergency Action				Premeditated Action													
		Accident, Request of Customer				Planning based on the analysis of monitoring													
Activity	Day	Qty RY1	Qty RY2	Qty RY3	Qty Total	Qty RY1	Qty RY2	Qty RY3	Qty Total	RY1	RY2	RY3		RY1	RY2	RY3			
1. Preparation Work																			
1.1 DMA Creation																			
Preparation of the map (GIS, Google map)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pipe network map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
POC list and location map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Design of DMA and Sub-zone		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pressure survey for Isolation		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pipe replacement (Area adjustment)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Finalization of zone area		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Finalization of POC list in DMA and Update of the list (New Connection)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Survey of the existing facilities in DMA (Valve, PRV, Pipe, etc.)													0	10,000	10,000	10,000	30,000	**30,000**	
Isolation valve installation								1					0		1,500,000		1,500,000	**1,500,000**	DN150x6
Valve installation for step test								1					0		1,140,000		1,140,000	**1,140,000**	DN100x6
1.2 Installation of Inlet and Outlet Facility																			
Inlet Facility (Chamber, Equipment)		-	-	-	-			1	1				0			8,837,000	8,837,000	**8,837,000**	PM4
Outlet Facility													0				0	**0**	
Total													0				11,747,000	**11,747,000**	
2. Activity for Commercial Loss reduction																			
2.1 Customer data analysis (Billing)																			
Analysis the Data inside the pilot area													0						
2.2 Customer Meter Survey/ POC Survey																			
Survey by visit all customers	3,250								1705				0				5,541,250	**5,541,250**	
2.3 Customer Questionnaire Survey																			
Questionnaire	3,250								222				0				721,500	**721,500**	
													0						
2.4 On-site Meter Test																			
Site Test	6,500								413				0				2,684,500	**2,684,500**	Table
2.5 Meter Replacement																			
Meter replacement	47,200								139				0				6,560,800	**6,560,800**	Service Charter
2.6 Inspection of illegal connection/use																			
Inspection work on site visit													0				800,000	**800,000**	
Total													0				16,308,050	**16,308,050**	
3. Activity for Physical Loss reduction		**RY1**	**RY2**	**RY3**	**Total**	**RY1**	**RY2**	**RY3**	**Total**										
3.1 Leakage Survey and Repair																			
1) Analysis of Leakage repair record													0		570,000		570,000	**570,000**	
2) Qmnf measurement & Step Test		-	-	-	-		12		12				0		2,520,000		2,520,000	**2,520,000**	
4) Leakage Repair (Include Preliminary work before repairing)																			25440
	2018/3	33	1	6	40	-	-	-	0	839,520	25,440	152,640	1,017,600	0	0	0	0	**1,017,600**	
	2018/4	37	3	2	42	-	-	-	0	941,280	76,320	50,880	1,068,480	0	0	0	0	**1,068,480**	
	2018/5	13	2	0	15	-	-	-	0	330,720	50,880	0	381,600	0	0	0	0	**381,600**	
	2018/6	16	2	3	21	-	-	-	0	407,040	50,880	76,320	534,240	0	0	0	0	**534,240**	
	2018/7	17	4	1	22	-	-	-	0	432,480	101,760	25,440	559,680	0	0	0	0	**559,680**	
	2018/8	16	3	1	20	-	-	-	0	407,040	76,320	25,440	508,800	0	0	0	0	**508,800**	
	2018/9	18	2	4	24	-	-	-	0	457,920	50,880	101,760	610,560	0	0	0	0	**610,560**	
	2018/10	3	1	1	5	-	-	-	0	76,320	25,440	25,440	127,200	0	0	0	0	**127,200**	
1	2018/11	18	3	9	30	-	-	-	0	457,920	76,320	228,960	763,200	0	0	0	0	**763,200**	
2	2018/12	21	3	9	33	-	-	-	0	534,240	76,320	228,960	839,520	0	0	0	0	**839,520**	
3	2019/1	15	2	1	18	-	-	-	0	381,600	50,880	25,440	457,920	0	0	0	0	**457,920**	
4	2019/2	18	5	4	27	-	-	-	0	457,920	127,200	101,760	686,880	0	0	0	0	**686,880**	
5	2019/3	0	1	2	3	13	3	-	16	0	25,440	50,880	76,320	330,720	76,320	0	407,040	**483,360**	
6	2019/4	18	2	6	26	-	-	-	0	457,920	50,880	152,640	661,440	0	0	0	0	**661,440**	
7	2019/5	18	5	6	29	-	-	-	0	457,920	127,200	152,640	737,760	0	0	0	0	**737,760**	
8	2019/6	10	0	0	10	-	-	-	0	254,400	0	0	30,000	0	0	0	0	**30,000**	
9	2019/7	13	2	3	18	2	-	-	2	330,720	50,880	76,320	457,920	50,880	0	0	50,880	**508,800**	
10	2019/8	16	1	1	18	12	-	-	12	407,040	25,440	25,440	457,920	305,280	0	0	305,280	**763,200**	
11	2019/9	17	1	1	19	-	-	-	0	432,480	25,440	25,440	483,360	0	0	0	0	**483,360**	
12	2019/10					-	-	-	0	0	0	0	0	0	0	0	0	**0**	
1	2019/11	15	1	5	21	-	-	-	0	381,600	25,440	127,200	534,240	0	0	0	0	**534,240**	
2	2019/12	11	5	8	24	-	-	-	0	279,840	127,200	203,520	610,560	0	0	0	0	**610,560**	
3	2020/1				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
4	2020/2				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
Sub-Total													**11,605,200**				**3,853,200**	**15,458,400**	
3.2 Pressure Control		-	-	-	-														
1) Pressure survey													0				0	**0**	
2) Planning of PRV installation point																			
3) PRV Installation	PRV1					1			1				0	4,000,000			4,000,000	**4,000,000**	Table
	PRV2						1		1						4,895,000		4,895,000	**4,895,000**	Table
	PRV3					1			1					779,000			779,000	**779,000**	Table
	PRV4					1			1					6,677,000			6,677,000	**6,677,000**	
	PRV5							1	1							3,000,000	3,000,000	**3,000,000**	
	63mm					1			1					3,000,000			3,000,000	**3,000,000**	
Sub-Total													**0**				**22,351,000**	**22,351,000**	
Total													**11,605,200**				**26,204,200**	**37,809,400**	
4. Pipe Replacement																			
Total																		**0**	
5. Monitoring/Evaluation													0				0	**0**	
NRW Rate Calculation		-	-	-	-														
Total													0				0	**0**	
Grand Total													**11,605,200**				**54,259,250**	**65,864,450**	
																	Without Meter Work	**56,619,150**	

Cost of NRW Reduction Activity for Ruyenzi Pilot Area Case 2

RWF

		WASAC activity				Project Activity				WASAC COST			TOTAL WASAC	PROJECT COST			TOTAL JICA	TOTAL COST	
		Emergency Action				Premeditated Action													
		Accident, Request of Customer				Planning based on the analysis of monitoring													
Activity	Day	Qty RY1	Qty RY2	Qty RY3	Qty Total	Qty RY1	Qty RY2	Qty RY3	Qty Total	RY1	RY2	RY3		RY1	RY2	RY3			
1. Preparation Work																			
1.1 DMA Creation																			
Preparation of the map (GIS, Google map)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pipe network map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
POC list and location map						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Design of DMA and Sub-zone		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pressure survey for Isolation		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Pipe replacement (Area adjustment)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Finalization of zone area		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Finalization of POC list in DMA and Update of the list (New Connection)						1	1	1	3				0	10,000	10,000	10,000	30,000	**30,000**	
Survey of the existing facilities in DMA (Valve, PRV, Pipe, etc.)													0	10,000	10,000	10,000	30,000	**30,000**	
Isolation valve installation								1					0		1,500,000		1,500,000	**1,500,000**	DN150x6
Valve installation for step test								1					0		1,140,000		1,140,000	**1,140,000**	DN100x6
1.2 Installation of Inlet and Outlet Facility																			
Inlet Facility (Chamber, Equipment)		-	-	-	-			1	1				0			8,837,000	8,837,000	**8,837,000**	PM4
Outlet Facility													0				0	**0**	
Total													0				11,747,000	**11,747,000**	
2. Activity for Commercial Loss reduction																			
2.1 Customer data analysis (Billing)																			
Analysis the Data inside the pilot area													0						
2.2 Customer Meter Survey/ POC Survey																			
Survey by visit all customers	3,250								1705				0				5,541,250	**0**	
2.3 Customer Questionnaire Survey																			
Questionnaire	3,250								222				0				721,500	**0**	
													0						
2.4 On-site Meter Test																			
Site Test	6,500								413				0				2,684,500	**0**	Table
2.5 Meter Replacement																			
Meter replacement	47,200								139				0				6,560,800	**0**	Service Charter
2.6 Inspection of illegal connection/use																			
Inspection work on site visit													0				800,000	**800,000**	
Total													0				16,308,050	**800,000**	
3. Activity for Physical Loss reduction		**RY1**	**RY2**	**RY3**	**Total**	**RY1**	**RY2**	**RY3**	**Total**										
3.1 Leakage Survey and Repair																			
1) Analysis of Leakage repair record													0		570,000		570,000	**570,000**	
2) Qmnf measurement & Step Test		-	-	-	-		12		12				0		2,520,000		2,520,000	**2,520,000**	
4) Leakage Repair (Include Preliminary work before repairing)																			25440
	2018/3	33	1	6	40	-	-	-	0	839,520	25,440	152,640	1,017,600	0	0	0	0	**1,017,600**	
	2018/4	37	3	2	42	-	-	-	0	941,280	76,320	50,880	1,068,480	0	0	0	0	**1,068,480**	
	2018/5	13	2	0	15	-	-	-	0	330,720	50,880	0	381,600	0	0	0	0	**381,600**	
	2018/6	16	2	3	21	-	-	-	0	407,040	50,880	76,320	534,240	0	0	0	0	**534,240**	
	2018/7	17	4	1	22	-	-	-	0	432,480	101,760	25,440	559,680	0	0	0	0	**559,680**	
	2018/8	16	3	1	20	-	-	-	0	407,040	76,320	25,440	508,800	0	0	0	0	**508,800**	
	2018/9	18	2	4	24	-	-	-	0	457,920	50,880	101,760	610,560	0	0	0	0	**610,560**	
	2018/10	3	1	1	5	-	-	-	0	76,320	25,440	25,440	127,200	0	0	0	0	**127,200**	
1	2018/11	18	3	9	30	-	-	-	0	457,920	76,320	228,960	763,200	0	0	0	0	**763,200**	
2	2018/12	21	3	9	33	-	-	-	0	534,240	76,320	228,960	839,520	0	0	0	0	**839,520**	
3	2019/1	15	2	1	18	-	-	-	0	381,600	50,880	25,440	457,920	0	0	0	0	**457,920**	
4	2019/2	18	5	4	27	-	-	-	0	457,920	127,200	101,760	686,880	0	0	0	0	**686,880**	
5	2019/3	0	1	2	3	13	3	-	16	0	25,440	50,880	76,320	330,720	76,320	0	407,040	**483,360**	
6	2019/4	18	2	6	26	-	-	-	0	457,920	50,880	152,640	661,440	0	0	0	0	**661,440**	
7	2019/5	18	5	6	29	-	-	-	0	457,920	127,200	152,640	737,760	0	0	0	0	**737,760**	
8	2019/6	10	0	0	10	-	-	-	0	254,400	0	0	30,000	0	0	0	0	**30,000**	
9	2019/7	13	2	3	18	2	-	-	2	330,720	50,880	76,320	457,920	50,880	0	0	50,880	**508,800**	
10	2019/8	16	1	1	18	12	-	-	12	407,040	25,440	25,440	457,920	305,280	0	0	305,280	**763,200**	
11	2019/9	17	1	1	19	-	-	-	0	432,480	25,440	25,440	483,360	0	0	0	0	**483,360**	
12	2019/10					-	-	-	0	0	0	0	0	0	0	0	0	**0**	
1	2019/11	15	1	5	21	-	-	-	0	381,600	25,440	127,200	534,240	0	0	0	0	**534,240**	
2	2019/12	11	5	8	24	-	-	-	0	279,840	127,200	203,520	610,560	0	0	0	0	**610,560**	
3	2020/1				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
4	2020/2				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
Sub-Total													**11,605,200**				**3,853,200**	**15,458,400**	
3.2 Pressure Control		-	-	-	-														
1) Pressure survey													0				0	**0**	
2) Planning of PRV installation point																			
3) PRV Installation	PRV1					1			1				0	4,000,000			4,000,000	**4,000,000**	Table
	PRV2						1		1						4,895,000		4,895,000	**4,895,000**	Table
	PRV3					1			1					779,000			779,000	**779,000**	Table
	PRV4					1			1					6,677,000			6,677,000	**6,677,000**	
	PRV5							1	1							3,000,000	3,000,000	**3,000,000**	
	63mm					1			1					3,000,000			3,000,000	**3,000,000**	
Sub-Total													**0**				**22,351,000**	**22,351,000**	
Total													**11,605,200**				**26,204,200**	**37,809,400**	
4. Pipe Replacement																			
Total																		**0**	
5. Monitoring/Evaluation													0				0	**0**	
NRW Rate Calculation		-	-	-	-														
Total													0				0	**0**	
Grand Total													**11,605,200**				**54,259,250**	**50,356,400**	
																	Without Meter Work	**50,356,400**	

