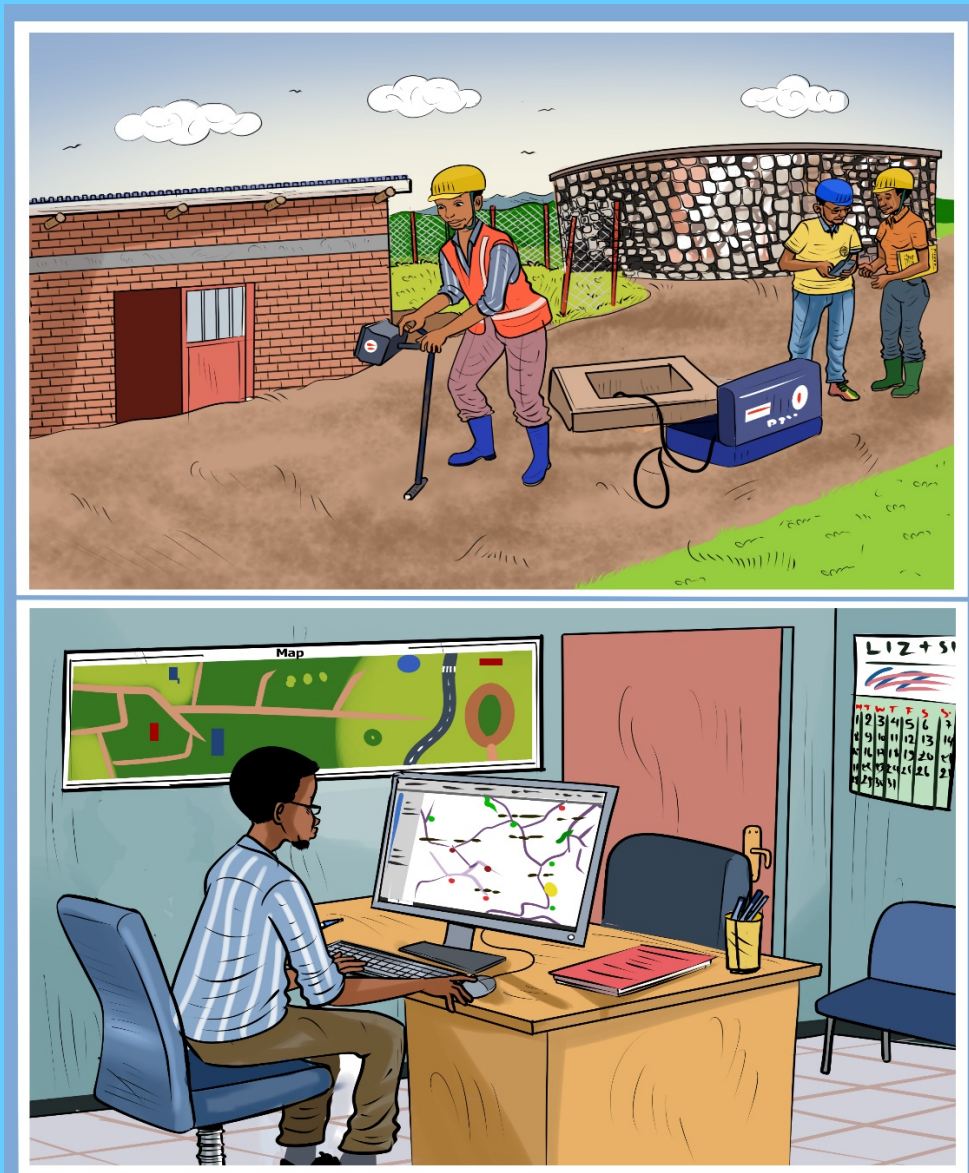


REPUBLIC OF RWANDA



MINISTRY OF INFRASTRUCTURE

District and Private Operator's Manual for Operation and Maintenance of Rural Water Supply Systems



Edition 2.0

May 2019

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Preface

Access to safe drinking water is crucial, not only for people's health and wellbeing, but also for poverty reduction and economic development; Improving the access, quality, availability and sustainability of water supply services in RWANDA is the top priority in the Sector; Rwanda has committed to reach SDGs targets by 2030 through the different programs such as the NST1 and 7 Years Government Program with the aim of achieving universal access to basic water and sanitation services by 2024. In order to achieve this target, an appropriate institutional system has to be in place.

The development of the National guidelines for Sustainable Rural Water Supply Services and all its supporting documents (Manuals, Training Modules, etc.) is part of the mechanism to develop the Operation and Maintenance in the Rural Water Supply, and make an important guidelines to Districts, Private Operators, User communities and all the stakeholders in the Rural Water Supply Services sub-sector.

I want to extend my appreciation to the stakeholders, especially JICA/RWANDA through the RWASOM Project, for the effort to have these important documents in place.

We look forward to positive impact of the developed documents through the O&M framework in the rural water services, sustainability of existing water infrastructures and overall, an improved and sustainable clean water supply service toward the communities in RWANDA.


Patricie UWASE

PERMANENT SECRETARY



Acknowledgements

The first edition of this guideline was produced through the “PPP for increased access to Sustainable Water Services in Rwanda (SusWas Project)” funded by NL EVD International, Programme FDW in 2015.

The elaboration of this second edition of guideline has been facilitated by the “Project for Strengthening Operation and Maintenance of Rural Water Supply Systems in Rwanda (RWASOM Project)” under the technical cooperation by Japan International Cooperation Agency (JICA) in 2017.

A series of workshops were held by the RWASOM Project, and lot of stakeholders in Water and Sanitation Sector, including four model Districts (Rwamagana, Kayonza, Ngoma and Kirehe) and Private Operators in Eastern Province contributed in the formulation of this second edition.

Special thanks are due to Mr. NIWENSHUTI Emmanuel (Head of the Operation and Maintenance Unit, Department of Rural Water and Sanitation Services, WASAC), and District WATSAN Officers in four model Districts, and FEPEAR, AYATEKE Star Company, Ltd, Ubuzima Bwiza Cooperative and WATRESCO for the enormous involvement in developing this second edition of the guideline.

NL EVD International, Programme FDW and JICA is acknowledged for the financial and technical support provided in the development of this guideline.

Without the support and active participation of all stakeholders mentioned above, in addition to many more we have not named, this guideline would never have been completed. Ministry of Infrastructure and WASAC gratefully acknowledges all the support received.

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Appendix II: Example contract: private connection

Attachment

- Attachment 1: Template of Operation and Maintenance Manual for Rural Water Supply System
- Attachment 2: Training Module on Procedure of Operation and Maintenance for Pipe Water Supply Systems

Abbreviations

DMA:	District Metering Areas
FEPEAR:	Forum des Exploitants Prives pour l'Eau et l'Assainissement en milieu Rural
GIS:	Geographic Information System
IWA:	International Water Association
NRW:	Non-Revenue Water
O&M:	Operation & Maintenance
PE:	Polyethylene
PO:	Private Operator
PVC:	Polyvinyl Chloride
PPP:	Public Private Partnership
RURA:	Rwanda Utilities Regulatory Authority
RWSS:	Rural Water Supply and Sanitation
WASAC:	Water and Sanitation Corporation
WATSAN:	Water and Sanitation
WHO:	World Health Organization

1. INTRODUCTION

1.1 Background

The public and private partnership (PPP) contract for rural water supply systems in Rwanda obliges private operators (POs) to develop their own operation and maintenance (O&M) manual for each and every water supply system.

As the result of the baseline survey in 2015 of the Project for Strengthening Operation and Maintenance of Rural Water Supply Systems in Rwanda (so called as “the RWASOM project”), there is no PO who provided their own O&M manual among 69 water supply systems in the 4 model districts (Rwamagana, Kayonza, Ngoma and Kirehe). One of big challenges is to develop O&M manual by POs. Because POs don’t have enough skills and staffs to develop the manual by themselves.

SusWAS project developed “District and Private Operator’s Guideline for Operation and Maintenance of Rural Water Supply System in Rwanda”. This document serves as a tool for PO to develop their own O&M manual.

Based on this guideline, RWASOM project developed the “Template of O&M manual (See Attachemnt 1)” as the training tools to develop O&M manual.

RWASOM project also developed the “Training Module on Procedure of Operation and Maintenance for Rural Water Supply Systems” (See Attachemnt 2) focusing on operation, preventive maintenance and curative maintenance by facility to make POs easy to understand the procedure of O&M and help POs to develop their own manual by themselves.

As the countermeasure against this challenge, the RWASOM project conducted the 1st training on 20th and 21st March 2017 and the 2nd training on 18th and 19th September 2018 to build the capacity of staffs of Districts and POs in the 4 model districts to develop O&M manual using these documents as the training materials.

Based on the experience of these trainings, these documents were combined as the “*District and Private Operator’s Manual for Operation and Maintenance of Rural Water Supply System*” as the package of tools to develop O&M manual.

1.2 Objective

The aim of this Document is to provide guidance to the District and Private Operator (PO) in order to have effective and professional operation and maintenance (O&M) of the rural water supply systems.

Specific objectives of are the followings.

- 1) To make POs’ staffs easy to develop O&M manual
- 2) To be used as the training tools for the training WATSAN officers and POs’ staffs to develop O&M manual

1.3 Output

Outputs of this document are the followings.

- 1) O&M manual for each and every rural water supply system in Rwanda will be developed.
- 2) Districts will be able to calculate real O&M cost including depreciation cost to prepare the budget for future operation, maintenance and rehabilitation of water supply system.
- 3) Developed O&M manual will be used as the part of tender documents for the selection of PO for the delegated management contract.
- 4) POs will be able to estimate appropriate O&M cost for the financial proposal of the tender.
- 5) Operation and maintenance for rural water supply services will be improved

1.4 Target group

The direct target group of this guide are PO's managing (or willing to manage) rural water supply systems in Rwanda. The guide serves as a tool for PO's to develop their own O&M manual.

The Districts will use the O&M manuals to monitor the O&M practices of the PO.

1.5 How to use this manual

The PPP contract for rural water supply systems in Rwanda obliges PO to develop an O&M manual according to this guideline.

In order to develop their own O&M manual, PO should follow all chapters of this guide and should collect and record the relevant data for their water supply system(s).

This should result in a document that covers all subjects as described in this guide. This document and its annexes (such as maps and procedures) should be submitted to the District for approval.

The O&M manual should be updated at least yearly after an evaluation-meeting of PO and district.

The Districts are responsible for the monitoring of the O&M practices of PO's.

The current guide also focuses on subjects of particular importance for Districts, notably with respect to asset management and monitoring and evaluation of O&M.

2. GENERAL INFORMATION

2.1 Information to be kept by PO's

2.1.1 Contact details

At least the following information should be included:

Private Operator

- Company Name;
- Company Representative Name;
- Contact person(s);
- Physical Address(es);
- Phone number(s);
- E-mail

District

- Name of District;
- Contact person(s);
- Phone number(s)
- E-mail;
- Website

2.1.2 Contract information

- Start and end date of PPP contract;
- Name of the water supply system(s) managed by the PO;
- Map of the area in which the water supply system(s) are located.

2.1.3 Staff

The PO includes a list of employed staff, with at least the function, name of employee, educational/training level and starting date.

The following list serves as an example and can be extended according to the PO's needs.

Table 1: List of PO's staff

No	Function	Name	Educational/ training level	Date of employment
	Manager			
	Accountant			
	Marketing Officer			
	Water meters reader			

No	Function	Name	Educational/ training level	Date of employment
	Pumping station officer			
	Treatment unit officer			
	Network technician			
	Electro mechanic			
	Plumber			
	Warehouse manager			
	Caretaker			

2.2 Information to be kept by Districts

2.2.1 Overview water supply systems

For each water supply system under delegated management of a PO, the District should collect and record:

- Name of the water supply system(s);
- Lengths of the water supply systems;
- Name of the private operator, contact person, address and phone number;
- Start and end date of PPP contract;
- Map of the location of the water supply system(s).

2.2.2 Staff

The District should keep a list of staff employed in the domain of water supply, with at least the function, name of employee, educational/training level and starting date.

The following list serves as an example and can be extended according to the District's needs.

Table 2: List of the district staff

Function	Name	Educational/ training level	Date of employment

3. DESCRIPTION OF WATER SUPPLY SYSTEM

In this section the PO provides general and current information about the different components of his water supply system(s). He describes the different components, their specifications and includes actual and current date drawings and additional information such as manufacturer's manuals and contact details.

The information in this section should not reflect the original, but the actual situation.

On an analogue drawing or in a GIS-system from all assets mentioned in this chapter, the following should be registered:

- X and Y coordinate related to the system used in Rwanda
- Z coordinate, the vertical distance to the reference level used in Rwanda

3.1 Water intake

Provide a description of the source(s) of supply:

3.1.1 Surface source(s)

Include a map of the catchment area including the drainage area in km², location of the water system facilities and names of major water sources.

3.1.2 Well (s)

- Describe the location, diameter, depth, length of casing, static water level, pumping water level, pumping rate, date of installation.
- Describe the drainage area around well site, nearest source of pollution, well seal, and well enclosure.
- Describe the land ownership access and control.

3.1.3 Spring(s)

Describe the location, capacity, enclosure, land ownership, access and control.

3.2 Treatment process

- Describe the treatment process in general terms.
- Include a flow diagram of the treatment facilities.
- Describe each part of the treatment process.

3.2.1 Intake of raw water source

- Describe the control gates or valves including size and type of operation.
- Describe any bar screens or trash removal facilities.
- Describe any raw water pumps.
- Include dates facilities were installed and/or modified.

3.2.2 Chemical additions

- Provide the name of the chemical applied, chemical formula and concentration (percentage of active content), name of chemical supplier.
- Indicate the type of chemical feeder, manufacturer's name, model number, maximum capacity, normal range of feed rates and date of installation.
- Describe where the chemical is applied to the water, what controls the dosage of chemical and what tests are made to determine dosage.
- Describe the safety precautions applicable to this chemical.

3.2.3 Rapid mix

- Describe the size, capacity and number of units of rapid mix chambers.
- Describe the detention time at design flow rate.
- Describe the mechanical mixers, manufacturer, size, model, speed and date of installation.

3.2.4 Flocculation

- Describe the size, capacity and number of units of the flocculator chambers.
- Describe the detention time at design flow rate.
- Describe the mechanical flocculates, including manufacturer, size, model, speed and date of installation.

3.2.5 Sedimentation

Describe the size, capacity, number of units, detention time at design rate and date of installation of the sedimentation basins.

3.2.6 Filters

Describe the filters size, the number of units, the filter material, capacity, filtration velocity, date of installation, type and size of filter valves.

3.2.7 Clear well

Describe size, detention time at rated plant capacity.

3.2.8 Disinfection

- Describe the disinfectant used.
- Chlorine feed equipment, point of application, and maximum capacity of chlorinators.

3.3 Pumps

Describe the type of each pump, size, capacity, flow rate per minute, manufacturer, model number, type of motor, motor manufacturer, power of the motor and pressure controls.

3.4 Storage facilities

- A drawing of the construction of the reservoir
- Describe the capacity, materials of construction, coatings, valves.

3.5 Transmission and Distribution system(s)

- Attach a detailed map of the transmission and distribution system.
- Include the following information for:

Mains:

- Nominal diameter [mm]
- Material
- Pressure class or other specification of the material
- Wall thickness [mm]
- Year of installation
- Total length of all the mains

Valves:

- Registration number
- Regular status (open or closed)
- Type of valve (butterfly, gate)
- Year of installation
- Total number of valves

Hydrants:

- Registration number
- Type (aboveground, underground)
- Nominal capacity
- Year of installation
- Total number of hydrants

Water points:

- Registration number
- Construction drawing
- Year of installation
- Total number of water points

House connections:

- House address
- Diameter of service connection

- Material of service connection
- Year of installation
- Registration number of water meter
- Total number of house connections

4. ASSETS

This section describes the responsibilities and activities of Districts and PO's with respect to the management of assets.

4.1 Asset roles

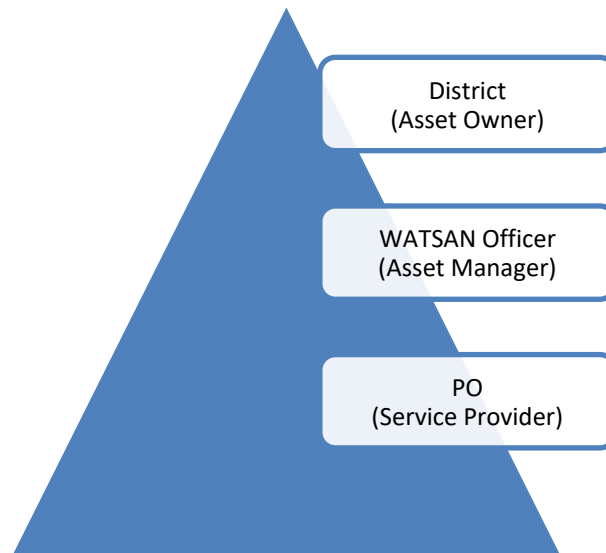


Figure 1: Asset roles

With respect to the management of the rural water supply infrastructure, three different asset roles can be defined.

The District is the owner of the assets and has the responsibility to provide the population with access to water supply. The District may delegate the daily management and operations of the water supply system to a PO (Service Provider), but remains responsible for a proper functioning of the infrastructure.

Therefore, the District should appoint a WATSAN officer (Asset Manager), who monitors the performance of the PO on behalf of the District.

4.2 Asset inventory

As owner of the rural water supply system(s), the District should have a complete overview of the assets.

The following sheet can be used to make an inventory and can be adapted according to the District's needs:

Table 3: Asset inventory sheet

Asset inventory sheet				
Completed/updated: date				
Asset	Year of construction	Theoretical technical lifespan	Acquisition cost	Book value
<i>Name of asset</i>	<i>(Estimated) year in which the asset was constructed</i>	<i>See list of theoretical technical lifespan</i>	<i>(Estimated) original cost of the asset</i>	<i>The value of the asset as it appears on the balance sheet</i>
Pump, located in place X	2006	10		
Reservoir, location X	1993	40		
PVC main pipeline	1995	30		

Source: table adapted from EPA, 2003, *Asset Management: A Handbook for Small Water Systems*, http://epa.gov/safewater/smallsystems/pdfs/guide_smallsystems_asset_mgmt.pdf

(1) Theoretical technical lifespan

The theoretical technical lifespan of an asset can be determined by using the manufacturer's recommendation or the following data.

Table 4: Theoretical technical lifespan

Asset category	Amortization period (year)	Depreciation rate (%)
Buildings	50	2
Civil Engineering Works	50	2
Wells and springs	30	3.33
Cast iron pipelines	50	2
PVC pipelines	30	3.33
PE pipelines	30	3.33
Connections	10	10
Water meters	10	10
Plumbing accessories (faucets, valves)	20	5
Electro-mechanical equipment	10	10

(2) Book value

The book value of an asset can be determined by reducing the acquisition costs of an asset with the accumulated depreciation.

For example: if the acquisition cost of an asset amounts to FRW 5,000,000 and the technical lifespan is 10 years, **the yearly depreciation** will be:

$$\text{FRW } 5,000,000 / 10 = \text{FRW } 500,000.$$

One year after construction, **the book value of the asset** will be:

$$\text{FRW } 5,000,000 - 500,000 = \text{FRW } 4,500,000.$$

Two years after construction, **the book value of the asset** will be:

$$\text{FRW } 5,000,000 - 500,000 - 500,000 = \text{FRW } 4,000,000 \text{ etc.}$$

4.3 Asset management

As owner of the assets, the District is also responsible for replacement. In order to plan for replacement, the District should have knowledge about the condition of the assets.

The following list can be used to plan for replacement. The table serves as an example and can be adapted according to the District’s needs.

Table 5: Asset management sheet

Asset management sheet							
Completed/updated: date							
Asset	Year of construction	Theoretical technical lifespan	Condition	Service history	Functional lifespan	Year of replacement	Priority
Name of asset	(Estimated) year in which the asset was constructed	See list of theoretical technical lifespan	Good, reasonable, poor	Maintenance activities, rehabilitation	Theoretical Technical Lifespan adjusted for condition and service history	Year of Construction + Functional Lifespan	The priority to replace the asset (1 is highest)
Pump, located in place X	2006	10	Good	Rehab. 2009	10	2016	2
Reservoir, location X	1993	40	Average		35	2028	3
PVC main	1995	30	Poor	3 repairs in 2012, 2 repairs in 2011	17	2012	1
Name of asset	(Estimated) year in which the asset was constructed	See list of theoretical technical lifespan	Good, reasonable, poor	Maintenance activities, rehabilitation	Theoretical Technical Lifespan adjusted for condition and service history	Year of Construction + Functional Lifespan	The priority to replace the asset (1 is highest)

Prior to the delegation of the management of a water supply system, the District should complete an asset management sheet. This sheet should be added to the tender document and the PPP contract itself. This allows POs to prepare an accurate offer. Without this information the PO needs to take into account uncertainty, which is likely to result in a much higher bid.

For water supply systems of which the management has already been delegated to a PO without an asset management sheet being part of the contract, the sheet should still be completed as soon as possible. Although the District can request the PO's assistance, she remains the ultimately responsible for the presence of the sheet.

The District should request the PO for a yearly update of the asset management sheet, containing actual information with respect to the:

- Condition of the asset;
- Service history in that year;
- Expected functional lifespan;
- Expected year of replacement;
- Priority of replacement.

The District's WATSAN officer should check the updated inventory that has been submitted by the PO, among others through field visits.

In case the information is incomplete or faulty, the WASH officer should make sure the PO delivers the additional or right information so that the asset inventory is complete and up-to-date.

(1) Functional lifespan

The functional life span can be estimated by using the theoretical lifespan as an indication and considering the asset's current condition and service history.

For example: if the asset is in a poor condition and needs to be repaired often, the functional lifespan might only be 12 years, although the technical lifespan has been fixed at 20 years.

(2) Priority

The priority to replace the assets can be defined by taking into account:

- The year of replacement;
- The importance of the asset for water supply;
- The possible damage caused to its surroundings in case of rupture of the asset (for example main road).

4.4 Asset budget

The District should, if necessary in cooperation with the PO, estimate the costs to replace using an asset budget sheet.

The following sheet serves as an example and can be adapted according to the District's needs.

Table 6: Asset budget sheet

Asset budget sheet				
Completed/updated: <i>date</i>				
Asset (list from highest to lowest priority)	Activity	Years until action needed	Costs expected	Reserve required current year
<i>Name asset</i>	<i>Replacement</i>	<i>= year in which replacement is needed minus the present year</i>	<i>To be determined for example by discussion with contractors, operators or other Districts</i>	<i>Costs divided by the years until action is needed</i>
Total reserve required in current year				<i>= Total of reserve required for all assets</i>

Source: table adapted from EPA, 2003, *Asset Management: A Handbook for Small Water Systems*, https://www.env.nm.gov/dwb/assistance/documents/Item35-43_EPAguide_smallsystems_asset_mgmt.pdf

5. SERVICE QUALITY

In this section the Private Operator provides information on the level of service quality he attains.

5.1 Standards

The following table summarizes the existing standards the PO should meet with respect to service quality.¹

Table 7: Standards of the water supply services quality

SUBJECT	STANDARDS
Water quality	95% of the water samples should be within Rwandan standards and/or WHO standards.
	Water sampling should meet the following requirements: <ul style="list-style-type: none"> ○ Frequency at least monthly ○ Number of samples at least 1 per 5,000 people served ○ At least three different locations of sample taking (raw water, distributed water, water at public taps and/or house connections).
Water pressure	The pressure of water supplied should at all times be in the range of (6 - 50 meter water column).
Reliability of supply	A minimum of 13 service hours, from 6.00- 19.00, should be guaranteed for each water point (public tap and private connection). Only in consultation with users, the number of service hours can be reduced.
Connections	New customers should be connected within 10 days in the case a water supply system is available at their property boundary.
	A contract should be signed between the PO and owner of the private connection, indicating the responsibilities of each party. See annex.
	A contract should be signed between the PO and tap manager indicating the responsibilities of both parties. See Annex 1.
Water metering	All water points should be metered.
	Meters should be read at least once monthly.
	Upon request of the customer, a water meter should be checked by the PO within 5 working days.
	A water meter should be repaired or replaced within 1 working day after the meter has been identified by the PO as faulty.
Billing	The bill collection efficiency should at least be 95%.
	Bills should be provided at least monthly.
	Bills should contain at least:

¹ This table is made after consultation of the RURA guidelines, the new PPP contract and the input of the workshop of March 2014.

SUBJECT	STANDARDS
	<ul style="list-style-type: none"> ○ Name of customer/ number of public tap ○ Period ○ Quantity of water consumption ○ Tariff per quantity ○ Other charges ○ Total amount
Complaints	Complaints should be dealt within 5 working days.
Disconnection & Reconnection	<p>Customers should pay their bills within 10 days. When payment is late more than 10 but less than 15 days, the customer should be disconnected after a written warning. When payment is late more than 15 days, the customer should be disconnected and the water meter should be removed after a written warning.</p> <p>Customers that have been disconnected because of non-payment should be reconnected within 24 hours after having settled their accounts and should pay all costs for reconnection.</p>

5.2 Records and procedures

The PO should make transparent to what extent he meets the requirements for service quality by providing the following information.