Cost of NRW Reduction Activity for Ruyenzi Pilot Area Case 3

RWF

		WASAC activity				Project Activity				WASAC COST			TOTAL WASAC	PROJECT COST			TOTAL JICA	TOTAL COST	
		Emergency Action				Premeditated Action													
		Accident, Request of Customer				Planning based on the analysis of monitoring													
Activity	Day	Qty RY1	Qty RY2	Qty RY3	Qty Total	Qty RY1	Qty RY2	Qty RY3	Qty Total	RY1	RY2	RY3		RY1	RY2	RY3			
1. Preparation Work																			
1.1 DMA Creation																			
Preparation of the map (GIS, Google map)						1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Pipe network map						1	1	1	3				0	10,000	10,000	10,000	0	**0**	
POC list and location map						1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Design of DMA and Sub-zone		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Pressure survey for Isolation		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Pipe replacement (Area adjustment)						1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Finalization of zone area		-	-	-	-	1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Finalization of POC list in DMA and Update of the list (New Connection)						1	1	1	3				0	10,000	10,000	10,000	0	**0**	
Survey of the existing facilities in DMA (Valve, PRV, Pipe, etc.)													0	10,000	10,000	10,000	0	**0**	
Isolation valve installation								1					0		1,500,000		0	**0**	DN150x6
Valve installation for step test								1					0		1,140,000		0	**0**	DN100x6
1.2 Installation of Inlet and Outlet Facility																			
Inlet Facility (Chamber, Equipment)		-	-	-	-			1	1				0			8,837,000	0	**0**	PM4
Outlet Facility													0				0	**0**	
Total													0				0	**0**	
2. Activity for Commercial Loss reduction																			
2.1 Customer data analysis (Billing)																			
Analysis the Data inside the pilot area													0						
2.2 Customer Meter Survey/ POC Survey																			
Survey by visit all customers	3,250								1705				0				5,541,250	**0**	
2.3 Customer Questionnaire Survey																			
Questionnaire	3,250								222				0				721,500	**0**	
													0						
2.4 On-site Meter Test																			
Site Test	6,500								413				0				2,684,500	**0**	Table
2.5 Meter Replacement																			
Meter replacement	47,200								139				0				6,560,800	**0**	Service Charter
2.6 Inspection of illegal connection/use																			
Inspection work on site visit													0				800,000	**800,000**	
Total													0				16,308,050	**800,000**	
3. Activity for Physical Loss reduction		**RY1**	**RY2**	**RY3**	**Total**	**RY1**	**RY2**	**RY3**	**Total**										
3.1 Leakage Survey and Repair																			
1) Analysis of Leakage repair record													0		570,000		570,000	**570,000**	
2) Qmnf measurement & Step Test		-	-	-	-		12		12				0		2,520,000		2,520,000	**2,520,000**	
4) Leakage Repair (Include Preliminary work before repairing)																			25440
	2018/3	33	1	6	40	-	-	-	0	839,520	25,440	152,640	1,017,600	0	0	0	0	**1,017,600**	
	2018/4	37	3	2	42	-	-	-	0	941,280	76,320	50,880	1,068,480	0	0	0	0	**1,068,480**	
	2018/5	13	2	0	15	-	-	-	0	330,720	50,880	0	381,600	0	0	0	0	**381,600**	
	2018/6	16	2	3	21	-	-	-	0	407,040	50,880	76,320	534,240	0	0	0	0	**534,240**	
	2018/7	17	4	1	22	-	-	-	0	432,480	101,760	25,440	559,680	0	0	0	0	**559,680**	
	2018/8	16	3	1	20	-	-	-	0	407,040	76,320	25,440	508,800	0	0	0	0	**508,800**	
	2018/9	18	2	4	24	-	-	-	0	457,920	50,880	101,760	610,560	0	0	0	0	**610,560**	
	2018/10	3	1	1	5	-	-	-	0	76,320	25,440	25,440	127,200	0	0	0	0	**127,200**	
1	2018/11	18	3	9	30	-	-	-	0	457,920	76,320	228,960	763,200	0	0	0	0	**763,200**	
2	2018/12	21	3	9	33	-	-	-	0	534,240	76,320	228,960	839,520	0	0	0	0	**839,520**	
3	2019/1	15	2	1	18	-	-	-	0	381,600	50,880	25,440	457,920	0	0	0	0	**457,920**	
4	2019/2	18	5	4	27	-	-	-	0	457,920	127,200	101,760	686,880	0	0	0	0	**686,880**	
5	2019/3	0	1	2	3	13	3	-	16	0	25,440	50,880	76,320	330,720	76,320	0	407,040	**483,360**	
6	2019/4	18	2	6	26	-	-	-	0	457,920	50,880	152,640	661,440	0	0	0	0	**661,440**	
7	2019/5	18	5	6	29	-	-	-	0	457,920	127,200	152,640	737,760	0	0	0	0	**737,760**	
8	2019/6	10	0	0	10	-	-	-	0	254,400	0	0	30,000	0	0	0	0	**30,000**	
9	2019/7	13	2	3	18	2	-	-	2	330,720	50,880	76,320	457,920	50,880	0	0	50,880	**508,800**	
10	2019/8	16	1	1	18	12	-	-	12	407,040	25,440	25,440	457,920	305,280	0	0	305,280	**763,200**	
11	2019/9	17	1	1	19	-	-	-	0	432,480	25,440	25,440	483,360	0	0	0	0	**483,360**	
12	2019/10					-	-	-	0	0	0	0	0	0	0	0	0	**0**	
1	2019/11	15	1	5	21	-	-	-	0	381,600	25,440	127,200	534,240	0	0	0	0	**534,240**	
2	2019/12	11	5	8	24	-	-	-	0	279,840	127,200	203,520	610,560	0	0	0	0	**610,560**	
3	2020/1				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
4	2020/2				0	-	-	-	0	0	0	0	0	0	0	0	0	**0**	
Sub-Total													**11,605,200**				**3,853,200**	**15,458,400**	
3.2 Pressure Control		-	-	-	-														
1) Pressure survey													0				0	**0**	
2) Planning of PRV installation point																			
3) PRV Installation	PRV1					1			1				0	4,000,000			4,000,000	**4,000,000**	Table
	PRV2						1		1						4,895,000		4,895,000	**4,895,000**	Table
	PRV3					1			1					779,000			779,000	**779,000**	Table
	PRV4					1			1					6,677,000			6,677,000	**6,677,000**	
	PRV5							1	1							3,000,000	3,000,000	**3,000,000**	
	63mm					1			1					3,000,000			3,000,000	**3,000,000**	
Sub-Total													**0**				**22,351,000**	**22,351,000**	
Total													**11,605,200**				**26,204,200**	**37,809,400**	
4. Pipe Replacement																			
Total																		**0**	
5. Monitoring/Evaluation													0				0	**0**	
NRW Rate Calculation		-	-	-	-														
Total													0				0	**0**	
Grand Total													**11,605,200**				**42,512,250**	**38,609,400**	
																	Without Meter Work	**38,609,400**	

添付資料 13. 無収水削減マニュアル

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

PROCEDURE MANUAL FOR NON-REVENUE WATER REDUCTION

May 2020

WATER AND SANITATION CORPORATION (WASAC)

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

Acknowledgement
Abbreviations
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High Water Pressure management
S:11 Protective Equipment Installation/ Rehabilitation Plan

Section 3. Distribution System Adjustment

Section 4. Water Leakage Survey and Repair

Section 5. Replacement of Pipe Network

Section 6. Water Distribution Reservoir Management

Section 7. Water Distribution Volume Management

Section 8. Billing and Customer Meter Management

Section 9. Monitoring of NRW

Section 10. Preparatory Work

Section 11. Equipment Instruction Manual

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【Annex】

Section 1. Introduction

1. Introduction

1.1 Background

Water and Sanitation Corporation (WASAC) is the entity setup to manage the water and sanitation services in Rwanda as a result of the Government of Rwanda (GoR) decision to replace the national utility former EWSA in 2015.

Hence, since the creation of WASAC the urbanization is progressing rapidly in Rwanda, especially in Kigali city. In accordance with the urbanization and concentration of population, water supply services and water resources are not satisfied to customers. On the other hand, Non-Revenue Water (NRW) ratio is still high and the reduction of NRW is to create new water resources.

WASAC has got many experiences and knowledge related to NRW reduction through the WASAC-JICA project implementation "Strengthening Non-Revenue Water Control in Kigali City Water Network". It is very important to continue NRW reduction activities. So, the manual development is a way of sustainability for NRW control and reduction.

1.2Purpose of Procedure Manual for NRW reduction

As WASAC Ltd. has the mission of providing quality, reliable and affordable water and sewerage services through continuous innovations and detailed care to its customers' needs, could be achieved only if the challenges faced by the company including a high NRW could be minimized.

Basing on partnership of WASAC-JICA project for "Strengthening Non Revenue Water Control in Kigali City Water Network", basing also on experience gained from NRW reduction activities done in pilot project areas and their implementation, this manual was developed to show all staff the appropriate procedure to be used as a tool for carrying out NRW reduction activities in 5 Years Strategic Plan (5YSP) effectively.

This Procedure Manual will serve as the general principle and guidance for NRW reduction. It shall be used by all WASAC staff concerned by NRW reduction activities and partners contributing in these activities. Since this document was produced based on information, provided by people mostly dealing with NRW, users are requested to comply with contained guidelines in their day to day activities. This Procedure Manual will not

only set standards procedures applicable generally to all water coverage areas but also shall contribute to the achievement of WASAC goal.

1.3Concept of NRW Reduction

1) Definition of NRW

Non-revenue water (NRW) is equal to the total amount of water flowing into the water supply network from a water treatment plant (the 'System Input Volume') minus the total amount of water that consumers are authorized to use (the 'Authorized Consumption').

NRW = System Input Volume - Billed Authorized Consumption

2) Component of NRW (Water Balance)

The International Water Association (IWA) has developed a detailed methodology to assess the various components of NRW which are shown in the table below. WASAC also follows this definition to calculate the NRW volume.

Table 1.1 Water Balance Sheet of the IWA

<table>
<tr><td rowspan="11">System Input Volume (Water distribution)</td><td rowspan="4">Authorized Consumption (Effective water)</td><td rowspan="3">Billed Authorized Consumption</td><td>Billed Water Exported</td><td rowspan="2">Metered</td><td rowspan="3">Revenue water</td></tr>
<tr><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td><td>Unmetered</td></tr>
<tr><td rowspan="2">Unbilled Authorized Consumption</td><td>Unbilled Metered Consumption</td><td>Metered</td><td rowspan="7">Non-Revenue water (NRW)</td></tr>
<tr><td>Unbilled Unmetered Consumption</td><td>Unmetered</td></tr>
<tr><td rowspan="7">Water Losses (Ineffective water)</td><td rowspan="2">Apparent Losses (Commercial losses)</td><td>Unauthorized Consumption</td><td>Metered/Unmetered</td></tr>
<tr><td>Customer Meter Inaccuracies and Data Handling Errors</td><td>Metered</td></tr>
<tr><td rowspan="5">Real Losses (Physical losses)</td><td>Leakage on Transmission and Distribution Mains</td><td rowspan="5">Leakage</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of Customer Meter</td></tr>
</table>

Note;

* Unbilled Authorized Consumption: Water for cleaning pipes, watering trees, firefighting, etc.
* Unauthorized Consumption: Water theft, unknown water
* Customer Meter Inaccuracies: Meter errors/non-detection, reading errors

- **Apparent losses**

Refers to water that has been produced, but not measured. It occurs due to failures in data and billing systems, customer meter inaccuracies and unauthorized consumption.

- **Real losses**

Real losses are the physical losses of water from the distribution system, including leakage and storage overflows. These losses increase the water utility's production costs and stress water resources since they represent water that is extracted and treated but never reaches beneficial use.

- **Unbilled authorized consumption**

Unbilled authorized consumption refers to Water used for cleaning pipes (Washout), cleaning reservoirs, firefighting, etc.

Table 1.2 Water Balance Sheet of WASAC

Water distribution	Effective water	Billed authorized consumption	Metered consumption		Revenue water
			Non-metered consumption	Use of average value	
				Use of estimated value	
			Water Tnaker		
		Unbilled authorized consumption	Water for firefighting		Non-revenue water
			Water for cleaning facilities	Water pipes, drain pipes, water distribution reservoirs	
			Water for testing	Flow test, etc.	
			Water for other management uses	Surge tank	
			Water tanker	Use in water supply suspension and emergency	
	Ineffective water	Operating losses	Water theft (without contract)	Illegal use of fire hydrant	
				Non-contract use (bypass pipes, deteriorated pipes)	
				Water use by uncontracted industrial estates	
			Water theft (with contract)	Use of bypass pipes	
				Removal and direct connection of water meters (permanent, temporary)	
				Vandalism of water meters	
			Metering errors	Malfunctioning of water meters (product defect, deterioration, failure, blockage)	
				Non-detection of water meters	
			Billing errors	Reading errors	
				Errors in billing of non-metered consumption (average value, estimated value)	
				Incomplete billing	
			Data processing errors	Billed water consumption	
		Physical losses	Leakage from primary distribution pipes	Visible, invisible	
			Leakage from secondary distribution pipes	Visible, invisible	
			Leakage from hydrants	Visible, invisible	
			Loss from distribution reservoirs	Overflow, Leakage	
			Unavoidable leakage		
			Losses from water tanker	Loss when loading water without meter	

Other losses

- Errors in the measurement of water distribution volume
- Errors in the calculation process of non-revenue water rate