5.2.1 Water quality

- Provide a record of sample taking, including at least information on date, location and result of sampling and - in case the sample did not meet the Rwandan standards and/or WHO standards - the action that has been carried out.
- Indicate the percentage of water samples that are within Rwandan standards and/or WHO standards.

5.2.2 Water pressure

- Indicate the minimum and maximum pressure that has been measured in the water supply system.
- Provide a record of locations that did not meet the prescribed minimum or maximum level of water pressure, including at least information on the duration and level of pressure.
- Procedure for informing customers in case of insufficient pressure; how, who etc.

5.2.3 Reliability of supply

- Indicate the minimum number of service hours that is guaranteed for all public taps and private connections in the water supply system.
- Provide a record of cases where the minimum of 8 service hours a day has not been achieved.
- Procedure for indicating the service hours at public taps and at local offices.

- Procedure for informing customers in case of planned works which caused temporarily absence of water delivery.

5.2.4 Connections

- Indicate the percentage of customers that has been connected within 10 days.
- Provide a record of requests for new connections, at least containing date of request and date of connection.
- Include an example of a contract between the PO and a customer with a private connection.
- Include an example of a contract between the PO and public tap manager.

5.2.5 Water metering

- Indicate the percentage of water points that are metered.
- Provide a list of all water meters in the network and its monthly meter readings.
- Provide a record of customer requests for meter testing, at least containing name of customer, date of request, date of meter testing, result of test and date of action (replacement or not).
- Provide a similar record for meter testing initiated by PO.

5.2.6 Billing

- Indicate the percentage of bill collection efficiency.
- Include an example of a bill for private customers and for public taps.
- Procedure for bill collection efficiency, specifying the actions that will be taken to improve the bill collection efficiency.

5.2.7 Complaints

- Indicate the percentage of complaints that is dealt with within 5 working days.
- Provide a record of complaints containing at least date and description of complaint, action taken to solve complaint and date of action.
- Procedure for dealing with complaints.

5.2.8 Disconnection & Reconnection

- Indicate the percentage of customers that is reconnected within 24 hours after having settled their accounts.
- Provide a record of disconnections, containing at least name/ location, amount of debt, and date of disconnection.
- Include a record of reconnections, containing at least name/ location, date of settling debts and date of reconnection.
- Procedure for/ file of written warnings of disconnection.

5.3 Action plan

In case the PO does not achieve the required level of service for one or more of these points, he should submit a Service quality action plan to the District.

In this plan, the PO specifies the actions that will be taken to achieve the required level of service including a realistic time schedule.

6. OPERATIONS

In this section the Private Operator provides information on the operation of the water supply system(s).

6.1 Operational procedures

For at least the following components, the PO describes the actions that should be carried out to guarantee a normal functioning of the system, specifying by whom.

6.1.1 Water intake

PO defines in the operational procedure for the intake among others:

- Keeping clean and tidy the surroundings of the intake
- Removing debris from the intake
- Cleaning of screens
- Cleaning/flushing of sand trap
- Manipulation of valves

6.1.2 Treatment process

PO defines in the operational procedure for the treatment process among others:

- Routine daily checking of installations
- Keeping clean and tidy the interior and surroundings of the treatment plant
- Preparation of chemical solutions
- Cleaning of screens
- Operation of dosing pumps
- Manipulation of valves
- Taking of samples
- Execution of Jar tests
- Fine-tuning of treatment process
- Backwashing of filters

6.1.3 Pumping system

PO defines in the operational procedure for the pumping system among others:

- Routine daily checking of engine and pump
- When to turn on/ switch off which pump
- How to turn on / switch off a pump
- How to regulate the pressure in the distribution system

6.1.4 Storage facilities

PO defines in the operational procedure for the storage facilities among others:

- Keeping clean and tidy of the surroundings of the storage facility
- Manipulation of valves

6.1.5 Transmission and distribution system

PO defines in the operational procedure for the transmission and distribution system among others:

- Manipulation of valves
- Reading of water meters
- Registration of all changes in the network
- Registration of complaints with a technical origin
- Supplying water to the customers at the public tap

6.1.6 Public tap

PO defines in the operational procedure for public taps among others:

- Keeping clean and tidy the surroundings of the public tap
- Checking for leakages
- Calibration of water meters

6.2 Common operational problems

For the most common operating problems, the PO should prepare a list including a description of the problem, its possible cause and possible remedy.

The following table serves as an example and should be adapted according to the specific features of the PO's water supply system.

Table 8: Example of the operational problems

Problem	Possible cause	Possible remedy
No water		
Flooded Pressure Tank		
Low Water Pressure in Distribution System		
Public disease outbreak caused by waterborne bacteria/parasites		

6.3 Operational records

Records of operation provide information on the functioning of the water supply system.

Private Operators should at least keep records on:

- ◆ Volume produced per hour
- ◆ Pumps
 - Running times (hours)
- ◆ Reservoirs
 - Water level per hour
 - System pressure per hour if manometers are installed
- ◆ Water quality tests
 - Date of testing

- Location in network
- Test result
- Actions taken
- ◆ Chemicals
 - Volume and type of chemicals used per day
- ◆ Water meter testing
 - List of meters that are tested
 - Date of testing
 - Test result
 - Actions taken

7. MAINTENANCE

In this section the Private Operator provides information on his preventive and curative maintenance program. The following subjects should be included in this program.

7.1 Maintenance tools

The PO provides a list of the available tools for maintenance activities and specifies the number of items he possesses. He should also indicate the responsible person for these tools.

The following list serves as an example and should be adapted or extended according to the PO's needs.

Table 9: Example of the list of the tools for maintenance activities

No.	DESCRIPTION OF TOOL	Qty
1	Ratcheting pipe threaders	
2	Adjustable wrenches	
3	Pipe wrenches	
4	Pipe cutter	
5	Crowbar	
6	Screwdrivers	
7	Pliers	
8	Open Wrenches	
9	Saws and hammers	
10	Bench Vise	
11	Mattock (Piko) and Shovels	

7.2 Spare parts

7.2.1 Spare parts inventory

The PO should specify in a table all assets of the RWSS and all necessary spare parts to make it possible to carry out curative maintenance.

The PO should define for each piece of equipment if and how many he wants to have in stock. The stock size of each item depends on how critical the item is for guaranteeing water supply and if the component can easily be purchased locally. Another way to define the minimum stock size is to take "1 item per 10 km network" or to have at least 3 articles in stock for each component present in the water supply system.

The following table serves as an example and should be adapted according to the PO's needs.

Table 10: Example of the list of the spare part

Asset	Spare part	Registration number of the spare part	Minimum number to have in stock
Intake			
Part of intake			
Treatment			
Rapid mix			
Sedimentation			
Flocculation			
Disinfection			
Pump			
Surge pipe			
Pump			
Motor			
Reservoir			
Washout			
Overflow			
Transmission-distribution			
PVC mains			
PE mains			
Ductile iron mains			
Steel mains			
Valves			
Hydrants			
Public tap			
House connection			
Water meter			

7.2.2 Stock location

The Private Operator should provide a brief description on the stock location and describe how the safety and hygiene are guaranteed.

7.2.3 Stock control

The Private Operator describes the procedure for using spare parts.

- Who decides on the use of spare parts?
- Who checks the use of spare parts?
- Who keeps the logbook?

The Private Operator includes a logbook that specifies which spare parts are used, for what reason, where and by whom.

The following table serves as an example.

Table 11: Example of the stock control sheet

No	Item	Used on dd/mm/yy	Used for description of failure	Location of failure	Used by (name + signature)	Issued by (name + signature)

7.3 Preventive maintenance program

The PO should have a preventive maintenance program. The objective of such a program is to prevent undesirable curative maintenance.

The maintenance program should include procedures for preventive maintenance, such as the type of maintenance to be performed, the frequency and person responsible.

The following sheets serve as an example and should be adapted and supplemented to the operator's needs.

7.3.1 Catchment area/ intake

Table 12: Preventive maintenance program for catchment area and intake

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE of inspection	INITIALS of person that carried out the inspection	MAIN FINDINGS Description of main findings during inspection	ACTIONS Description of actions that have been carried out	DATE Date the actions have been carried out	INITIALS Initials of person that carried out the actions	
1	EXTENDED PROTECTED AREA	Check with respect to presence of latrines, traces of livestock, plants with strong roots, standing water.	Water technician	Quarterly							
2	PROTECTION DITCH	Check on proper functioning. Repair holes. Compact the side slope. Plant shrubs if necessary.									
3	FENCE	Inspect if the fence is in good condition.									
4	DIRECT PROTECTED AREA	Cut the grass. Pull out shrubs. Plant grass if necessary. Prevent/stop erosion .									
5	COLLECTION ROOM AND / OR COLLECTOR	Inspect (roots in drains and pipes, leaks, cement, damaged strainer) and clean if necessary. Check whether the flow and the turbidity seems normal.									

7.3.2 Flow measurement of the water intake with the help of a bucket

Table 13: Preventive maintenance program for flow measurement of the water intake

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE of inspection	INITIALS of person that carried out the inspection	MAIN FINDINGS of main findings during inspection	ACTIONS of actions that have been carried out	DATE of actions have been carried out	INITIALS of person that carried out the actions
1	PREPARE	Calibrate bucket and stop-watch. With two persons; one to perform the measurement with the bucket and another to measure the time with the stop watch.								
2	MEASURE	The person with the bucket calls "START" and "STOP" respectively when he starts filling the bucket and when the bucket is full.								
3	REGISTER THE MEASUREME NT	The measurement is registered in a logbook, indicating: date, time, name, precise measurement point with drawing, volume of the bucket, filling time in seconds.	Water technician	Quarterly maximum monthly if possible						
4	CONTROL	Measure 3 times and use the average result.								
5	CALCULATE THE FLOW	Finally add calculation: Obtained e.g. 40 litres (4 buckets) in 80 seconds: or $40/80 = 0.5 \text{ l / s}$ flow.								
6	PLOT RESULT IN A GRAPH	Plot the result in a graph to observe possible seasonal changes or a gradual deterioration of the source.								

7.3.3 Water treatment

Table 14: Preventive maintenance program for water treatment

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE of inspection	INITIALS of person that carried out the inspection	MAIN FINDINGS Description of main findings during inspection	ACTIONS Description of actions that have been carried out	DATE Date the actions have been carried out	INITIALS Initials of person that carried out the actions	
1	CHLORINATION	Check the functioning of the dosing equipment	Water technician	Depending on the equipment and the manufacturers recommendations							
2	RAPID MIX	To be described in case there is a rapid mix									
3	FLOCCULATION	To be described in case there is flocculation									
4	SEDIMENTATION	To be described in case there is sedimentation									
5	FILTRATION	To be described in case there is a filtration									
6	SLUDGE DISPOSAL	To be described in case there is a sludge disposal									

7.3.4 Pumps

Table 15: Preventive maintenance program for pump

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
1	PUMP	To be described according to manufactures recommendations	Water technician	Depending on the equipment and the manufacturers recommendations	Date of inspection	Initials of person that carried out the inspection	Description of main findings during inspection	Description of actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions

7.3.5 (Collection and break pressure) Reservoirs

Table 16: Preventive maintenance program for reservoirs

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
1	GENERAL	Check if the name of the valves and piping such as washout, inlet, outlet, by-pass, overflow is be painted clearly and repaint if necessary.			Date of inspection	Initials of person that carried out the inspection	Description of main findings during inspection	Description of actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions
2	TANK outside	Check the appearance and seals and clean if necessary. Check that there are no threatening erosions around the facility. Fix what does not need a mason, otherwise report and propose action.	Plumber/ Water technician	Quarterly						
3	MASONRY	Control the appearance and coatings and sealing; clean if necessary.								

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
					<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
4	COVER / SLAB	Check corrosion and grease hinges if necessary. If corrosion propose action.								
5	INLET Pipe, flow limiter, float valve	Check if there are no roots in the pipes, scrape deposits. Check inlet, the operation of float valve (adjust if necessary). Dismantle the coupling, clean up.								
6	VALVES: Inlet, Outlet, By-pass	Check the operation and clean all valves and fittings.								
7	VENTILATION	Verify the free passage of air and the prevention of access of water and detritus from the outside. If corrosion propose action.								

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
8	OVERFLOW	<p>Check free passage of water and protection against access of water and detritus from outside.</p> <p>Check status of fittings and valves.</p>								
9	DRAIN or WASH OUT	<p>Check status.</p> <p>Maintain against erosion.</p> <p>Check status of fittings and valves</p>								
10	LADDERS	<p>Check the condition and clean.</p> <p>Propose action if corrosion appears.</p>								
11	WATER METER (if present)	<p>Calibrate the water meter at the discharge side of the reservoir by closing some time the flow to the reservoir and measuring the decrease in water level, multiply it with the surface of the reservoir and compare the volume with the registration of the water meter at</p>								

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
		the beginning and at the end of this operation. Alternative: calibrate the water meter with the help of calibration equipment if available.			<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>

7.3.6 Transmission and distribution pipes

Table 17: Preventive maintenance program for transmission and distribution pipes

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
					<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
1	PIPES	To walk all lines. Inspect field interviewing people. Check for leaks.								
2	CROSSING AND OTHER AIR PASSAGES	Control erosion that may threaten the conduct.		After heavy rains for sensitive points (Including crossings rivers) and after heavy rain.						
3	AIR VALVE	Check outside masonry and inside of manhole. Ensure that water can infiltrate through the bottom of the sump. Check the status of the metallic cover / slab and good closure. Check if there are no leaks Operate the stop valve.	Plumber/ Water technician							

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
					<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
		Unscrew the cap on the head, to bring forth some water. Let out the air and dust. Close the cap.								
4	DRAIN / WASH OUT	Check outside masonry and inside of manhole. Ensure that water can infiltrate through the bottom of the sump, Check the status of cover / slab and good closure. Check if there are no leaks. Open the valve until clear water comes out. Close the valve.								
5	HOUSE CONNECTION	Check on illegal connection by those people who are not yet registered as a customer		When NRW is above 20 %						

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
6	HOUSE CONNECTION	Check the customers with suspiciously low consumption		In case there are customers with suspiciously low consumption	Date of inspection	Initials of person that carried out the inspection	Description of main findings during inspection	Description of actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions
7	VALVES	<p>Locate the valve in the field.</p> <p>Check if the location is the same as shown on the drawing.</p> <p>Check whether the valve can be reached by men.</p> <p>Check if the key can be put on the valve to operate it.</p> <p>Control if the valve is in the right (open or close) position (the normal position).</p> <p>Check if the valve can be turned without excessive force.</p>		Once a year						

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
		<p>Check if the valve can be turned at least three times 360°.</p> <p>Preferably it is checked if the section (the part of the network which is bordered by two or more valves) can be fully closed (take into consideration that the customers have no water for some time).</p>			<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
8	HYDRANTS	<p>Locate the hydrant in the field.</p> <p>Check if the location is the same as shown on the drawing.</p> <p>Check whether the hydrant can be reached by men.</p> <p>Check if the stand post can be put on the hydrant to operate</p>		Once a year						

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
		<p>it (just in case of underground hydrant).</p> <p>Monitor if the hydrant delivers water when the hydrant is fully opened; let the water flow until the water is visually clear without turbidity (in fact part of network is flushed).</p>			Date of inspection	Initials of person that carried out the inspection	Description of main findings during inspection	Description of actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions

7.3.7 Public tap

Table 18: Preventive maintenance program for public tap

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
					<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
1	GENERAL	Check on cleanliness and on leakages								
2	KEY POINTS	The water meter, and drainage are key points to monitor.								
3	WATER METER	<p>Check the condition of the protection box, check cleanliness, Observe the operating status of the meter.</p> <p>Ensure that the lead has not been removed.</p> <p>Calibrate the water meter by filling some buckets and compare the volume with the registration of the water meter; if the</p>	Water technician	Monthly (Stay a half-hour in place to collect information)						

N°	SUBJECT	ACTION	STAFF	FREQUENCY	DATE	INITIALS	MAIN FINDINGS	ACTIONS	DATE	INITIALS
					<i>Date of inspection</i>	<i>Initials of person that carried out the inspection</i>	<i>Description of main findings during inspection</i>	<i>Description of actions that have been carried out</i>	<i>Date the actions have been carried out</i>	<i>Initials of person that carried out the actions</i>
		difference is more than 5 % replace the water meter. ²								
5	TAP	Check that flow occurs, the appearance of water, smell, taste.								
6	DRAINAGE OF WASTEWATER	Check the condition. Make sure the drainage is well maintained. If not, educate users or tap manager and note in the report.								
7	HYGIENE AROUND WATER POINT	If hygiene around the water point is not good, talk to users or seller / manager.								

² For private connections it is recommended to test the accuracy of water meters once every 5 years.

7.4 Corrective maintenance

The PO should have procedures for the most common corrective maintenance.

The following table serves as an example and should be completed by the PO.

Table 19: Example of the list of the corrective maintenance

Asset	Problem	Corrective maintenance
Intake	Description of the problem	Description of the maintenance activity
Treatment	Description of the problem	Description of the maintenance activity
Pump	Description of the problem	Description of the maintenance activity
Engine	Description of the problem	Description of the maintenance activity
Source of energy	Description of the problem	Description of the maintenance activity
Reservoir	Too high turbidity of the water delivered by the reservoir	Describe how to clean the reservoir
	Leak	Describe how to repair the leak
	Other problems	Description of the maintenance activity
Transmission and distribution system	Big leak when the pipe is broken	Describe how to repair a big leak
	Small leak	Describe how to place a repair-bush around the pipe
	Many complaints about water quality	Describe how to flush the upstream feeding main and the mains in the area of the complaints
	Valve cannot be reached	Make the valve reachable
	Valve cannot be turned	Replace the valve
	No water is coming out of the hydrant	Replace the hydrant
Water point	Other problem	Description of the maintenance activity
	Low speed at the water tap	Check the reservoir, remove- reassemble the tap.
	Dirty water	Check the reservoir. Purge the line.

8. NON-REVENUE WATER (NRW)

In this section the Private Operator provides information on the level of NRW in his system, the main causes and how he will reduce the level of NRW.

8.1 Calculation of NRW

The PO should specify the monthly percentages of NRW in his monthly reports. Non-revenue water is water that is distributed, but does not result in revenues for the utility.

The percentage of NRW can be calculated as follows: $(A-B)/A \times 100\%$

A = Total volume distributed in m³/month

B = Total volume billed in m³/month

Example:

Total volume distributed in the month of May = 1.622 m³

Total volume billed in the month of May = 1.078 m³

The percentage of NRW for May is $(1,622-1,078/1,622) \times 100\% = 33.5\%$.

8.2 Analysis of NRW

The PO should analyse the level of NRW. He should describe what he thinks are the main causes of NRW in his system. This will help him to develop his NRW reduction program.

There are different origins of NRW. The following table will help to understand the different origins of NRW.

Table 20: Standard terminology for the water balance according to the IWA

	Authorized consumption	Billed authorized consumption	Billed metered consumption	Revenue water	
			Billed un-metered consumption		
Distribution System input volume	Authorized consumption	Unbilled authorized consumption	Unbilled metered consumption	Non-Revenue Water	
			Unbilled un-metered consumption		
	Water losses	Apparent (or commercial) losses	Unauthorized consumption		
			Customer meter inaccuracies or data handling errors		
		Real (or physical) losses	Leakage in transmission and distribution mains		
			Water storage leaks and overflows from water storage tanks		
	Service connection leaks before household water meter				

Source: Table adapted from 'Standard Water Balance' by IWA (International Water Association).

The following table gives some examples of the different origins of NRW. This might help the PO to define which origins of NRW are common in the system.

Table 21: Type of NRW

Type of NRW	Examples
Unbilled metered consumption	Special connections which are metered but not billed for instance if they serve a social goal
Unbilled un-metered consumption	<ul style="list-style-type: none"> ○ Rinse disinfection ○ Use for firefighting ○ Use for flushing ○ Special connection which are not metered and not billed for instance if they serve a social goal
Unauthorized consumption	<ul style="list-style-type: none"> ○ Illegal connection ○ Legal connection but not willing to pay
Customer meter inaccuracies or data handling errors	<ul style="list-style-type: none"> ○ Water meters which do not accurately register the amount of water used ○ Meter reading errors.
Leakage in transmission and distribution mains	Breakage of pipes, Leaks at joints, tees, sockets, valves, hydrants
Water storage leaks and overflows from water storage tanks	<ul style="list-style-type: none"> ○ Walls and leaky rafts, ○ Overflow of a reservoir situated downstream of the bulk water meter (the big water meter at the beginning at the beginning of a water transmission system)
Service connection leaks upstream of water meter	Breakage of pipes, Leaks at joints, tees, sockets, in the house connection

8.3 NRW reduction plan

For each water supply system in Rwanda, the PO should have a NRW reduction plan. The higher the percentage the more intensive the reduction plan should be. In this plan, the PO describes what will be done to reduce the level of NRW. He specifies the actions that will be carried out, by whom and in which period. At least quarterly, the PO describes the activities that have been carried out and updates the NRW reduction plan.

The following list summarizes some possible approaches to reduce the level of NRW. The PO can use this list to prepare his own NRW reduction plan and he can also think of other ways to improve the efficiency of the network.

Table 22: Possible approaches to be reduce the level of NRW

Type of NRW	Examples	Possible approach
Unbilled metered consumption	Special connections which are metered but not billed for instance if they serve a social goal	Try to make an agreement with these customers that they will pay for the water used.
Unbilled un-metered consumption	Rinse for disinfection	Make a realistic assumption how much water is used for rinsing.
	Use for fire fighting	Make a realistic assumption how much water is used for firefighting.
	Use for flushing	Make a realistic assumption how much water is used for flushing.
	Special connection which are not metered and not billed for instance if they serve a social goal	Try to make an agreement with these customers that they will pay for the water used.
Unauthorized consumption	Illegal connection	<ul style="list-style-type: none"> ○ Check the houses which do not have an official connection. ○ Develop a severe fine policy. *1 ○ Give the employee a bonus when he discovers an illegal connection.
	Legal connection but not willing to pay	Develop a policy in cooperation with the district to cope with customers who are not willing to pay.
Customer meter inaccuracies or data handling errors	Water meters which do not accurately register the amount of water used	<ul style="list-style-type: none"> ○ Install good quality water meter ○ Calibrate yearly some water meters. ○ Determine the maximum life time of a water meter and replace the meter after this time.
	Meter reading errors	Verify some meter reading results and seriously warn or fire the employee who continues to make mistakes.
Leakage in transmission and distribution mains	Breakage of pipes, Leaks at joints, tees, sockets, valves, hydrants	<ul style="list-style-type: none"> ○ Repair a main immediately after appearance. ○ Replace mains with too many leaks. ○ Learn technicians in practise how to repair mains. ○ Create District Meter Areas (DMA's)*2 to prioritise the areas on level of NRW.

Type of NRW	Examples	Possible approach
		<ul style="list-style-type: none"> ○ Do night flow measurement in some areas and search for leaks if the night flow suddenly rises. ○ Think about raising a provincial Leakage-team to actively search for leaks.
Water storage leaks and overflows from water storage tanks	Leaking walls.	Repair the leaks in the reservoir.
	Overflow of a reservoir situated downstream of the bulk water meter (the big water meter at the beginning of a water transmission system)	Install a floating valve which shuts off the reservoir when the maximum level is reached.
Service connection leaks upstream of water meter	Breakage of pipes, Leaks at joints, tees, sockets, in the house connection.	<ul style="list-style-type: none"> ○ Replace mains with too many leaks. ○ Learn technicians in practise how to repair mains.

***1: Detailed information about reducing illegal connections:**

The PO detects illegal connections (do not forget bypass meters) by land inspection, collection of information and analysing the historical consumption of large consumers to find if they decreased their billing without decreasing their business.