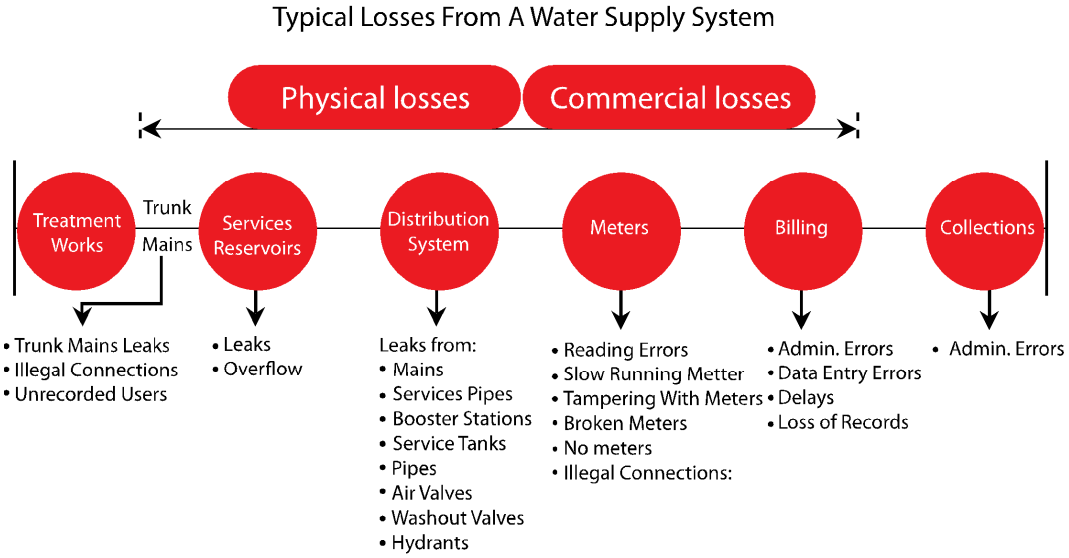


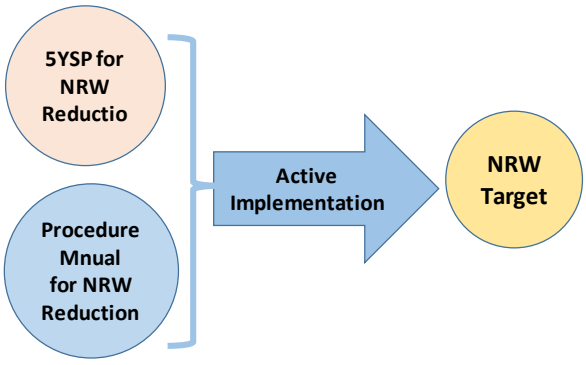
Fig. 1.1 Conception Diagram of Non-Revenue Water

Accordingly, it is necessary to carry out a causal analysis for each item in this water balance sheet to reduce non-revenue water. The causal analysis will clarify the priorities to consider in developing the measures to reduce non-revenue water and enable efficient implementation of the operations to reduce non-revenue water by setting targets for the implementation.

1.4 Activities of the 5YSP

The NRW reduction 5YSP of WASAC developed as a specific, realistic and integrated strategic plan where all issues related to NRW have been diagnosed, root causes clarified, strategies and specific actions to address the identified issues proposed with estimated budget and timeline.

NRW reduction activities to be carried out in WASAC are listed in this 5YSP (refer to Annex-1 of this procedure manual). The activities which have high priority in the 5YSP are monitored by NRW Monthly Report (refer to Annex-2).



This procedure manual is used as the tools to implement the activities of the 5YSP efficiently.

1.5Strategy of NRW Reduction Activity

Based on the result of the two pilot projects, Kadobogo and Ruyenzi, effective activities with high priority for NRW reduction were clarified in the activities of 5YSP as follows;

1) High water pressure management
2) Distribution system adjustment
3) Water leak survey and repair
4) Distribution and service pipe replacement
5) Water distribution reservoir management
6) Water distribution management
7) Billing and customer management

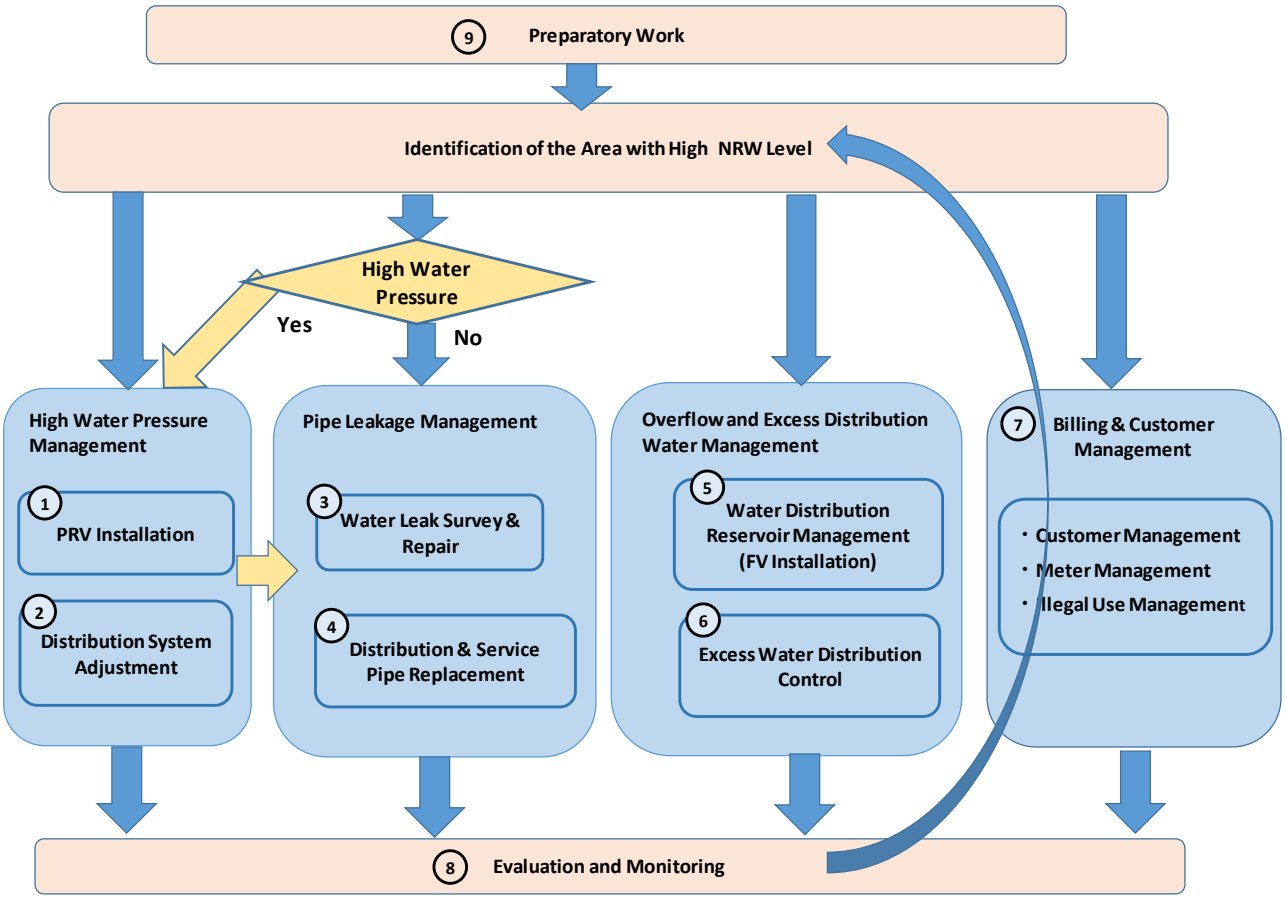
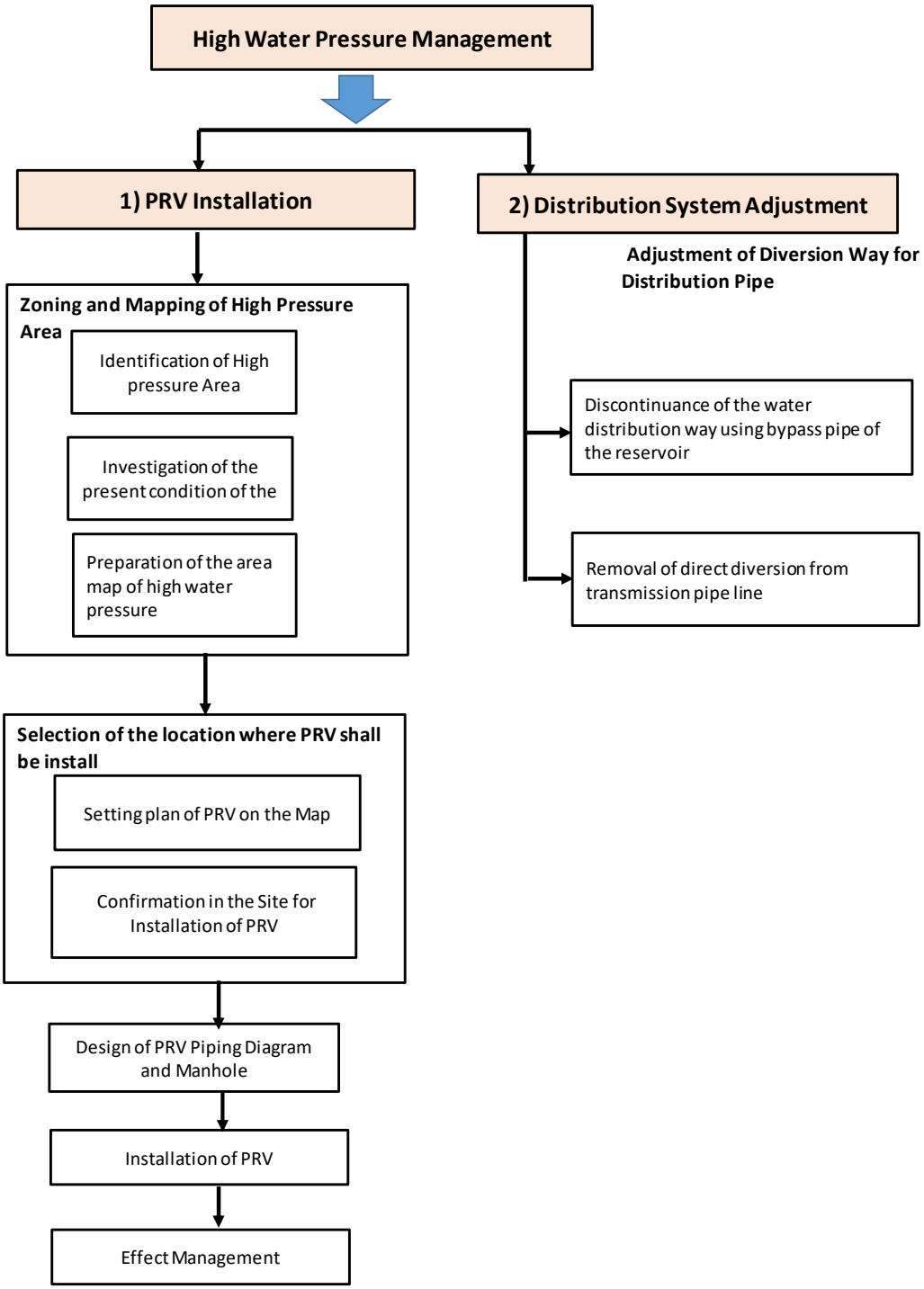


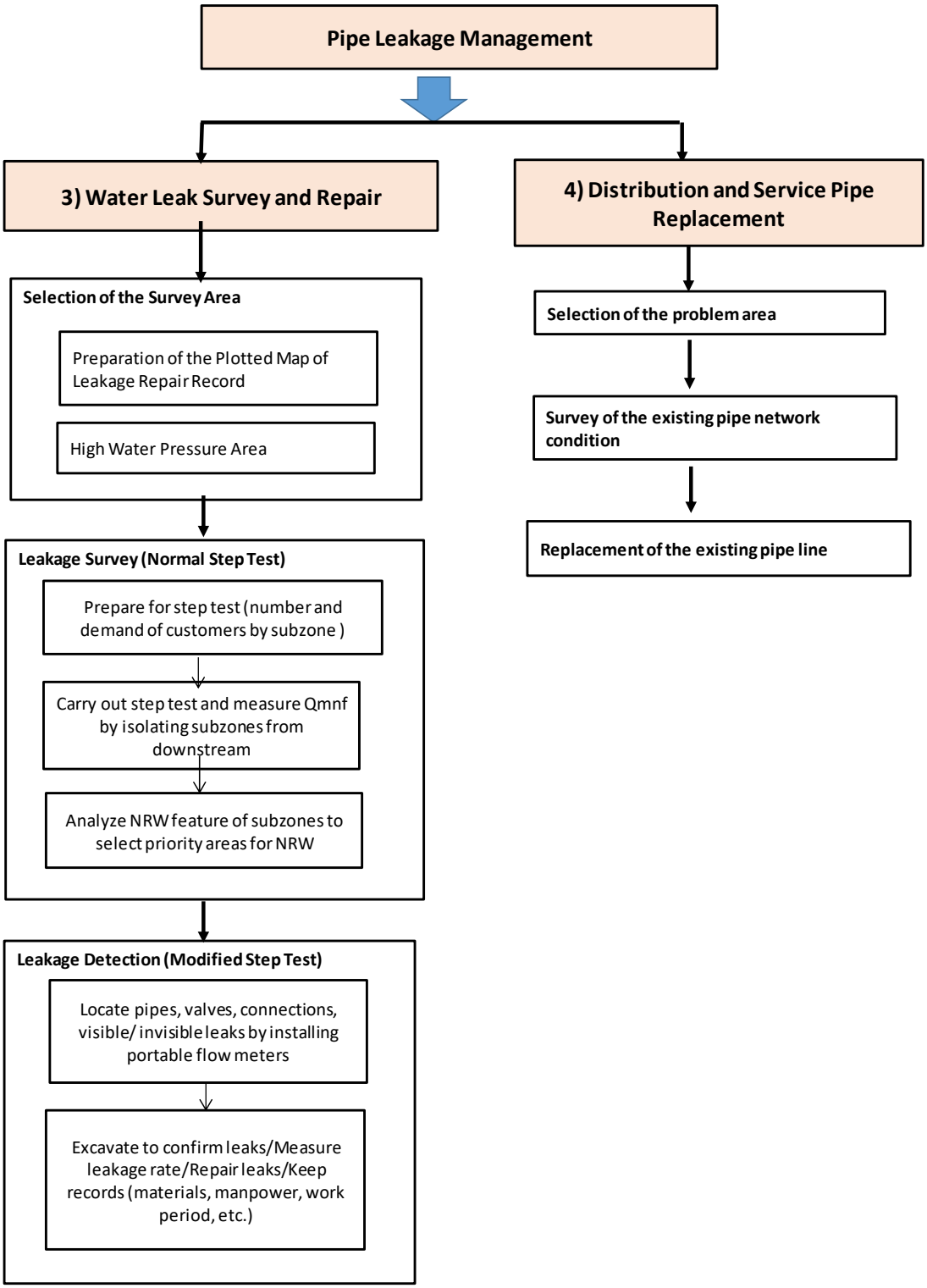
Fig. 1.3 NRW Reduction Activities with High Priority

Break down of the high prioritized projects are shown below.