***2: Detailed information about creating District Metering Areas (DMA's):**

The PO divides the network into sections that can be isolated (through valves) and controlled (by water meters) to identify zones with a high level of NRW. The following figure illustrates a possible segmentation:

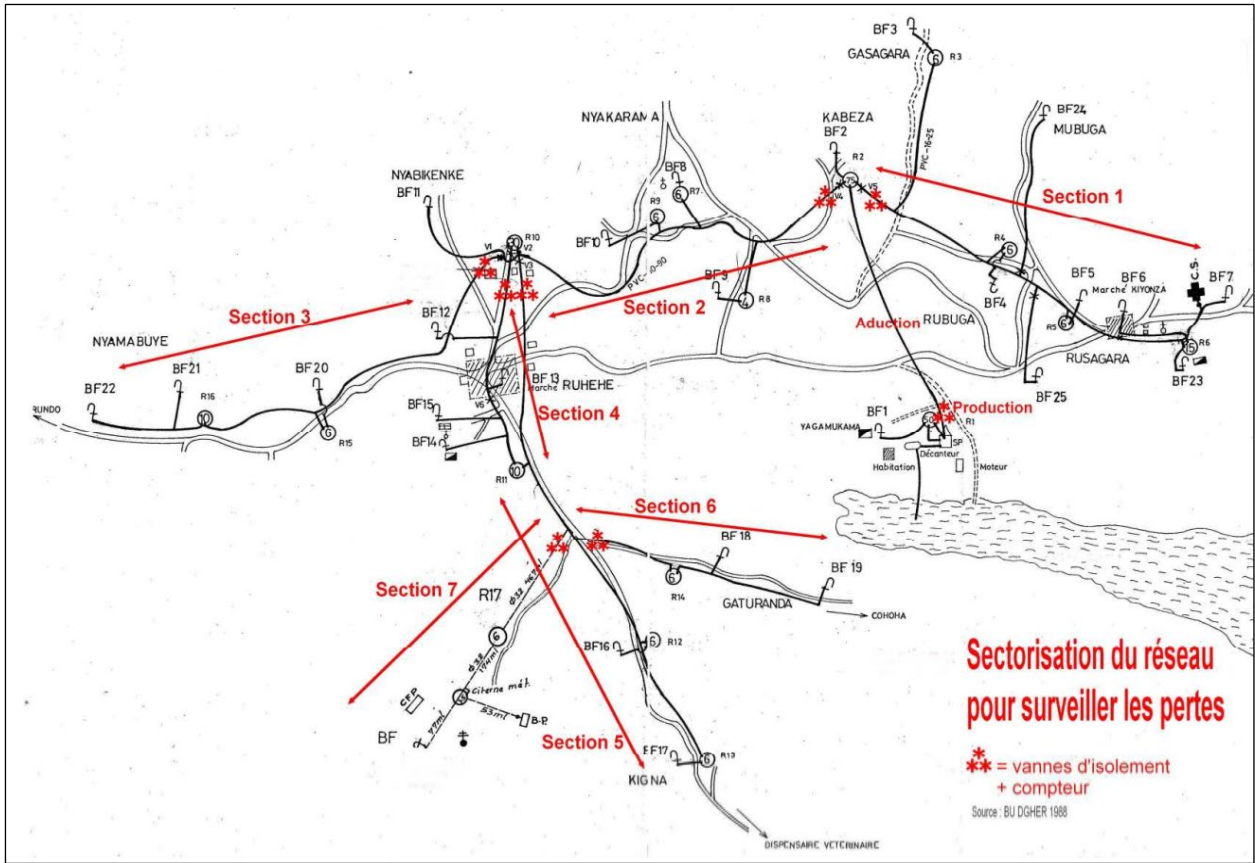


Figure 2: Example of isolation for the District Metering Areas

9. OPERATING COST

In this section the Private Operator includes the calculation of the operating cost for his water supply system(s).

9.1 Operating cost calculation sheet

The PO includes a completed operating cost calculation sheet. Ideally, the PO has already attached this sheet to his bid at the time the tender has been launched. If this sheet has not already been completed, the PO should do so as part of his O&M manual. This will make the operating cost transparent.

The following sheet (See next page) should be used to calculate the operating cost. In the example, the operating cost has been calculated for gravity systems (pumping height = 0m). The same sheet can be used to calculate the operating cost for electric pumped and diesel pumped systems. In case of striking or deviating data, the PO should provide an additional explanation to this sheet.

9.2 Annual indexation of the PO remuneration

In accordance with the Contract the remuneration of the PO shall be annually indexed in order to compensate for changes in the cost of electricity, fuel and labour.

Table 23: Example of the operating cost calculation sheet

Basic data												
Consumption			unit			Pumping/Treatment plant			unit			
Population	30.000	inh				Energy						
Specific consumption	8	l/c/d				Pumping height	0	m				
Annual consumption	87.600	m ³ /y				Specific energy consumption\	0,0060	kwh/m ³ m; l/m ³ m				
Volume of a jerry-can	22,5	l				0.006 kwh/m ³ m ou 0.0015 l/m ³ m						
Value of assets			unit			Chemicals						
Civil works	300,0	million RFR				Specific chemical consumption	18	RWF/m ³				
Pipes	240,0	million RWF				Water losses in treatment plant	0	%				
Electro mechanical	10,0	million RWF				Distribution & Sales			unit			
Operating equipment	30,0	million RWF				Non revenu water	25	%				
Rate of asset maintenance			unit			Billing collection efficiency	95	%				
Civil works	0,3	%/y				Costs			unit			
Pipes	0,3	%/y				Energy tariff (electricity or diesel)	132	RWF/kWh; RWF/l				
Electro mechanical	4,0	%/y				Remuneration of public tap operators	90	RWF/m ³				
Operating equipment	6,0	%/y				Cost of operating staff	17,0	million RWF/y				
Depreciation			unité			Functioning cost of operator	10,0	million RWF/y				
Civil works	2,5	%/y				Royalty of the District	50,0	RWF/m ³				
Pipes	2,5	%/y				VAT	18,0	%				
Electro mechanical	7,0	%/y				Commercial margin of operator						
Operating equipment	20,0	%/y				Commercial margin	10	%				
						Credits and interest to be reimbursed by the operator						
						Amount	0,0	million RWF/y				
Expenses												
Distribution			unit			Production			unit			
Non revenu water	25	%				Water losses in treatment plant	0	%				
Billed volume	87.600	m ³ /y				Produced volume	116.800	m ³ /y				
Volume put in distribution	116.800	m ³ /y				Energy consumption	0	kwh/y; l/y				
Collection efficiency	95	%				Energy cost	0,0	million RWF/y				
Paid volume	83.220	m ³ /y				Cost of chemicals	2,1	million RWF/y				
Remuneration of public tap operators	7,5	million RWF/y				Production cost	2,1	million RWF/y				
Cost of distribution	7,5	million RWF/y										
Mangement			unité			Maintenance			unit			
Cost of operating staff	17,0	million RWF/y				Civil works	0,9	million RWF/y				
Functioning cost of operator	10,0	million RWF/y				Pipes	0,7	million RWF/y				
Credits and interest to be reimbursed by the operator	0,0	million RWF/y				Electro mechanical	0,4	million RWF/y				
Management cost	27,0	million RWF/y				Operating equipment	1,8	million RWF/y				
						Maintenance cost	3,8	million RWF/y				
Depreciation cost for operator (Level 2)						Depreciation cost Level 3			unit			
Depreciation of operating equipment	6,00	million RWF/y				Civil works	7,5	million RWF/y				
Depreciation electromechanical equipment	0,7	million RWF/y				Pipes	6,0	million RWF/y				
Depreciation	6,70	million RWF/y				Depreciation cost	13,5	million RWF/y				
Result Level 2 cost price			unité			Result Level 3 cost price			unité			
Operating cost	47,1	million RWF/y				Operating cost	60,6	million RWF/y				
Operating cost per billed and paid m ³	566	RWF/m ³				Operating cost per billed and paid m ³	728	RWF/m ³				
Commercial margin of the operator	57	RWF/m ³				Commercial margin of the operator	73	RWF/m ³				
Cost for the operator	623	RWF/m³				Cost for the operator	801	RWF/m³				
Royalty of the District	50	RWF/m ³				Royalty of the District	50	RWF/m ³				
Cost price of water excl. VAT	673	RWF/m³				Cost price of water excl. VAT	851	RWF/m³				
VAT (18%)	121	RWF/m ³				VAT (18%)	153	RWF/m ³				
Cost price of water incl. VAT	794	RWF/m³				Cost price of water incl. VAT	1.004	RWF/m³				
Cost price of water incl. VAT	15,2	RWF/jcan				Cost price of water incl. VAT	19,2	RWF/jcan				

9.3 Cost recovery

In Rwanda, three levels of cost recovery are distinguished:

Level 1: running costs: Covering operation and maintenance including labour, consumables and spare parts requirements

Level 2: running costs + all repairs, including replacement of electro-mechanical equipment (Level 1 plus major repairs, including replacement of electromechanical equipment.)

Level 3: running costs + all repairs + depreciation of assets This level covers full cost recovery including asset replacement.

The cost calculation sheet is helpful in determining what level is/can be attained. Although only cost recovery level 3 can guarantee sustainability of the rural water sector in the long term, it is impossible to attain level 3 through the water tariff, because water then would become unaffordable for the population.

Districts should therefore strive for cost recovery level 2. When the cost calculation sheet shows it is impossible to attain this level for a certain system, alternative ways to attain level 2 should be considered, for example by:

- Clustering water supply systems (gravity and pumped systems) into one tender, so that one average tariff can be applied.
- Applying a uniform water tariff for different water supply systems in the District (and using the surplus of gravity systems for pumped systems).

10. REPORTING

This section describes the PO's obligations with respect to reporting.

10.1 Reports

The requirements with respect to monthly and annually reporting are included in the PPP contract. The PO should provide the District with a soft copy of the monthly report according to the prescribed model within 15 days after the end of the month. The PO should provide the District with a soft copy of the annual report according to the prescribed format before the end of the first quarter of the next year.

The District should provide the PO with a written response within 15 days and should organize a meeting between the PO, District and any other relevant actors (WASAC, community etc.) in case of any peculiarities.

10.2 Benchmark

Annually, FEPEAR organizes a benchmark in which the performance of PO's is compared. As member of FEPEAR, the PO can participate in this benchmark on a voluntary base. A set of 15 indicators is used to measure the performance of PO's.

PO's willing to participate in this benchmark should keep the following data on a monthly base and can request FEPEAR for a format to fill in at the end of the calendar year:

Table 24: List of indicators to measure the performance of PO

Category	Description	Unit
Operational	Installed production capacity	max, m3/day
Operational	System input Volume	m3/month
Operational	Pumps	number
Operational	Pump failures, out of order	number of days
Operational	Mains length	km
Operational	Leaks repaired	number
Operational	Required treated water quality tests carried out	number
Quality of service	Service complaints	number
Quality of service	Served population	number
Economic & Financial	Costs of operation and maintenance	RWF
Economic & Financial	Energy costs	RWF
Quality of service	Public Taps	number
Economic & Financial	Volume Billed at Public Taps	m3/month
Economic & Financial	Amount Billed at Public Taps	RWF/month
Economic & Financial	Amount Collected at Public Taps	RWF/month
Quality of service	Household Connections	number
Economic & Financial	Volume Billed at Households	m3/month
Economic & Financial	Amount Billed at Households	RWF/month
Economic & Financial	Amount Collected at Households	RWF/month
Quality of service	Connected Institutions	number

Category	Description	Unit
Economic & Financial	Volume Billed at Institutions	m3/month
Economic & Financial	Amount Billed at Institutions	RWF/month
Economic & Financial	Amount Collected at Institutions	RWF/month

11. MONITORING

The table below presents the monitoring framework for rural water supply provision.

Table 25: Monitoring framework

Actor	Role	Responsibility	Monitoring focus	Documents	Activities
MININFRA	Policy maker	Formulation of National policies and strategies	Overall sector monitoring		
RURA	Independent regulator	Observance of regulations	Overall sector monitoring	License	
WASAC/RWS	Executor of policy	Implementation of policies and strategies	Monitoring Districts		Periodical meetings and field visits in varying compositions
Districts	Asset owner	Functioning of infrastructure and service delivery	Monitoring Private Operators	Delegated Management Contracts Annual reports MIS	
Private Operators	Operator	Operation and maintenance of infrastructure		Operation and maintenance plan Audits Monthly reports	Contract for private connection and regulations
Community	Consumer	Signalling function		License	
<i>Focus on: WASAC/RWS, Districts and Private Operators</i>					

Appendix I: Example contract: public tap manager

CONTRACT BETWEEN XXXXX AND PUBLIC TAP MANAGER

XXXXX Ltd represented by Mr. XXXX having ID N°issued at
..... TEL: 0788*****

and

Mr. /Ms..... resident of XXXXX District,
.....Sector,Cell,.....Village, who has the ID
N°:.....issued at, herewith referred to as Public Tap Stand Manager.

It was agreed as follows:

Article 1:

XXXXX Ltd which is in charge of water supply in sectors of****, ****, ****, **** and ***** of**** District, **** Province, has a written agreement with Mr./Mrs..... of providing water services to public tap n°.....connected to water supply scheme of.....in.....Sector,.....Cell,.....Village

Article 2:

1. To each cubic meter used, the public tap manager will pay ****** thousand **** hundred and **** Rwandan francs (Frw ****)** to XXXXX Ltd. The amount will be deposited to the account n°:.....open in bank/(SACCO) of

The manager will sell water to users at ****** Rwandan francs (**Rfw) per jerrycan** not exceeding 22.5L; this price can change when both parties agree

2. The manager's remuneration is ****** hundred Rwandan francs per each cubic meter (**frw/m³)**. He/she will be paid per month following the quantity of water supplied in the very month. The payment will be done through the account n°.....opened in the bank/SACCO

Article 3:

The water used is determined by reading the water meter index

Article 4:

The manager accepts to pay the whole quantity of water used billed by of XXXXX Ltd after taking the meter reading index. The bill may be issued after three days, a week or after fifteen days. The bill must be payed not later than three days after its issuance.

Article 5:

1. Failure to comply with **Article 4**, the tap manager will pay a fine of 10% of the total due for every thirty (30) days delay;
2. Fault to pay a fine within thirty (30) days following the day of bill issuance, the company reserves the right to consider the tap manager dishonest, to terminate the contract and to take the case to the competent organs to get the payment from him/her by the power of law;

3. The tap manager who increases the water price will incur a fine of **** thousand Rwandan francs (Frw ****), and water theft will result in a fine of **** thousand Rwandan francs (Frw ****). Failure to pay the above fine within thirty (30) days, the contract will be terminated without prior notice and the company has the right deal with them for payment.

Article 6:

XXXXX Ltd must ensure the safety the pipe lines for the regular water supply to the public tap. When there is interruption in water supply, the company must communicate the incident with in twenty-four (24) hours

Article 7:

The Tap manager must:

1. Maintain the public tap and sale water according to the pricing in **Article 3** of this contract;
2. Keep clean the public tap and its surroundings;
3. Protect the public tap equipment from any damage;
4. Attend meetings organized by XXXXX Ltd when invited in writing or by any other way of communication
5. Be present to the public tap on time agreed with users;
6. Give the management report upon request by company staff

Article 8:

XXXXX Ltd has the right to visit, when necessary, the water meter and check it. When water meter does not work properly, it is replaced on request of one party

Article 9:

The company will replace the public tap equipment when it is clear that the damage is not result of mismanagement or wearing out. The Tap manager will bear responsibility for damages due to their mismanagement

Article 10:

By taking **Article 5** into account, this contract can also be terminated upon the will of one or both parties. The termination is done with advance written notice of fifteen (15) days.

Article 11:

1. All disputes that may arise in the implementation of this contract will be resolved amicably. failure to reach a common solution, the competent institutions in this matter shall apply. To issues not stated in this contract, the commercial laws shall apply.
2. Some or all articles of this contract can be amended following the agreement of both parties. The willing party proposes the contract revision in writing, fifteen days before the new contract takes effect.

Article 12:

This contract is done in two (2) original copies, one for each party. It takes effect on the day it is signed by both parties. The contract is valid from .../.../20** and cannot go beyond the contractual time between the XXXXX Ltd. and ***** District

Done at Kigali on .../.../20**

Public Tap Manager

Names: (Signature)

Telephone:

For XXXXX Ltd

Names: (Signature)

***** District XXXXXXLtd Telephone: 0788*****

Appendix II: Example contract: private connection

CONTRACT BETWEEN XXXXX Ltd AND PRIVATE CONNECTION

XXXXX Ltd represented by Mr. ***** Tel: 0788*****

and

Mr. /Ms..... resident ofDistrict,
.....Sector,Cell,Village, ID
N^o:.....issued at, hereinafter **Private Connection**.

It was agreed as follows:

Article 1:

AYATEKE STAR COMPANY Ltd which is in charge of water supply in sectors of Kigina, Kirehe, Gatore, Gahara and Mushikiri in Kirehe District, Eastern Province, passes a written agreement with Mr./Mrs..... of owning a private connection linked to water scheme in..... Sector,..... Cell, Village.

Article 2:

To each cubic meter used, the private connection will pay ******* thousand and ***** hundred Rwandan francs (Frw *****)** to the company. This price can change following an agreement between the two parties.

Article 3:

The water used is determined by using the water meter index or another reading tool when the water meter is not working. The water meter working inappropriately must be replaced within three working days.

Article 4:

The private connection owner accepts to pay the total bill in accordance with water meter reading index. The cooperative issues the bill every fifteen days or every month. The bill must be cleared not later than three days after its issuance.

Article 5:

Failure to comply with provisions of **Article 4**, the private client will pay a fine of 10% of the total due for every month delay in addition to the regular fee. When the debt goes beyond ninety days, the cooperative may take measures including depriving him/her ownership of a private connection, to consider the private client as a dishonest, to terminate the contract and to take the case to the competent institutions for payment.

Article 6:

XXXXX Ltd must ensure the safety of pipe lines for the regular water supply to the tap. When there is interruption in water supply, the company must communicate the incident within in seventy-two (72) hours

Article 7:

XXXXXX Ltd has the right to visit, when necessary, the water meter and check it. When water meter does not work properly, it is replaced on the request of one party

Article 8:

The company will replace the equipment of public connection. It is not responsible for the damage of private connection.

Article 9:

The private connection client must:

7. Ensure safety of equipment of private connection;
8. Not sell water to neighbour or other person;
9. Keep clean the tap
10. Not damaging the water meter by changing index and protecting it from damage by other people
11. Using water read by the water meter
12. Pay water bill on time to avoid penalties;
13. To attend meetings organized by XXXXXX Ltd when invited in writing or any other means of communication.

Article 10:

This contract can be terminated upon the will of either or both parties with written advance notice of thirty (30) days.

Article 11:

3. All disputes that may arise in the implementation of this contract will be resolved amicably. failure to reach a common solution, the competent institutions in this matter shall apply. To issues not stated in this contract, the commercial laws shall apply.
4. Some or all articles of this contract can be amended following the agreement of both parties. The willing party proposes the contract revision in writing, fifteen days before the new contract takes effect.

Article 12:

This contract is done in two (2) original copies, one for each party. It takes effect on the day of the day it is signed by both parties. The contract is valid from .../.../20** and cannot go beyond the contractual time between the XXXXXX Ltd. and Kirehe District

Done at Kigali on .../ .../ 20**

For Private connection

Names: (Signature)

Telephone:

For XXXXX Ltd

Names: (Signature)

***** District XXXXXXLtd Telephone: 0788*****

Attachment 1:

Template of Operation and Maintenance Manual for Rural Water Supply System

REPUBLIC OF RWANDA



MINISTRY OF INFRASTRUCTURE

**Template
of
Operation and Maintenance Manual
for
Rural Water Supply Systems**

Edition 1.0

May 2019

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List of Acronyms

NRW	Non Revenue Water
O&M	Operation and maintenance
PO	Private Operator
PPP	Public Private Partnership
WASAC	Water and Sanitation Corporation

1 How to use this tool

PO's staffs shall describe their information into the blank of the tables from the following chapter in accordance with the instruction.

Before describing, PO's staffs shall carefully read the referring part of the Annex I and Annex II in order to describe the appropriate information.

2 General information

2.1 Information to be kept by PO's

2.1.1 Contact details

Information about the private operator (PO) and the district are shown in the Table 1 and Table 2.

Table 1: Information about the private operator

Item	Description
Company name	
Company representative name	
Contact person	
Physical address of contact person	
Phone number	
E-mail	
Physical address of company office	
Official Phone number of the PO	
Official E-mail of the PO	
Awarded RURA License	
Legal Status (Cooperative, Company, Joint venture ...)	

Table 2: Information about the district

Item	Description
District name	
Contact person	
Physical address	
Phone number	
E-mail	

2.1.2 Contract information

Information about PPP delegated water supply service contract for this water supply system is show in the Table 3.

Table 3: PPP contract information

Item	Description
Date of PPP contract start	
Date of PPP contract end	
Name of the water supply system	
Map of the area in which the water supply system is located	Shown in appendix

2.1.3 Staff

List of staffs working for this water supply system is shown in the Table 4.

Table 4: List of staffs

No	Function	Name	Educational/ training level	Date of employment
1	Manager			
2	Accountant			
3	Marketing Officer			
4	Water meters reader			
5	Water meters reader			
6	Water meters reader			
7	Pumping station officer			
8	Treatment unit officer			
9	Network technician			
10	Electro mechanic			
11	Plumber			
12	Warehouse manager			
13	Caretaker			

2.2 Information to be kept by Districts

2.2.1 Overview water supply systems

Overview of this water supply system is shown in the Table 5.

Table 5: Overview water supply systems

Item	Description
Name of the water supply system	
Lengths of the water supply systems	
Name of the private operator	
Name of the contact person	
Address and phone number	
Date of PPP contract start	
Date of PPP contract end	

2.2.2 Staff

List of the district staffs related to water supply services is shown in the Table 6.

Table 6: List of the district staff

Function	Name	Educational/ training level	Date of employment
WATSAN officer			
Infrastructure engineer			
Hygiene & sanitation officer			

3 Description of water supply system

3.1 Water intake

3.1.1 Surface source

Information of surface water source is shown in the Table 7.

Table 7: Information of surface water source

Item	Information
Map of the catchment area including the drainage area in km ²	
Location of the water system facilities	
Names of major water sources	

3.1.2 Well and borehole

Information of well and borehole is shown in the Table 8.

Table 8: Information of well and borehole

Item	Information
Location (village/ cell/ sector/ district)	
UTM-E (m)	
UTM-N (m)	
Ground level (Altitude)(m)	
Static water level(m)	
Type (Dug well/ borehole)	
Drilling date	
Contractor	
Operation start date	
Maximum pumping rate (m ³ /h)	
Draw down at maximum pumping rate (m)	
Specific capacity (m ³ /h/m)	
Casing material	
Casing diameter (mm)	
Casing depth (m)	
Screen material	
Screen position (m)	
Drainage area around well site	
Nearest source of pollution	
Land ownership access and control.	

3.1.3 Spring

Information of springs is shown in the Table 9.

Table 9: Information of spring

Item	Information
Spring name(s)	
Location	
Capacity(discharge)	

Enclosure or Protection	
Land ownership, access and control	

3.2 Treatment Process

Description of treatment process is shown in the Table 10.

Table 10: Description of treatment process

Item	Description
Treatment process in general	
Flow diagram of treatment facility	
Treatment process for each part	

3.2.1 Intake of raw water source

Information of intake facilities is shown in the Table 11.

Table 11: Information of intake facilities

Item	Description
Control gates or valves	
Size of control gates or valves	
Type of operation of control gate gates or valves	
Bar screens or trash removal facilities	
Raw water pump	
Dates facility were installed or modified	

3.2.2 Chemical additions

Information of chemical additions is shown in the Table 12.

Table 12: Information of chemical additions

Item	Description
Name of the chemical applied	
Chemical formula and concentration	
Name of chemical supplier	
Type of chemical feeder	
Manufacturer's name	
Model number	
Maximum capacity,	
Normal range of feed rates	
Date of installation;	
Where the chemical is applied to the water	
What controls the dosage of chemical	
What tests are made to determine dosage	
The safety precautions applicable to this chemical	

3.2.3 Rapid mix

Information of rapid mix is shown in the Table 13.

Table 13: Information of rapid mix

Item	Description
Size of rapid mix chamber	
Capacity of rapid mix chamber	
Number of units of rapid mix chambers	
Detention time at design flow rate	
Mechanical mixers	
Manufacturer of mechanical mixers	
Size of mechanical mixers	
Model of mechanical mixers	
Speed of mechanical mixers	
Date of installation of mechanical mixers	

3.2.4 Flocculation

Information of flocculation is shown in the Table 14.

Table 14: Information of flocculation

Item	Description
Size of flocculator chambers	
Capacity of flocculator chambers	
Number of units of flocculator chambers	
Detention time at design flow rate	
Mechanical flocculator	
Manufacturer of mechanical flocculator	
Size of mechanical flocculator	
Model of mechanical flocculator	
Speed of mechanical flocculator	
Date of installation of mechanical flocculator	

3.2.5 Sedimentation

Information of sedimentation is shown in the Table 15.

Table 15: Information of sedimentation

Item	Description
Size of sedimentation basins	
Capacity of sedimentation basins	
Number of unit of sedimentation basins	
Detention time at design rate of sedimentation basins	
Date of installation of sedimentation basins	
Type of sedimentation system (Open Basin, Lamellae, ...)	

3.2.6 Filters

Information of filters is shown in the Table 16.

Table 16: Information of filters

Item	Description
Filters size	
Number of units	
Filter material	
Filter capacity	
Filtration velocity	
Date of installation	
Type of filter valves	
Size of filter valves.	

3.2.7 Clear well

Information of clear well is shown in the Table 17.

Table 17: Information of clear well

Item	Description
Size of clear well at the rated plant capacity	
Detention time at the rated plant capacity	

3.2.8 Disinfection

Information of disinfection is shown in the Table 18.

Table 18: Information of disinfection

Item	Description
Disinfectant used and its description	
Chlorine feed equipment: <input type="checkbox"/> Injection pump <input type="checkbox"/> Manual <input type="checkbox"/> Klorman <input type="checkbox"/> Overhead tank <input type="checkbox"/> Other.....	
Point of application	
Maximum capacity of chlorinator (in litre / second)	

3.3 Pumps

Information of pumps is shown in the Table 19.