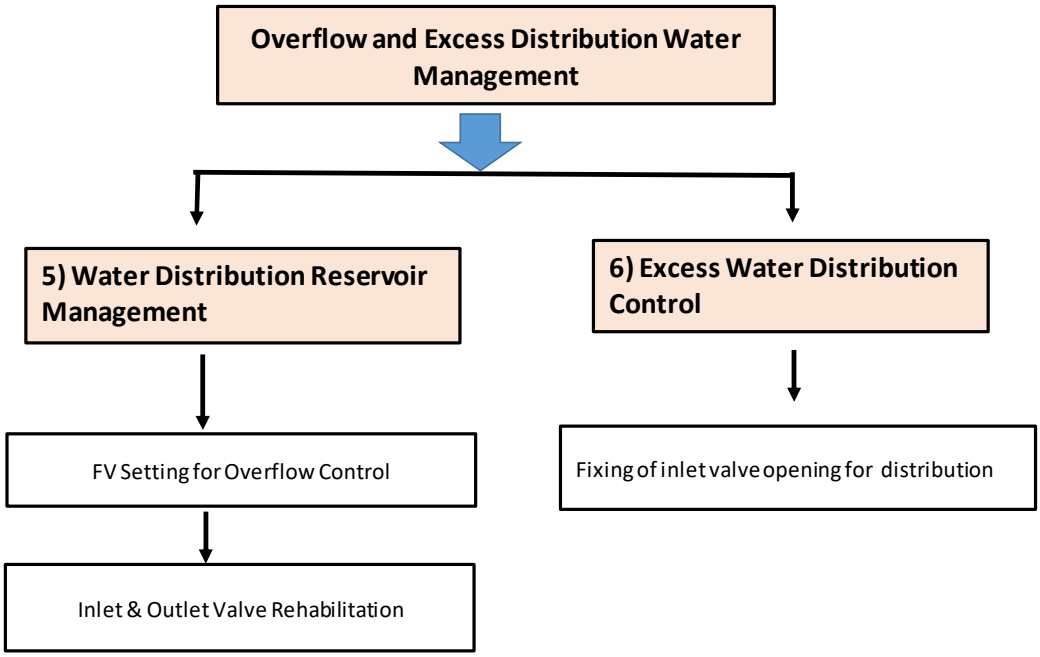
NRW Reduction Activity on Physical Loss



NRW Reduction Activity on Physical Loss



NRW Reduction Activity on Physical Loss



NRW Reduction Activity on Commercial Loss

7) Billing and Customer Management

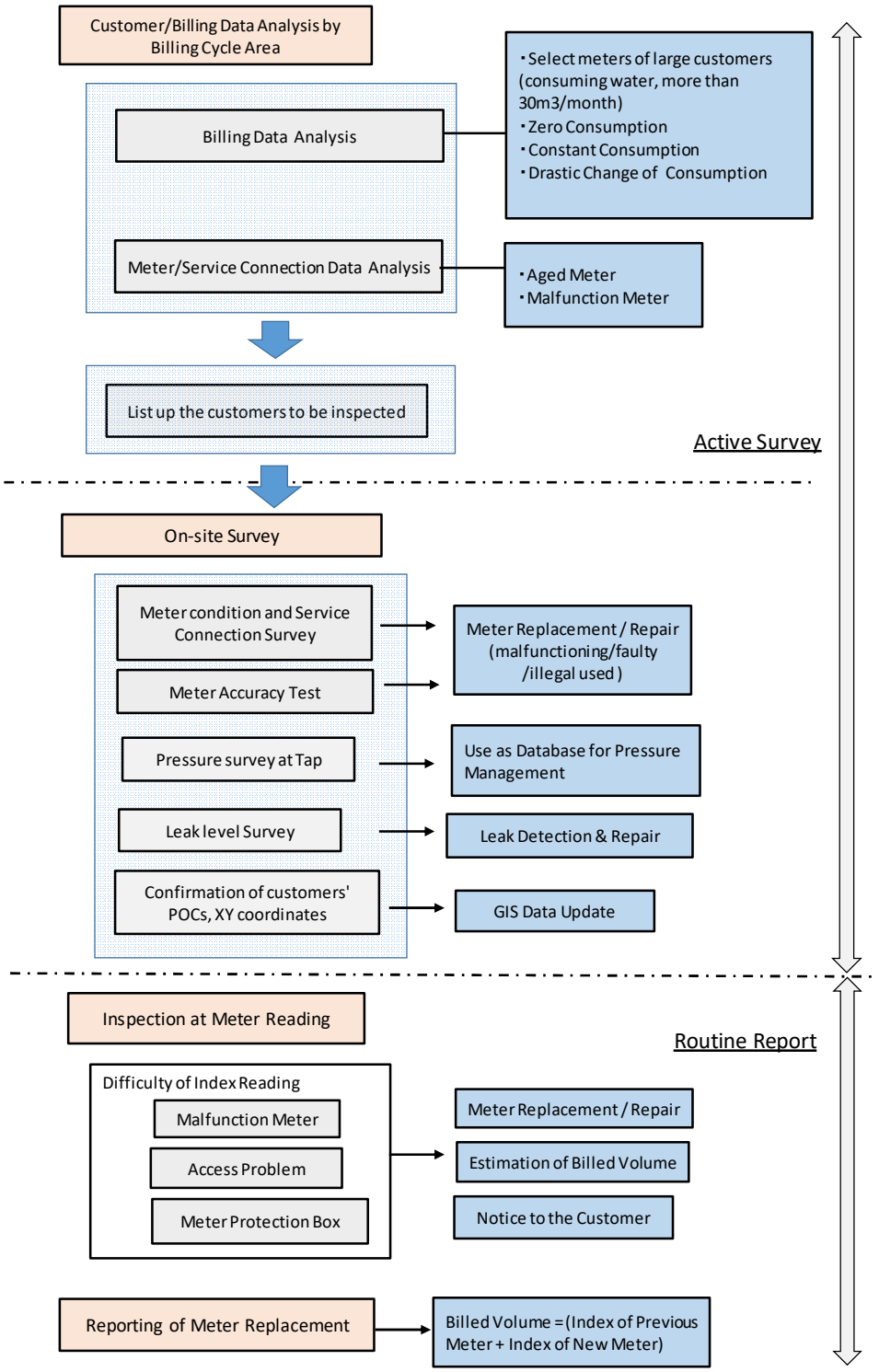
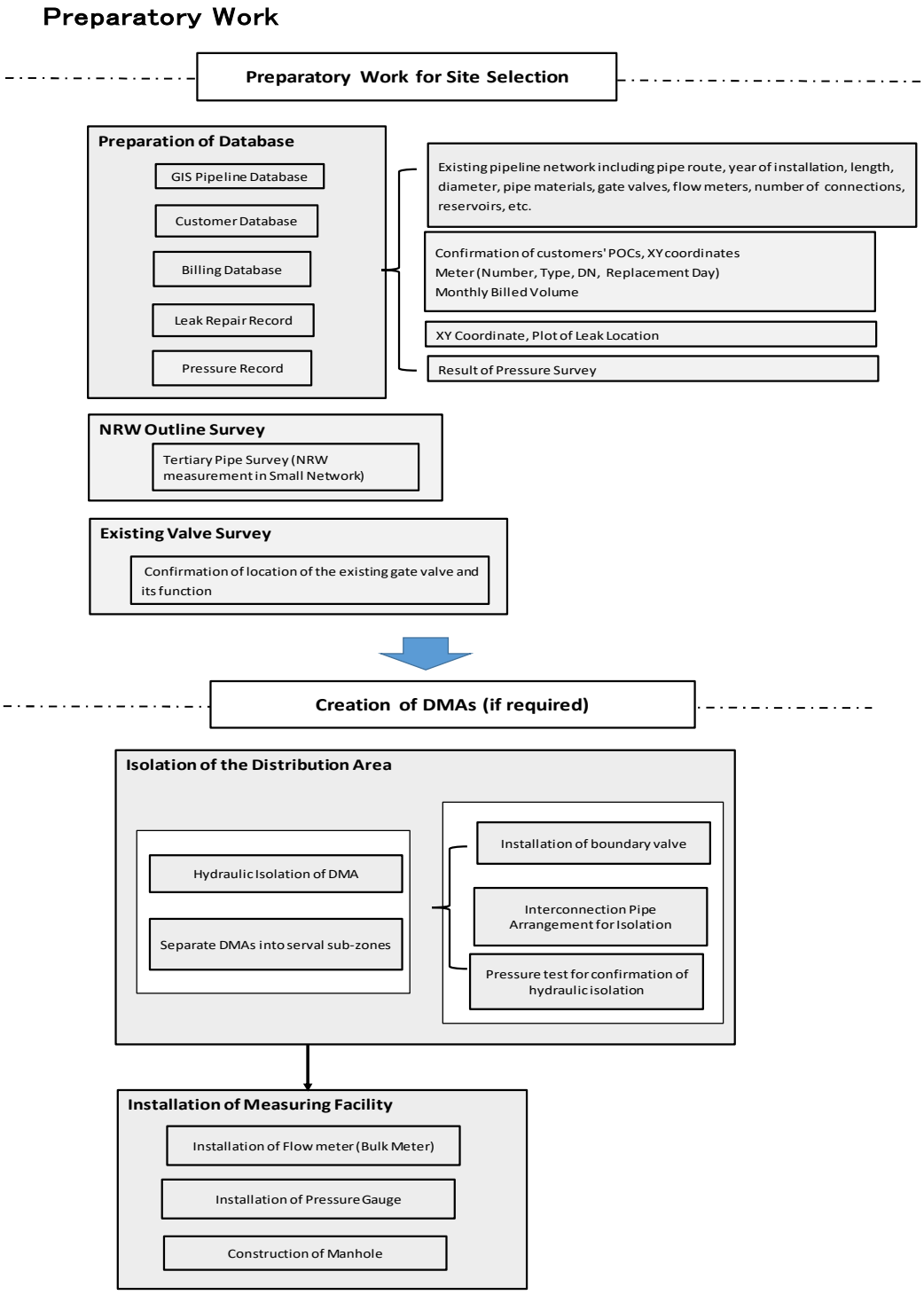


Fig. 1.3 Conception Diagram of NRW Reduction Activities

1.6Preparatory Work and Workflow of NRW Reduction

The preparatory works are preparation of basic information for the implementation of NRW reduction activities and creation of DMA if required. More details will be found in Section 10 “Preparatory Works for NRW Reduction Activities”.



Section 2. High Water Pressure Management

Reference;

2. High Water Pressure Management

2.1 Necessity of the Pressure Control

Topographic feature of Rwanda is hilly, and undulation of ground is very steep. Therefore, the difference of elevation between highest area and lowest area is very big in water distribution area. The biggest factor to cause a leakage in the pipeline network is the high water pressure.

Pressure management is one of the most important NRW management interventions to reduce leakage. Since leakage is driven by pressure, any efforts which result in the reduction of water pressure to the required average pressure will reduce the leakage to some extent.

Water pressure management helps to:

a. Reduces water demand and leaks to help meet water conservation targets,
b. Improves the reliability and continuity of supply by reducing pipe breaks,
c. Reduces pressure fluctuations to achieve more consistent water pressure across the system,
d. Extends the life of water supply pipes and assets,
e. Reduced repair and reinstatement cost,
f. Reduce cost and active leakage control, all leading to fewer customer complaints;

The NRW division shall plan and coordinate all activities related to pressure management and control by conducting all activities: planning, implementation and reporting.

The zoning and mapping will produce contour maps for critical specific areas (high or low pressure zones) based on hydraulic models.

For the management of pressure, Pressure Reducing Valves (PRVs) shall be installed to reduce pressure in high pressure zones and take appropriate action for its control. PRVs are installed in water network to stabilize the pressure and regulate the flow based on what is needed in the area to be supplied.

2.2Standard of Pressure

1) WASAC Standard (Water Supply and Sewerage Systems Procedure Manual)

No description about the numerical value of water pressure in the WASAC Standard.

2) Japanese Standard (The Design Criteria for Water Supply Facilities: Ministry of

Health, Labor and Welfare)

It is recommended to control water pressure between 1.5 – 7.4 bar on the pipeline.

"The minimum dynamic water pressure at the tapping points on the distribution main for branching of service connections shall be more than 0.15 MPa. 2. The maximum static water pressure at the tapping points on the distribution main for branching of service connections shall be less than 0.74 MPa."

2.3 Zoning and Mapping of High Pressure Area

The zoning/mapping work of high water pressure area in the distribution network shall be performed by use of the GIS database.

It is desirable to perform the water pressure measurement at the several points in the zoning/mapping area to support drawing figures.

Work procedure is as follows:

1) Identification of the high pressure area

- Identify the high pressure area in the distribution network GIS map, based on the information of Branch Office such as leakage repair record, plotting map of leakage history and knowledge of the staffs. It is preferable for the area to be isolated, but it is not always necessary.
- Draw contour line in the network area map.