Table 19: Information of pumps

Item	Intake pump 1	Intake pump 2	Lifting pump 1	Booster pump1
Pump				
Location(village, cell, sector)				
Pump type				
Installation date				
Brand name/ manufacturer				
Model				

Item	Intake pump 1	Intake pump 2	Lifting pump 1	Booster pump1
Output (kW)				
Pumping rate (m3/h)				
Dynamic water level				
Total head (m)				
Pump setting depth (m)				
Riser pipe diameter (mm)				
Power source				
Installation date				
Brand of engine				
Model of engine				
No. of cylinder				
Brand of alternator				
Model of alternator				
Output (standby) (kVA)				
Output (prime) (kVA)				
Volt/Hz/phases				
Brand of transformer				
Model of transformer				
Output of transformer (kVA)				
Volt/Hz/phases				
Anti ram system				
Model of vessel				
Capacity of the vessel				
Maximum pressure load				
Type (Spring, membrane)				

3.4 Storage facilities

Information of storage facilities is shown in the Table 20.

Table 20: Information of storage facilities

Type	Capacity(m ³)	Location			Material of construction	Inside coatings(mortar, epoxy, paint, etc.)	Hydraulic equipment / Fittings (Valves, Unions, TE, Sockets, Nipples, reducers, joints ...)	Schematic drawing of valves
		Village	Cell	Sector				

3.5 Transmission and distribution system

A detailed map of the transmission and distribution system shall be attached.

3.5.1 Mains

Information of main pipeline is shown in the Table 21.

Table 21: Information of main pipeline

Nominal diameter(mm)	Material	Pressure class/ specification	Wall thickness(mm)	Year of installation	Total length (m)
Total					

3.5.2 Valves

Information of valves is shown in the Table 22.

Table 22: Information of valves

Identification of the chamber	Regular status of the valve (open or closed)	Type of valves (butterfly, gate, ball, global etc.)	Year of installation	Description of each valve
Total				

3.5.3 Hydrants

Information of hydrant is shown in the Table 23.

Table 23: Information of hydrant

Registration number	Type	Nominal capacity	Year of installation	Total number (piece)
Total				

3.5.4 Water points (public tap/ kiosk)

Information of water points is shown in the Table 24.

Table 24: Information of water points

Identification (ID, Nearby household, Simple or Kiosk)	Location			Year of installation	Total number (tap)
	Village	Cell	Sector		
Total					

3.5.5 House connections

Information of house connection is shown in the Table 25.

Table 25: Information of house connections

House address/ customer name	Location			Diameter of service connection (mm)	Material of service connection	Year of connection	Registration number of water meter
	Village	Cell	Sector				

4 Assets

4.1 Asset inventory

Asset inventory is shown in the Table 26.

Table 26: Asset inventory sheet

Asset name	Location			Year of construction	Theoretical technical lifespan (year)	Acquisition cost (RWF)	Book value (RWF)
	Village	Cell	Sector				
Total							

4.2 Asset management

Asset management sheet is shown in the Table 27.

Table 27: Asset management sheet

Asset	Location		Year of construction	Theoretical technical lifespan (year)	Condition	Service history	Functional lifespan (year)	Year of replacement	Priority
	Village	Cell							

4.3 Asset budget

Asset budget sheet is shown in the Table 28.

Table 28: Asset budget sheet

Asset name (list from highest to lowest priority)	Location			Activity	Years until action needed	Costs expected (RWF)	Reserve required current year (RWF)
	Village	Cell	Sector				
Total							

5 Service quality

5.1 Standards

Service quality of this water supply system is shown in the Table 29.

Table 29: Service quality of this water supply system

Subject	Standards/ Reference
Water quality	
Water pressure	
Reliability of supply	
Connections	
Water metering	
Billing	
Complaints	
Disconnection & Reconnection	

5.2 Records and procedures

5.2.1 Water quality

Form of water quality test record is shown in the Table 30.

Table 30: Record of water quality test

Sampling date:			
Sampling location:			
Parameters	Measured value (unit)	Standard (unit)	Action to be taken in case the standard is not satisfied
Total coliforms		Absent	
E-coli		Absent	
Turbidity		≤5NTU	
PH		≤6.5≤8.5	
Aluminium(as Al ³⁺)		≤0.2	
Nitrate(as NO ₃ ⁻)		≤4.5	
Ammonia(as NH ₃)		≤0.5	
Total Iron(as Fe)		≤0.3	
Manganese(an Mn)		≤0.1	
Copper(as Cu)		≤1.000	
Phosphates (as PO ₄ ³⁻)		≤2.2	
Residual free chlorine		≤0.2≤0.5	

5.2.2 Water pressure

Form of record of water pressure is shown in the Table 31.

Table 31: Form of record of water pressure

Item	Data
Minimum pressure(meter of water column)	
Maximum pressure(meter of water column)	
Location that don't meet minimum pressure	

Location that exceed maximum pressure	
Level of pressure(meter of water column)	
Duration(start and end)	
Procedure of informing to customers	

5.2.3 Reliability of supply

Form of reliability of supply is shown in the Table 32.

Table 32: Form of reliability of supply

Item	Data
Minimum number of service hours	
Place where 8 service hours have not been achieved	
Procedure of indicating the service hours at public tap and local offices	
Procedure of informing customers in case of planned works which caused temporarily absence of water delivery	

5.2.4 Connections

Form of record of requests for new connection is shown in the Table 33.

Table 33: Form of record of requests for new connection

Customer name	Location			Date of request	Date of connection
	Village	Cell	Sector		

Form of percentage of customers that has been connected within 10 days is shown in the Table 34.

Table 34: Percentage of customers that has been connected within 10 days

Month/ year	Number of customers who requested the connection	Number of customers who got the connection in 10 days	% of customers who got the connection in 10 days (%)

5.2.5 Water metering

Form of record of percentage of water points that are metered is shown in the Table 35.

Table 35: Percentage of water points that are metered

Item	Figure
Total number of water points	
Number of water points which are metered	

Number of water points which are not metered	
% of water point which are metered	

Form of list of all water meters in the network and its monthly reading is shown in the Table 36.

Table 36: List of all water meters in the network and its monthly reading

Water meter name	Location			Reading at the beginning of month(m ³)	Reading at the end of month(m ³)	Consumption(m ³)
	Village	Cell	Sector			

Form of customer request for meter testing is shown in the Table 37.

Table 37: Customer request for meter testing

Customer name	Location			Date of request	Date of test	Result of test	Date of replacement
	Village	Cell	Sector				

Form of record for meter testing initiated by PO is shown in the Table 38.

Table 38: Record for meter testing initiated by PO

Customer name	Location			Date of test	Result of test	Action to be taken	Date of taken action
	Village	Cell	Sector				

5.2.6 Billing

Form of percentage of bill collection efficiency is shown in the Table 39.

Table 39: Percentage of bill collection efficiency

Month/ year	Billed amount (Rwf)	Collected amount (Rwf)	Bill collection efficiency (%)
January 2017			
Total			
Procedure for bill collection			
Action to be taken to improve the bill collection efficiency			

5.2.7 Complaints

Form of percentage of complaints that is dealt with within 5 working days is shown in the Table 40.

Table 40: Percentage of complaints that is dealt within 5 working days

Month/ year	Number of complaints	Number of complaints dealt within 5 working days	% of complaints dealt within 5 working days

Form of record of complaints is shown in the Table 41.

Table 41: Record of complaints

Date of complaint	Location			Customer name	Description of complaint	Action taken to solve complaint	Date of action taken
	Village	Cell	Sector				

5.2.8 Disconnection and reconnection

Form of record of disconnection is shown in the Table 42.

Table 42: Record of disconnection

Customer name	Location			Reason of disconnection	Amount of debt (Rwf)	Date of disconnection
	Village	Cell	Sector			

Form of record of reconnection is shown in the Table 43.

Table 43: Record of reconnection

Customer name	Location			Date of settling debt	Date of reconnection
	Village	Cell	Sector		

5.3 Action plan

Service quality action plan is shown in the Table 44.

Table 44: Service quality action plan

Point that the level of service is not achieved	Action to be taken to achieve the required level of service	Time schedule of achieving the required level of service

Point that the level of service is not achieved	Action to be taken to achieve the required level of service	Time schedule of achieving the required level of service

6 Operations

6.1 Operational procedures

6.1.1 Water intake

Action against operational procedure is shown in Table 45.

Table 45: Action against operational procedure

Operational procedure	Action to be taken
Keeping clean and tidy the surrounding of the intake	
Removing debris from the intake	
Cleaning of screens	
Cleaning/flushing of sand trap	
Manipulation of valves	

6.1.2 Treatment process

Action against operational procedure is shown in Table 46.

Table 46: Action against operational procedure

Operational procedure	Action to be taken
Routine daily checking of installations	
Keeping clean and tidy the interior and surroundings of the treatment plant	
Preparation of chemical solutions	
Cleaning of screens	
Operation of dosing pumps	
Manipulation of valves	
Taking of samples	
Execution of Jar tests	
Fine-tuning of treatment process	
Backwashing of filters	

6.1.3 Pumping system

Action against operational procedure is shown in Table 47.

Table 47: Action against operational procedure

Operational procedure	Action to be taken
Routine daily checking of engine and pump	
When to turn on/ switch off which pump	
How to turn on/ switch off a pump	
How to regulate the pressure in the distribution system	

Electrical schematic drawing in the control panel	Existing inside the control panel
---	-----------------------------------

6.1.4 Storage facilities

Action against operational procedure is shown in Table 48.

Table 48: Action against operational procedure

Operational procedure	Action to be taken
Cleaning and disinfection of the storage facilities(inside)	
Keeping clean and tidy the surroundings of the storage facility	
Manipulation of valves	

6.1.5 Transmission and distribution system

Action against operational procedure is shown in Table 49.

Table 49: Action against operational procedure

Operational procedure	Action to be taken
Inspection of transmission and distribution system	
Manipulation of valves	
Reading of water meters	
Registration of all changes in the network	
Registration of complaints with a technical origin	
Supplying water to the customers at the public tap	

6.1.6 Public tap

Action against operational procedure is shown in Table 50.

Table 50: Action against operational procedure

Operational procedure	Action to be taken
Keeping clean and tidy the surroundings of the public tap	
Checking for leakages	
Calibration of water meters	
Checking for public tap protection	

6.2 Common operational problems

List of common operational problems is shown in Table 51.

Table 51: List of common operational problems

Description of problem	Possible cause	Possible remedy

6.3 Operational records

6.3.1 Volume produced per day

Form of volume produced per day is shown in the Table 52.

Table 52: Form of operational record of volume produced per day

Description of the source	Date	Production	
		Reading of flow meter (m3)	Volume (m3)

6.3.2 Pumps

Form of operational record of pump per hour is shown in the Table 53.

Table 53: Form of operational record of pump

Date	Pressure (bar)	Time		Hours	Production		Energy consumption (Kwh)	Fuel (l)	Observation
		Start	Stop		Reading of flow meter (m3)	Volume (m3)			

6.3.3 Reservoirs

Form of operational record for reservoirs is shown in the Table 54.

Table 54: Form of operational record for reservoirs

Description of the reservoirs	Date	Distribution	
		Reading of flow meter (m3)	Volume (m3)

6.3.4 Water quality test

Form of operational record for water quality test is shown in the Table 55.

Table 55: Form of operational record for water quality test

Parameters	Date	Location	Measured value	Standard	Action to be taken in case the standard is not satisfied

6.3.5 Chemicals

Form of operational record for chemicals is shown in the Table 56.

Table 56: Form of operational record for chemicals

Date	Type of chemical	Volume of chemical used per day

6.3.6 Water metering testing

Form of operational record for water meter testing is shown in the Table 57.

Table 57: Form of record for water meter condition

Name	Location			Date of meter testing	Results of test	Condition	Action taken
	Village	Cell	Sector				

7 Maintenance

7.1 Maintenance tools

List of the available tools is shown in the Table 58.

Table 58: List of the available tools

ID	Description	Size	Number of tools

7.2 Spare parts

7.2.1 Spare parts inventory

List of the spare parts inventory is shown in the Table 59.

Table 59 List of the spare parts

Asset description	Spare parts	Minimum number required to have in stock	Number of this spare parts available in the stock

7.2.2 Stock location

Information about the store is shown in the Table 60.

Table 60: Information about the store

Location				Responsible person	Condition	
Village	Cell	Sector	District		Security	Hygiene

7.2.3 Stock control

Name of the person who decides the use of spare part:

Name of the person who checks the use of spare part:

Name of the person who keeps the logbook:

Logbook for spare parts is shown in the Table 61.

Table 61: Logbook for spare parts

Item	Date of used	Used for (description of asset and failure)	Location of failure	Used by name/ signature	Issued by name/ signature	Number of spare parts available in the store before repair	Number of spare parts taken for repair	Number of spare parts available in the store after repair

7.3 Preventive maintenance program

7.3.1 Catchment area/ intake

Preventive maintenance program for catchment area and intake is shown in the Table 62.

Table 62: Preventive maintenance program for catchment area and intake

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding Description of main findings during inspection	Actions Description of actions that have been carried out	Date Date the actions have been carried out	Initials Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.2 Flow measurement of the water intake with the help of a bucket

Preventive maintenance program for flow measurement of the water intake is shown in the Table 63.