2) Investigation of the present condition of the area

- Grasp topographic condition of the area.
- Calculate statistic water pressure in the area based on the water head of water supply source such as pumping station and water distribution reservoir and altitude of the area. (see Reference 1)
- Measure water pressure at the several spots in the area such as highest point, middle point and lowest point at daytime and night time, if possible 24 hours.
- Grasp water supply situation of the customer (water pressure, water supply available time, rationing) based on hearing investigation.

3) Preparation of control area map of high water pressure

- Finalize the boundary line of the control area. (see Reference 2, 3)
- Mark measured points and write their water pressure on the map.

- Clarify the customer number and locations in the area map.
- Clarify pipeline route, location of existing valves.

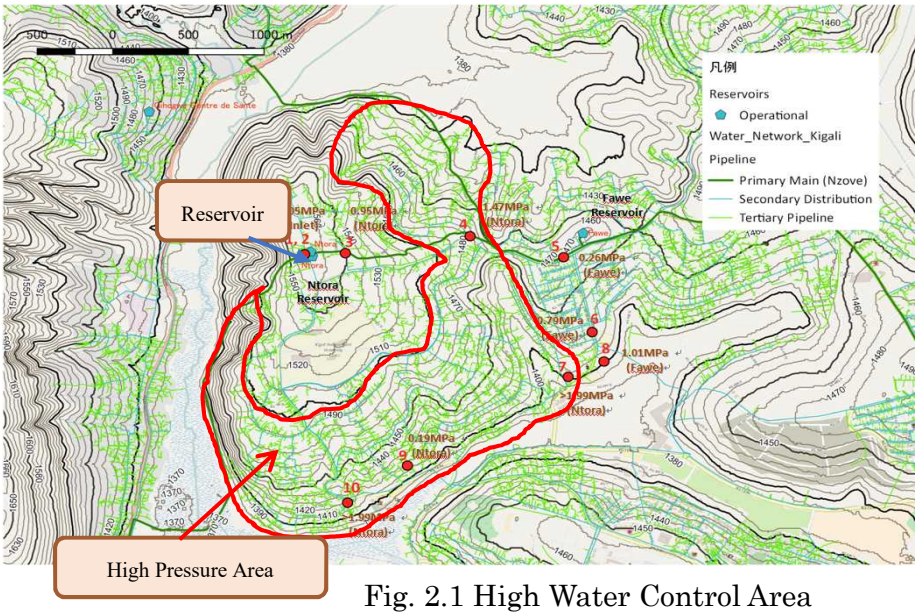


Fig. 2.1 High Water Control Area

2.4 Setting Plan of PRV on the Map and Site Investigation

- Determination of the required number of PRVs and its setting altitude by calculation excel table for the pressure reduction plan (see Reference 4, 5)
- Positioning of PRVs on the map (XY Coordinate)
- Site investigation for existing distribution pipe (location, material, class, diameter), other underground facility (electricity line, communication line), landholding, soil condition, XY coordinate and so on.

2.5 Design of PRV Piping Diagram and Manhole

- Design piping diagram and manhole
- Preparation of BoQ of the equipment and materials
- Procurement of the equipment and materials

2.6 PRV Installation and Effect Measurement

- Construction of manhole and installation of PRV
- Qmnf measurement before setting pilot valve of PRV
- Qmnf measurement after setting pilot valve of PRV

Cause of High Water Pressure

Types of water transmission

There are three types of water transmission

the gravity flow type

the pumped type

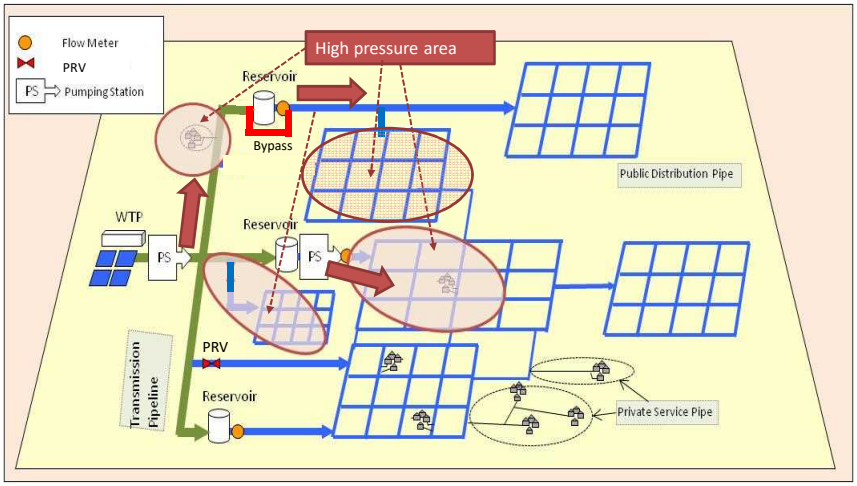
the combined type

Types of water transmission and distribution in WASAC networks

There are two types of water transmission and
Three types of water distribution

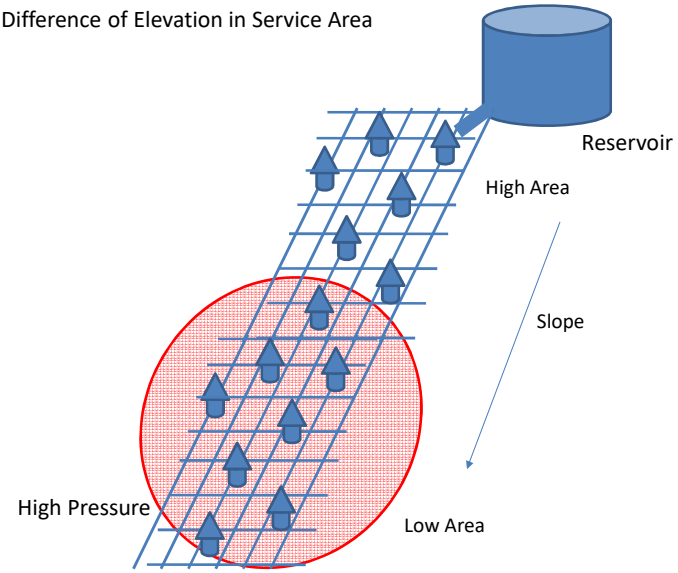
1. Transmission
   - by pumping to reservoir
   - by gravity from reservoir to another reservoir
2. Distribution
   - by gravity from reservoir
   - by direct branch from transmission pipe
   - by bypassing reservoir from transmission pipe

Types of water distribution



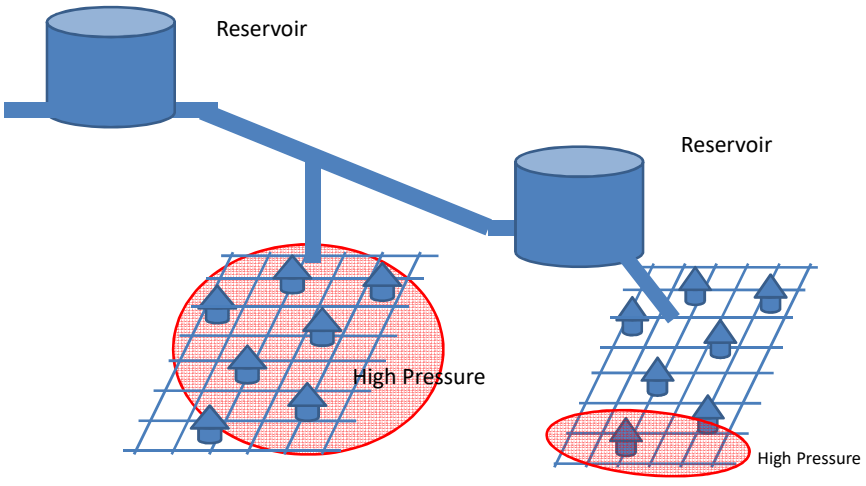
Cause of High Pressure

1. Big Difference of Elevation in Service Area



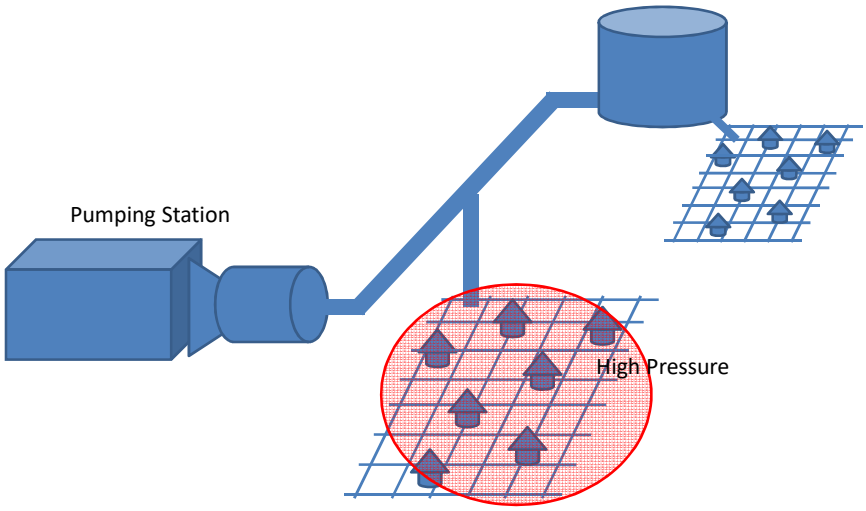
Cause of High Pressure

2. Direct Branch from Transmission Line



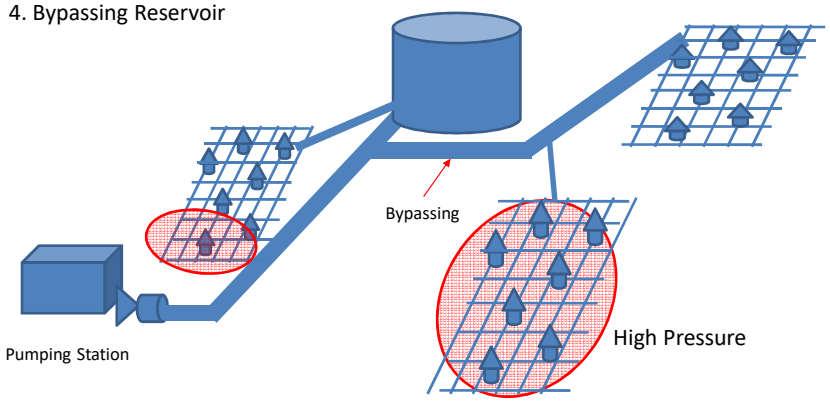
Cause of High Pressure

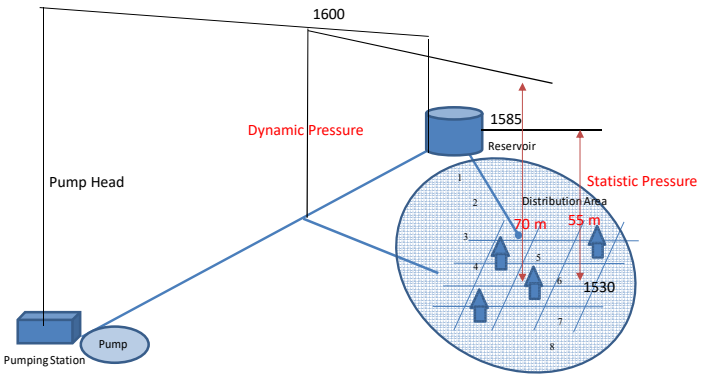
3. Direct Branch from Transmission Line



Cause of High Pressure

4. Bypassing Reservoir



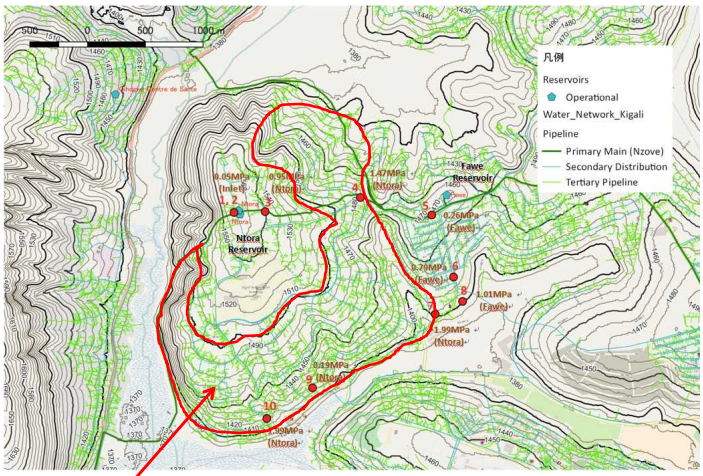


Hydraulic pressure

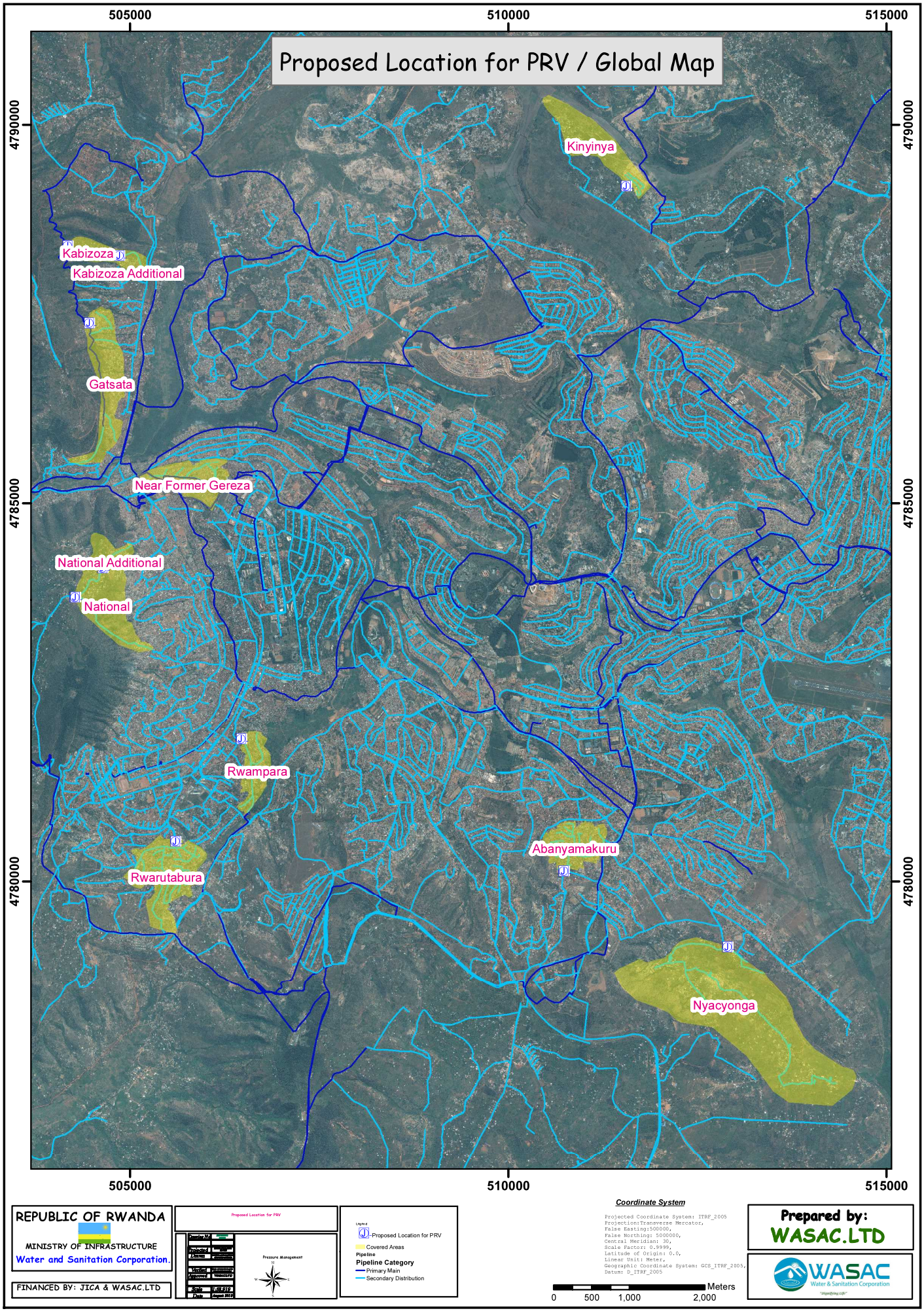
Distribution Area		Dynamic Pressure	Statistic Pressure
No.	Elevation	Pump Head + El of Pump Station	Reservoir HWL
	m	1600 m	1585 m
1	1580	20	5
2	1570	30	15
3	1560	40	25
4	1550	50	35
5	1540	60	45
6	1530	70	55
7	1520	80	65
8	1510	90	75

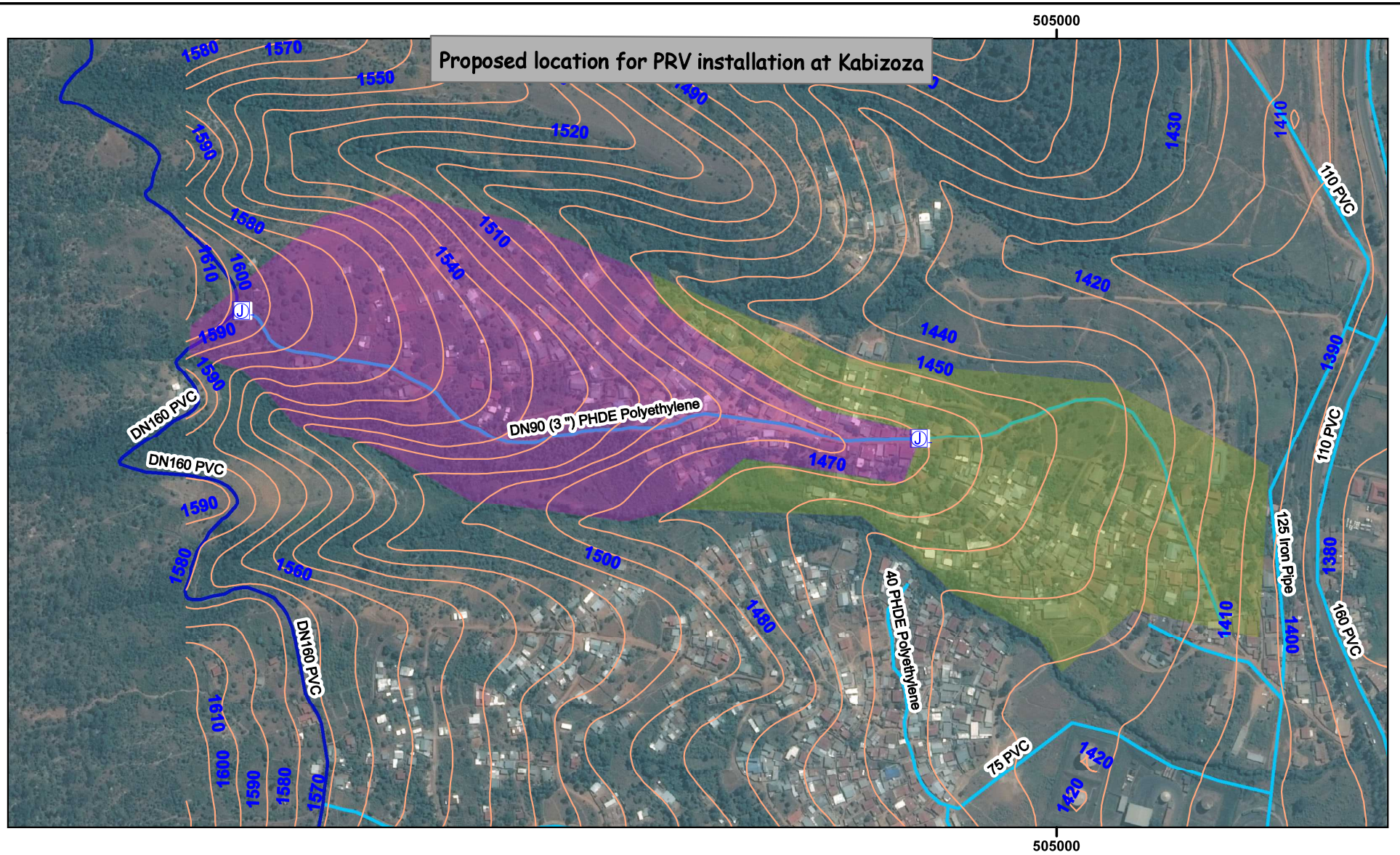
Pressure Calculation

High Pressure Zone by Pressure



Higu Pressure Area


Proposed Location for PRV / Global Map
505000
510000
515000
4790000
4785000
4780000
Kinyinya
Kabizoza
Kabizoza Additional
Gatsata
Near Former Gereza
National Additional
National
Rwampara
Abanyamakuru
Rwarutabura
Nyacyonga
REPUBLIC OF RWANDA
MINISTRY OF INFRASTRUCTURE
Water and Sanitation Corporation.
FINANCED BY: JICA & WASAC.LTD
Proposed Location for PRV
Covered Areas
Pipeline
Pipeline Category
Primary Main
Secondary Distribution
Coordinate System
Projected Coordinate System: ITRF_2005
Projection:Transverse Mercator,
False Easting:500000,
False Northing: 5000000,
Central Meridian: 30,
Scale Factor: 0.9999,
Latitude of Origin: 0.0,
Linear Unit: Meter,
Geographic Coordinate System: GCS_ITRF_2005,
Datum: D_ITRF_2005
0
500
1,000
2,000
Meters
Prepared by:
WASAC.LTD
WASAC
Water & Sanitation Corporation



R2-7

REPUBLIC OF RWANDA

MINISTRY OF INFRASTRUCTURE

Water and Sanitation Corporation. Ltd

FINANCED BY: WASAC. LTD & JICA

Pressure Zone

Drawing No

Projected

Drawn

Verified

Approved

Scale

Date

Pressure Management

Nyamirambo Branch

Legend

- Proposed Location for PRV
- contour 10 Meters
- Additional PRV
- Proposed PRV

Pipeline

Pipeline Category

- Primary Main
- Secondary Distribution

N W E S

Coordinate System

Projected Coordinate System: ITRF_2005
Projection:Transverse Mercator,
False Easting:500000,
False Northing: 5000000,
Central Meridian: 30,
Scale Factor: 0.9999,
Latitude of Origin: 0.0,
Linear Unit: Meter,
Geographic Coordinate System: GCS_ITRF_2005,
Datum: D_ITRF_2005

0 25 50 100 150 200 Meters

Prepared by:

WASAC.LTD

WASAC Water & Sanitation Corporation

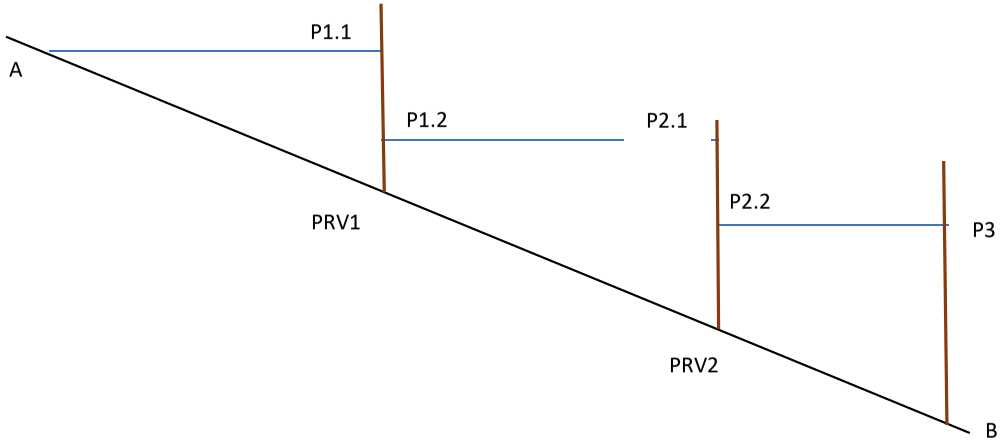
"Dignifying Life"

Pressure Reduction Plan by PRV

Allowable Cavitation Number (Can) = 0.5
P1: Primary Pressure
P2: Secondary Pressure **Cn: (P2+10)/(P1-P2)>Can0.5**
Acceptable max. pressure **140 m**

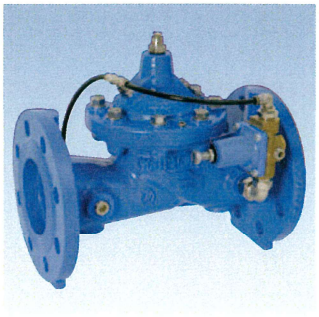
No	Names	Branch	Pipeline Material	Diameter	Water Source	Elevation (m)				Pressure (m)							Customer	Areas	Qleak x Customer	Priority
										PRV1		PRV2		P3	A-B	Pressure Reduction				
				mm	A	A	PRV1	PRV2	B	P1.1	P1.2	P2.1	P2.2	P3	m	m	POC	ha	CL x POC	
1	Gatsata	Nyarugenge	HDPE	160	Kabizoza 54	1,663	1,531	-	1,390	132	37	0	0	178	273	95	200	65.0	1.95	5
2, 3	Kabizoza	Nyarugenge	HDPE	90	Kabizoza 54	1,663	1,596	1,472	1,410	67	16	140	40	102	253	151	81	23.6	1.00	9
4	Kinyinya	Remera	PVC	90	Ntora 109	1,564	1,445	-	1,390	119	33	0	0	88	174	86	126	55.3	1.17	8
5, 6	National	Nyarugenge	HDPE	110, 63	Mt. Kigali 100	1,793	1,719	1,597	1,520	74	18	140	40	117	273	156	111	75.9	1.39	6
7	Near Former Gereza	Nyarugenge	PVC	110	Kimisagara WTP EL 1417m Pump 115m	1,532	1,439	-	1,390	93	24	0	0	73	142	69	457	42.9	3.79	3
8	Nyacyonga	Gikond	PVC	110	Rwandatel 144, exPRV 1535m	1,650	1,535	1,427	1,350	115	32	140	40	117	300	183	92	286.1	1.24	7
9	Rwampara	Nyamiranbo	PVC	90	Mt Kigali Bas 113	1,677	1,517	-	1,420	160	47	0	0	144	257	113	332	28.0	3.53	4
10	Rwarutabura	Nyamiranbo	HDPE	110	Mt Kigali Bas 113	1,677	1,535	-	1,460	142	41	0	0	116	217	101	772	71.3	7.77	1
11	Abanyamakuru	Gikond	PVC	160	Nyanza 116	1,703	1,563	-	1,476	140	40	0	0	127	227	100	441	41.1	4.41	2
12	Reservoir 72 Rwesero	Nyamirambo	PVC	100	Kigali Fuaut 101	1,790	1,609	-	1,583	181	54	0	0	80	207	127				

R2-8



Proposed PRV List

No	Names	Branch	Elev. of Water Source (m)	Elev. of PRV (m)	Elev. of Lowest Point (m)	Water Source	Source No	Source Name	Customer	Pipeline Category	Pipeline Material	Diameter (mm)	Areas (ha)
1	Gatsata	Nyarugenge	1,663	1,531	1,390	Kabizoza	Reservoir 54	Gatsata	200	Primary Main	PVC	DN160	65.0
2	Kabizoza	Nyarugenge	1,663	1,596	1,471	Kabizoza	Reservoir 54	Kabizoza	16	Secondary Distribution	PHDE Polyethylene	DN90 (3 '')	13.0
3	Kabizoza Additional	Nyarugenge	1,596	1,471	1,410	Kabizoza PRV	Reservoir 54	Kabizoza Additional	65	Secondary Distribution	PHDE Polyethylene	DN90 (3 '')	10.6
4	Kinyinya	Remera	1,564	1,444	1,390	Ntora Kinyinya	Reservoir 109	Kinyinya	126	Secondary Distribution	PVC	90	55.3
5	National	Nyarugenge	1,793	1,719	1,631	Mont Kigali	Reservoir 100	National	54	Secondary Distribution	PHDE Polyethylene	110	52.9
6	National Additional	Nyarugenge	1,719	1,631	1,520	National PRV	Reservoir 100	National Additional	57	Secondary Distribution	PVC	63	22.9
7	Near Former Gereza	Nyarugenge	1,417	1,439	1,390	Kimisagara WTP (Pump) (115 m)	WTP	Near Former Gereza	457	Secondary Distribution	PVC	110	42.9
8	Nyacyonga	Gikondo	1535+32	1,464	1,350	Rwandatel Exiting PRV+3.2 bar	Reservoir 144	Nyacyonga	92	Secondary Distribution	PVC	DN110 (4 '')	286.0
9	Rwampara	Nyamirambo	1,677	1,512	1,420	Kivugiza Nyakabanda (Mt. Kigali Bas)	Reservoir 113	Rwampara	332	Secondary Distribution	PVC	90	28.0
10	Rwarutabura	Nyamirambo	1,677	1,535	1,460	Kivugiza Nyakabanda (Mt. Kigali Bas)	Reservoir 113	Rwarutabura	772	Secondary Distribution	PHDE Polyethylene	110	71.2
11	Banyamakuru	Gikondo	1,703	1,563	1,476	Nyanza	Reservoir 116	Banyamakuru	441	Secondary Distribution	PVC	DN160	41.1



WATTS PR500 pressure reducing valve with flanges

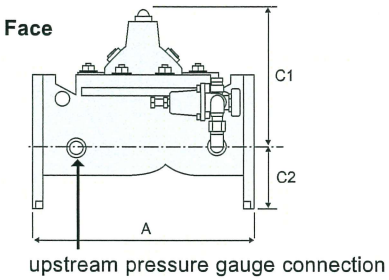
For all the drinkable water supply networks : building, distribution of water, industry, pumping.

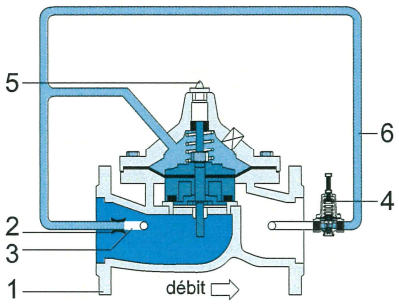
Stabilizes automatically the pressure downstream with the regulated value.

Very simple adjustment of the pressure by system screw and nut.
Body cast iron covered epoxy integral interior, outside
Seat : stainless.

Simple construction.
Minimum maintenance.

Max. pressure : 25bar
Max. temperature : 20°C
Adjustable : 1 to 7 bar,
(see cavitation curves).

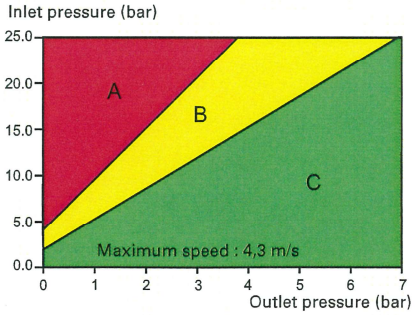




1 - Body / Main valve
2 - Fixed orifice
3 - Flow strainer
4 - Pilot valve
5 - Air vent
6 - Flexible tubing

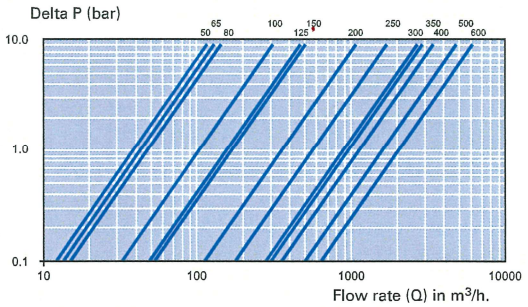
models	DN	PN	A (mm)	B1 (mm)	B2 (mm)	C1 (mm)	C2 (mm)	weight (kg)	pressure gauge connections
PR500-50	60	16	290	170	85	165	95	25	F 3/8"
PR500-65	65	16	290	170	85	165	95	25	F 3/8"
PR500-80	80	16	310	175	85	165	100	30	F 3/8"
PR500-100	100	16	350	190	120	210	110	40	F 1/2"
PR500-125	125	16	400	200	150	285	125	70	F 1/2"
PR500-150	150	16	480	210	150	285	145	90	F 1/2"
PR500-200	200	16	600	235	200	360	170	150	F 1/2"
PR500-250	250	16	730	280	255	475	200	400	F 1/2"

A Cavitation (unauthorized)
B Possibility of cavitation (not recommended)
C No cavitation (recommended)



Cavitation :
If the differential of pressure between the upstream and the desired downstream is too large, then it will be necessary to reduce the pressure in several stages by the installation of a series of pressure reducing valves. A high inlet pressure and a low downstream pressure can cause a deterioration of the valve by cavitation. To avoid this phenomenon, please refer to the curves opposite.

Exemple : 15 bar upstream, 1 bar downstream = cavitation, unauthorized
bar upstream, 4 bar downstream = no cavitation, authorized



diameter	range	type	ref. code
DN 50	1 to 7 bar	PR500 PN16	500 050 546
DN 65	1 to 7 bar	PR500 PN16	500 065 546
DN 80	1 to 7 bar	PR500 PN16	500 080 546
DN 100	1 to 7 bar	PR500 PN16	500 100 546
DN 125	1 to 7 bar	PR500 PN16	500 125 546
DN 150	1 to 7 bar	PR500 PN16	500 150 546
DN 200	1 to 7 bar	PR500 PN16	500 200 546
DN 250	1 to 7 bar	PR500 PN16	505 200 546

Annex 11: Operation & Maintenance Procedure of a Common PRV

PRVs need delicate operation. Stop valves should be slowly opened and closed with the speed of around a quarter turn per 5 seconds. In order to make the next operation easy, the valve handle should be slightly turned around in reverse after the valve is fully opened or fully closed. Pressure surges should be avoided to protect the pressure gauges on PRVs. The following shows steps of initial setting, operation, and maintenance of ordinary PRV.

1. Initial Setting

For the first time when a PRV is installed on line certain adjustments are needed for the PRV to function as desired. This process is known as Initial Setting. Valve manufacturers provide detailed instruction on how to conduct initial setting but for quick reference these steps are briefly outlined below.

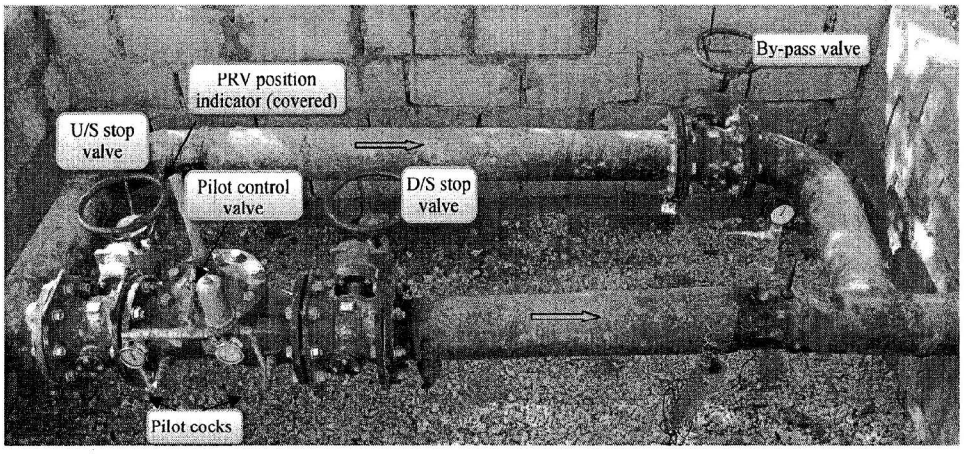
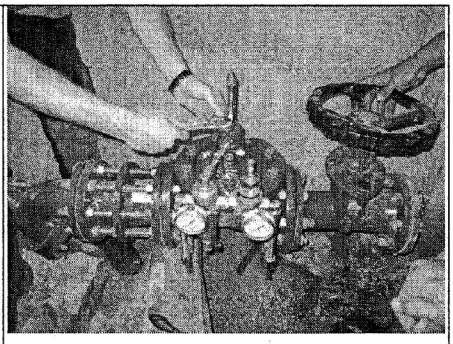
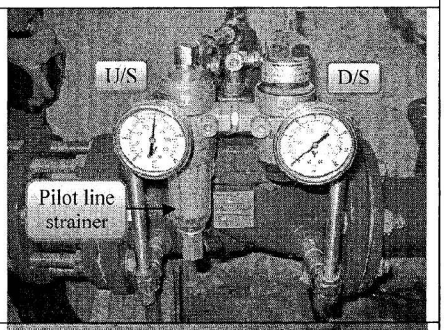
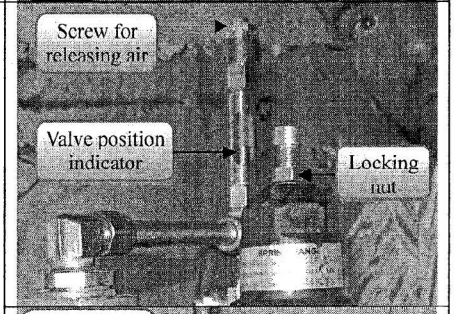
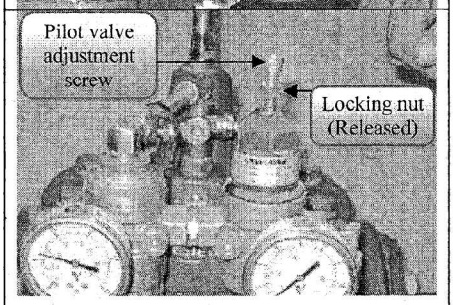
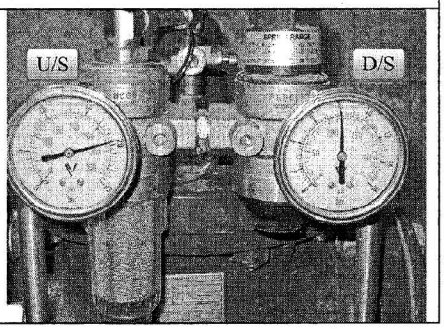
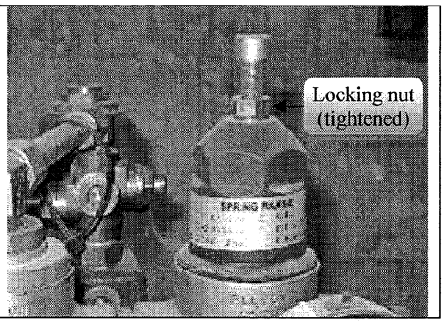


Figure A11-1: Outline of a simple PRV installation

Steps in initial setting:

① Install the position indicator which comes separately from the PRV assembly. (Refer to valve manufacture's manual for detail instructions)	
② Close the by-pass valve and both upstream and downstream shut-off valves on the main line.	Refer to Fig. A11-1.

③ Make sure that the main line is filled with water and water is available for supply through this line.	
④ Open fully both the stop-cocks on pilot line if they are not open.	Refer to Fig. A11-1.
⑤ Partly open the upstream (U/S) valve on the main line for controlled filling of the PRV. At this time the U/S pressure gauge should start showing some pressure but the D/S pressure should show no pressure as there is no flow and the PRV is still closed. ⑥ Purge the pilot line strainer by opening the valve on it and letting water flow through it.	
⑦ Release the locking nut to about middle position. ⑧ Loosen the screw at the top of the position indicator and let air-mixed water pass through it. When no more air bubbles are noted in the water, close the screw. ⑨ Open the U/S valve completely. Then partly open the D/S valve. ⑩ Turn the pilot valve adjustment screw clockwise (like tightening) slowly. This will start flow and operation of PRV. ⑪ Wait until the noise is reduced, vibration is subsided, and the D/S pressure gauge is stable showing some pressure. ⑫ Continue slowly the process of opening D/S valve and adjusting pilot valve. Allow enough time (a few minutes) between each adjustment for D/S pressure to stabilize. If excessive noise and vibration occurs, it may be due to air. Open the air venting screw a bit and let air-water pass until the noise subsides.	 
⑬ Once the D/S valve is fully open, adjust the pilot valve until the D/S pressure comes to the desired set pressure. For the setting, the U/S pressure should be more by at least about 2 bars than the desired D/S pressure, otherwise setting cannot be done. For example, if we want to set D/S pressure to 6 bar, the upstream pressure should be about 8 bars or more. If the U/S pressure has not reached yet that level, wait until the U/S pressure reaches that level.	

⑭ Once the initial setting is completed, fastened the locking nut of pilot control valve in order to fix the adjustment screw in this position. Once fixed, it is not necessary to adjust the pilot control valve in future unless a change in D/S pressure setting is required.	

2. Operation in intermittent supply

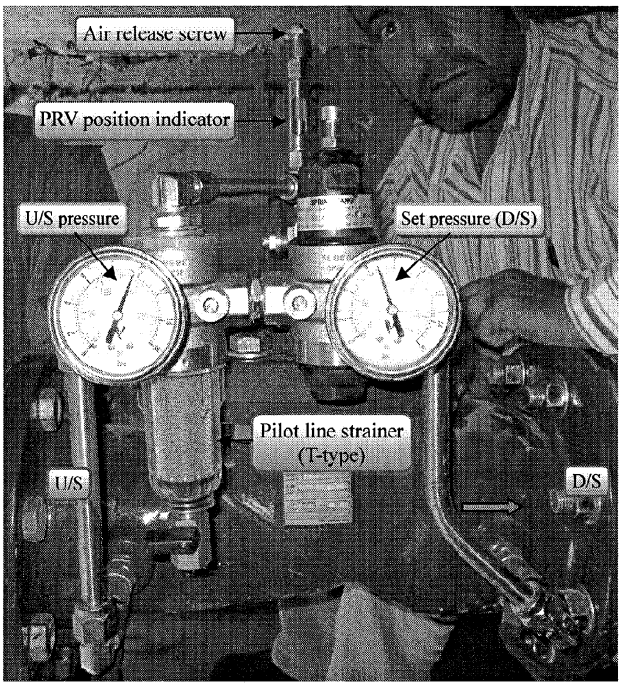


Figure A11-2: PRV assembly (showing pressure gauges, pilot control valve, and stop-cocks on pilot line for 16/25 bar PRVs)

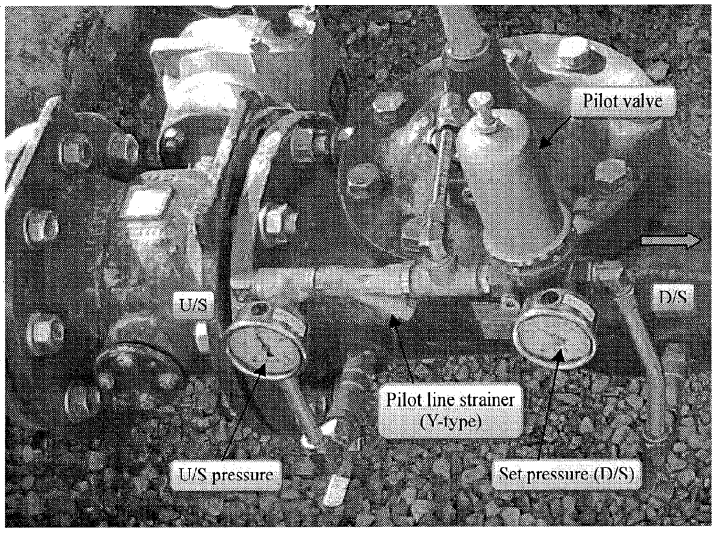


Figure A11- 3: PRV assembly (showing pressure gauges, pilot control valve, and stop-cocks on pilot line for a 40 bar PRV)

A. Operation during the beginning of supply

① Slowly open the U/S valve on main line (Ref. Fig. A11-1).

② Slowly open the D/S valve on the main line (Ref. Fig. A11- 1). PRV starts "pressure reducing function".

③ Confirm that the PRV controls downstream pressure at the setting pressure and there is no abnormal noise (Ref. Fig. A11-2, Fig. A11-3).

④ If noise persists, it may be due to entrapped air. Open the air venting screw and allow air-water mix to pass. Close the screw once the noise is reduced.

B. Operation during supply period

① It should be confirmed that stable operation of the PRV continues (Ref. Fig. A11-2.)

C. Operation for stopping water supply

① Close the D/S valve (Ref. Fig. A11-1) slowly. Valve position indicator (Ref. Fig. A11-2) of PRV remains "Open".
- Indicator is at the bottom: PRV is fully closed,
- Indicator is at the top: PRV is fully opened,
- Indicator is in between: PRV is controlling pressure by opening/closing partially.

② Close the U/S valve (Ref. Fig. A11-1) slowly.

③ If there is any additional valve on U/S side, close it fully.

D. Operation after stopping water supply

① In order to make the next operation easy, the valve handle should be slightly turned around in

reverse after fully closing the valves.

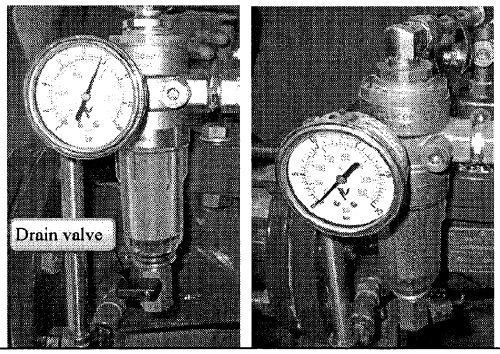
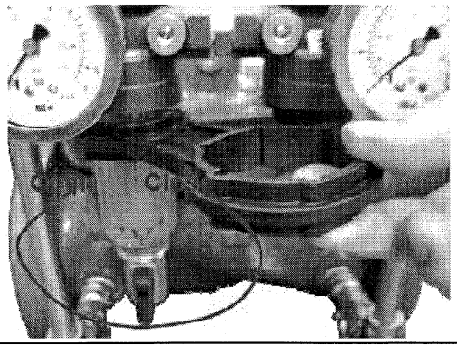
② Pressure gauges (both U/Sand D/s) of pilot line should indicate zero pressure.

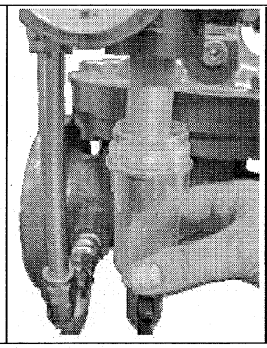
3. Maintenance

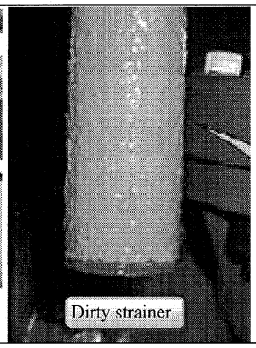
Maintenance of a PRV includes cleaning of strainer on the pilot line and checking inside for any damage to diaphragm, guiding rod, and valve body. In addition, periodic cleaning of strainer on the main line is also necessary to protect PRVs from foreign objects.

The filter in the pilot line should be cleaned periodically in accordance with the condition of filter. Types of filter on pilot line differ depending upon the rating of PRV. For PRV up to 25 bar T-type strainers are generally used and when the rating is above 25 bar Y-type strainers are used. The main differences between these types are filter casing and stop cocks on these filters. The T-type filter has a transparent plastic case and easy opening stop cock while the Y-type strainer has metallic case and opening is by unplugging end cap.

A. Cleaning of T-Type strainer

① Figures on right-hand side show a clean and slightly dirty T-type strainer. When the filter is only slightly dirty it can be cleaned by purging with water. In order to purge the strainer, keep the stop-cocks on pilot line open and open the drain valve of the strainer. Water will rush through the strainer and out through the valve. This will flush out the loosely attached dirt from the filter.	
② When the filter is very dirty cleaning by purging alone is not enough. It should be cleaned by taking out of its case. For this, ➢ Close both the stop-cocks on pilot line, ➢ Drain the filter by opening the valve in the filter, ➢ Remove the plastic case with special tool provided, ➢ Clean the soiled filter with water and soft brush, and ➢ Reinstall the filter after cleaning and put back the case with the tool provided.	

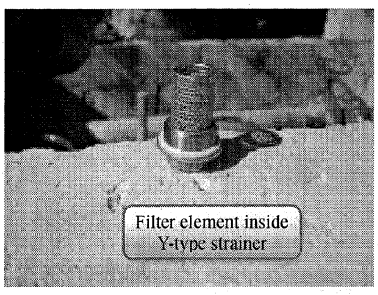




B. Cleaning of Y-Type strainer on pilot line

① Unlike T-type strainer, there is no provision to flush Y-type strainer. The strainer should be removed from its case, cleaned, and put back.
- Unscrew the plug
- Remove the strainer from the casing
- Clean with water
- Reinsert and tighten

Ref. to Fig. A11-3.



C. Cleaning of Y-Type strainer on the main line

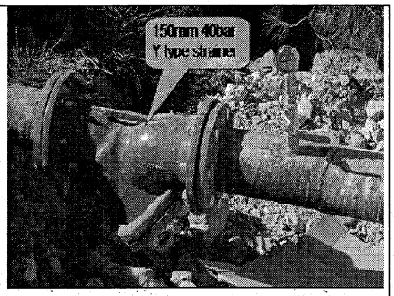
① Isolate the section containing the strainer by closing valves on upstream and downstream sides.

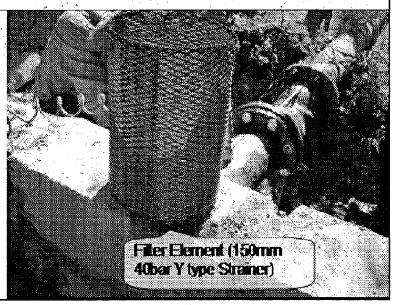
② Take out the filter element by removing the blind flange.

③ Clean the filter element with clean water.

④ Reinsert the element, put back the flange and tighten.

⑤ Make sure that there is no leak from the flange. If it leaks, tighten more or remove once and insert again.





D. Checking diaphragm condition

Condition of diaphragm can be checked for possible damage without opening valve body as follows:

① Close the D/S side of the shut-off valve.

② Close both shut-off ball valves on the control circuit.

③ Open the venting screw on the position indicator.

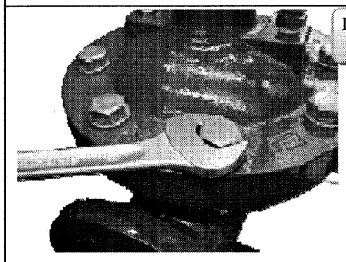
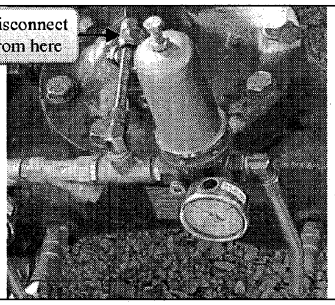
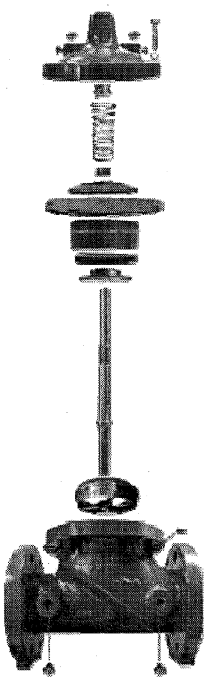
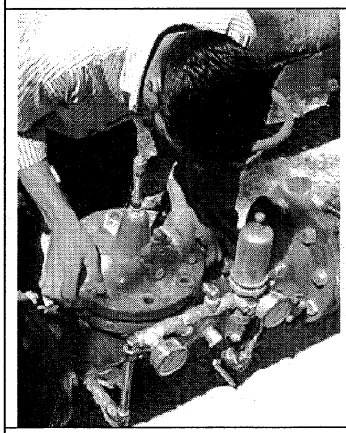
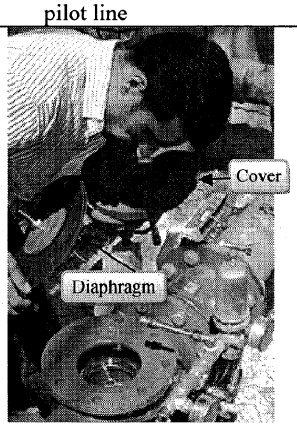
④ The PRV must open and the water must escape from the diaphragm chamber through the venting hole.

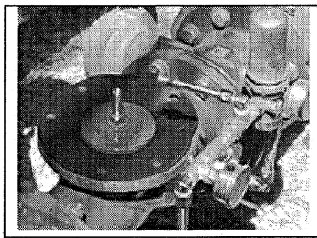
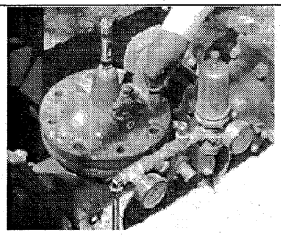
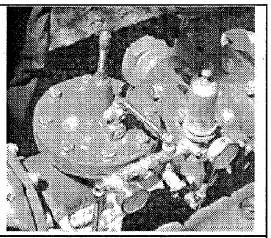
⑤ When the valve is completely open no water should escape any more.

⑥ If water continues to escape the diaphragm is damaged.

E. Opening and closing valve body for visual check and repair

For visual check of diaphragm, valve guiding rod, or other parts the valve body must be opened. Follow these steps for opening and closing the valve body.

<table>
<tr><td colspan="3">① Dismantling valve body</td></tr>
<tr><td>  </td><td> 
</td><td rowspan="2">  </td></tr>
<tr><td>a. Remove the bolts</td><td>b. Disconnect the top portion of pilot line</td></tr>
<tr><td>  </td><td> 
</td><td></td></tr>
<tr><td>c. Remove the top by pulling it up</td><td>d. Inspect if there is any damage or abnormality on diaphragm, guiding rod etc.</td><td>e. Parts of the valve</td></tr>
<tr><td colspan="3">② Assembling</td></tr>
</table>

		
a. Put back the diaphragm assembly, make sure that the end of the guiding rod is placed on the hole at the bottom	b. Put back the bolts and nuts, do not tighten them yet	c. Reconnect the pilot line to the valve cover, tighten it and the bolts on the cover

Progress report of Protective Equipment Installation/ Rehabilitation Plan

S11

Branch KACYIRU

Period DECEMBER 2019

	Plan								Implementation	
N	Equipment to be rehabilitated	DN of the equipement (mm)	Place/Location	State of the equipement to protected	Work requested (New installation /Replacement / Maintenance)	Coordinates (X,Y)		Budget (Rwf)	Status (%)	Observation
	[Sectionning valve]									
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Prepared by (Water Distribution Officer)

Approved by (Branch Manager)