Table 63: Preventive maintenance program for flow measurement of the water intake

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding during inspection	Actions that have been carried out	Date actions have been carried out	Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.3 Water treatment

Preventive maintenance program for water treatment is shown in the Table 64.

Table 64: Preventive maintenance program for water treatment

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding during inspection	Actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.4 Pumps

Preventive maintenance program for pumps is shown in the Table 65.

Table 65: Preventive maintenance program for pump

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding during inspection	Actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.5 (Collection and break pressure) Reservoirs

Preventive maintenance program for reservoirs is shown in the Table 66.

Table 66: Preventive maintenance program for reservoirs

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding during inspection	Actions that have been carried out	Date actions have been carried out	Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.6 Transmission and distribution pipes

Preventive maintenance program for transmission and distribution pipes is shown in the Table 67.

Table 67: Preventive maintenance program for transmission and distribution pipes

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding during inspection	Actions that have been carried out	Date the actions have been carried out	Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										

7.3.7 Public tap

Preventive maintenance program for public tap is shown in the Table 68.

Table 68: Preventive maintenance program for public tap

No.	Subject	Action	Staff	Frequency	Date of inspection	Initials of person that carried out the inspection	Main finding Description of main findings during inspection	Actions Description of actions that have been carried out	Date Date the actions have been carried out	Initials Initials of person that carried out the actions
1										
2										
3										
4										
5										
6										
7										

7.4 Corrective maintenance

Procedure and record of most common corrective maintenance is shown in the Table 69.

Table 69: Procedure of the most common corrective maintenance

Asset	Description of Problem	Description of Corrective maintenance	Materials used	Human resources	Cost

Table 70: History of corrective maintenances

Date	Asset identification	Problem	Description of maintenance activities taken	Materials used	Human resources	Cost

8 Non-revenue water (NRW)

8.1 Calculation of NRW

Calculation of NRW is shown in the Table 71.

Table 71: Calculation of NRW by month

Month/ year	Distributed water volume (m ³)	Billed water volume (m ³)	NRW (m3)	% of NRW
	(A)	(B)	= (A) – (B)	= (A-B)/A * 100
Total				

8.2 Analysis of NRW

Check list to determine the cause of NRW is shown in the Table 72.

Table 72: Check list to define the cause of NRW

Type of NRW	Cause
Unbilled metered consumption	
Unbilled un-metered consumption	
Unauthorised consumption	
Customer meter inaccuracies and data handling errors	
Leakage in transmission and distribution pipes	
Water storage leaks and overflow from water storage tank	
Service connection leaks upstream of water meter	

8.3 NRW reduction plan

NRW reduction plan is shown in the Table 73.

Table 73: NRW reduction plan

Type of NRW	Cause	Possible approach
Unbilled metered consumption		

Type of NRW	Cause	Possible approach
Unbilled un-metered consumption		
Unauthorised consumption		
Customer meter inaccuracies and data handling errors		
Leakage in transmission and distribution pipes		
Water storage leaks and overflow from water storage tank		
Service connection leaks upstream of water meter		

9 Operating cost

9.1 Operating cost calculation sheet

Operating cost calculation sheet is shown in the table 74.

Table 74: Operating cost calculation sheet

Basic data		
Consumption		
		Unit
Population		inh
Specific consumption		l/c/d
Annual consumption		m ³ /y
Volume of a jerry-can		l
Value of assets		
		Unit
Civil works		million RWF
Pipes		million RWF
Electro -mechanical		million RWF
Operating equipment		million RWF
Rate of asset maintenance		
		Unit
Civil works		%/y
Pipes		%/y
Electro -mechanical		%/y
Operating equipment		%/y
Depreciation		
		Unit
Civil works		%/y
Pipes		%/y
Electro -mechanical		%/y
Operating equipment		%/y
Pumping/Treatment plant		
		unit
Energy		
Pump height		m
Specific energy consumption		kwh/m ³ /m; l/m ³ /m
0.006 kwh/m ³ /m or 0.0015 l/m ³ /m		
Chemicals		
Specific chemical consumption		RWF/m ³
Water loss in treatment plant		%
Distribution & Sales		
		Unit
Non revenue water		%
Billing collection efficiency		%
Cost		
		Unit
Energy tariff(electricity or diesel)		RWF/kWh; RWF/l
Remuneration of public tap operators		RWF/m ³
Cost of operating staff		million RWF/y
Functioning cost of operator		million RWF/y
Royalty of the District		RWF/m ³
VAT		%
Commercial margin of operator		
Commercial margin		%
Credit and interest to be reimbursed by the operator		
Amount		million RWF/y
Expenses		
Distribution		
		Unit
Non revenue water		%
Billed volume		m ³ /y
Volume put in distribution		m ³ /y
Collection efficiency		%
Paid volume		m ³ /y
Remuneration of public tap operators		million RWF/y
cost of distribution		million RWF/y
Management		
		Unit
Cost of operation staff		million RWF/y
Functioning cost of operator		million RWF/y
Credits and interest to be reimbursed by the operator		million RWF/y
Management cost		million RWF/y
Production		
		Unit
Water losses in treatment plant		%
Produced volume		m ³ /y
Energy consumption		kwh/y; l/y
Energy cost		million RWF/y
Cost of chemicals		million RWF/y
Production cost		million RWF/y
Maintenance		
		Unit
Civil works		million RWF/y
Pipes		million RWF/y
Electro -mechanical		million RWF/y
Operating equipment		million RWF/y
Maintenance cost		million RWF/y
Depreciation Level 2 cost		
		Unit
Depreciation of electro-mechanical equipment		million RWF/y
Depreciation of operating equipment		million RWF/y
Depreciation		million RWF/y
Depreciation Level 3 cost		
		Unit
Civil work		million RWF/y
Pipes		million RWF/y
Depreciation cost		million RWF/y
Result		
Result Level 2 cost price		
		Unit
Operating cost		million RWF/y
Operating cost per billed and paid m ³		RWF/m ³
Commercial margin of the operator		RWF/m ³
Cost for the operator		RWF/m ³
Royalty of the District		RWF/m ³
Cost price of water excl. VAT		RWF/m ³
VAT(18%)		RWF/m ³
Cost price of water incl.VAT		RWF/m ³
Cost price of water incl.VAT		RWF/jcan
Result Level 3 cost price		
		Unit
Operating cost		million RWF/y
Operating cost per billed and paid m ³		RWF/m ³
Commercial margin of the operator		RWF/m ³
Cost for the operator		RWF/m ³
Royalty of the District		RWF/m ³
Cost price of water excl. VAT		RWF/m ³
VAT(18%)		RWF/m ³
Cost price of water incl. VAT		RWF/m ³
Cost price of water incl. VAT		RWF/jcan

10 Reporting

10.1 Reports

Reporting schedule is shown in the Table 75.

Table 75: Reporting schedule

Type of report	Date of submit to the district	Copied institutions	Date of feedback from the district
Monthly report			
Quarterly report			
Annual report			

10.2 Benchmark

List of indicators, which shall be the standard of MININFRA, to measure the performance of PO is shown in the Table 76.

Table 76: List of indicators to measure the performance of PO

Category of indicators	Description	Unit	Performance achieved
Physical indicator	Installed production capacity	max, m3/month	
Physical indicator	System input Volume	m3/month	
Physical indicator	Pumps	number	
Operational	Pump failures, out of order	number of days / year	
Operational	Mains length	km	
Operational	Leaks repaired	Number / km / month	
Operational	Required treated water quality tests carried out	Number / year	
Quality of service	Service complaints	Number / year	
Quality of service	Served population	number	
Economic & Financial	Costs of operation and maintenance	RWF /year	
Economic & Financial	Energy costs	RWF / year	
Quality of service	Public Taps	number	
Economic & Financial	Volume Billed at Public Taps	m3/month	
Economic & Financial	Amount Billed at Public Taps	RWF/month	
Economic & Financial	Amount Collected at Public Taps	RWF/month	

Category of indicators	Description	Unit	Performance achieved
Economic & Financial	Volume Billed at Households	m3/month	
Economic & Financial	Amount Billed at Households	RWF/month	
Economic & Financial	Amount Collected at Households	RWF/month	
Quality of service	Connected Institutions	number	
Economic & Financial	Volume Billed at Institutions	m3/month	
Economic & Financial	Amount Billed at Institutions	RWF/month	
Economic & Financial	Amount Collected at Institutions	RWF/month	
Economic & Financial		E billing	
Personnel	Staff at the office	Size of office team	
Physical indicator	Coverage	%	
Operational	Number of new connection per year	Number / year	
Operational	Collection efficiency	%	
Economic & Financial	Increase Capital	Amount	
Operational	Reduced production cost	Amount	
	Frequency for preparation of plan	Period	
Water Resources	Practices activities for the Sustainability of Environment	Number	
Operational	Innovation achieved	Number of innovations / year	
Operational	Partnership developed	Number of partners	
Quality of service	Accountability / Change of address	Number of inconveniences / year	
Quality of service	Complains system and feedback	Average number of days for responding	
Operational	Promote customers panel	Yes / No	
Operational	Behavior	Number of corruption case / year	
Operational	Incentive practices	Number / year	
Quality of service	Intermittent service	Days of interruption / year	
Personnel	Staff per 1000 Connections	Number	
Economic & Financial	NRW	%	
Economic & Financial	Annual Turnover	Amount	
Economic & Financial	Profit	Amount	

11 Monitoring

Monitoring framework for rural water supply provision is shown in the Table 77.

Table 77: Monitoring framework

Actors	Role	Responsibility	Monitoring focus	Documents	Activities
MININFRA	Policy maker	National Water supply Policy updated in December 2016	Overall sector monitoring		
RURA	Independent Regulator	Observance of Regulations	Overall sector monitoring	Licence	Periodical meetings and field visits in varying compositions.
WASAC/RWS	Policy implementation	Implementation of Policies and Strategies	Monitoring District		
Districts	Assets owners	Functioning of infrastructures and service delivery	Monitoring private Operators	Delegated Management Contracts Annual reports MIS	
Private Operators	Operator	Operation and maintenance of infrastructures		Licence O&M plan	Monthly reports Audits Contract for Private Connections and regulations
Community	Consumer	Signaling function			

Table 78. Monitoring activities performed

Date	Actor	Description	Findings	Actions taken / fines	Recommendations

Attachment 2:

Training Module
on
Procedure of Operation and Maintenance
for Pipe Water Supply Systems

REPUBLIC OF RWANDA



MINISTRY OF INFRASTRUCTURE

**Training Module
on
Procedure of Operation and Maintenance
for
Pipe Water Supply Systems**

Edition 1.0

May 2019

Preface

Access to safe drinking water is crucial, not only for people's health and wellbeing, but also for poverty reduction and economic development;

Improving the access, quality, availability and sustainability of water supply services in RWANDA is the top priority in the Sector;

Rwanda has committed to reach SDGs targets by 2030 through the different programs such as the NST1 and 7 Years Government Program with the aim of achieving universal access to basic water and sanitation services by 2024. In order to achieve this target, an appropriate institutional system has to be in place.

The development of the National guidelines for Sustainable Rural Water Supply Services and all its supporting documents (Manuals, Training Modules, etc.) is part of the mechanism to develop the Operation and Maintenance in the Rural Water Supply, and make an important guidelines to Districts, Private Operators, User communities and all the stakeholders in the Rural Water Supply Services sub-sector.

I want to extend my appreciation to the stakeholders, especially JICA/RWANDA through the RWASOM Project, for the effort to have these important documents in place.

We look forward to positive impact of the developed documents through the O&M framework in the rural water services, sustainability of existing water infrastructures and overall, an improved and sustainable clean water supply service toward the communities in RWANDA.



Patricie UWASE

PERMANENT SECRETARY

Acknowledgement

This module was produced by the “Project for Strengthening Operation and Maintenance of Rural Water Supply Systems in Rwanda” under the technical cooperation by Japan International Cooperation Agency (JICA).

A series of workshops were held in the project, and a lot of stakeholders in Rwanda, development partners, and NGOs technically contributed in the formulation of the module. The Ministry of Infrastructure and Water and Sanitation Cooperation Ltd (WASAC) therefore, extends special thanks to these stakeholders for allowing their staff to participate in the production of this module.

The Ministry is also indebted to JICA for assisting in the development of the module, and many who have not been mentioned here but contributed in different ways.

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List of Acronyms

AC	Asbestos Cement
CI	Cast Iron pipes
DI	Ductile Iron
FRP	Fiber Reinforced Pipes
GS	Galvanized Steel
PE	Poly Ethylene
PVC	Polyvinyl Chloride
NPSHA	Net Positive Suction Head Available
NPSHR	Net Positive Suction Head Required
RPM	Rotations Per Minute
RTD	Resistance Temperature Detector
VFD	Variable Frequency Drive

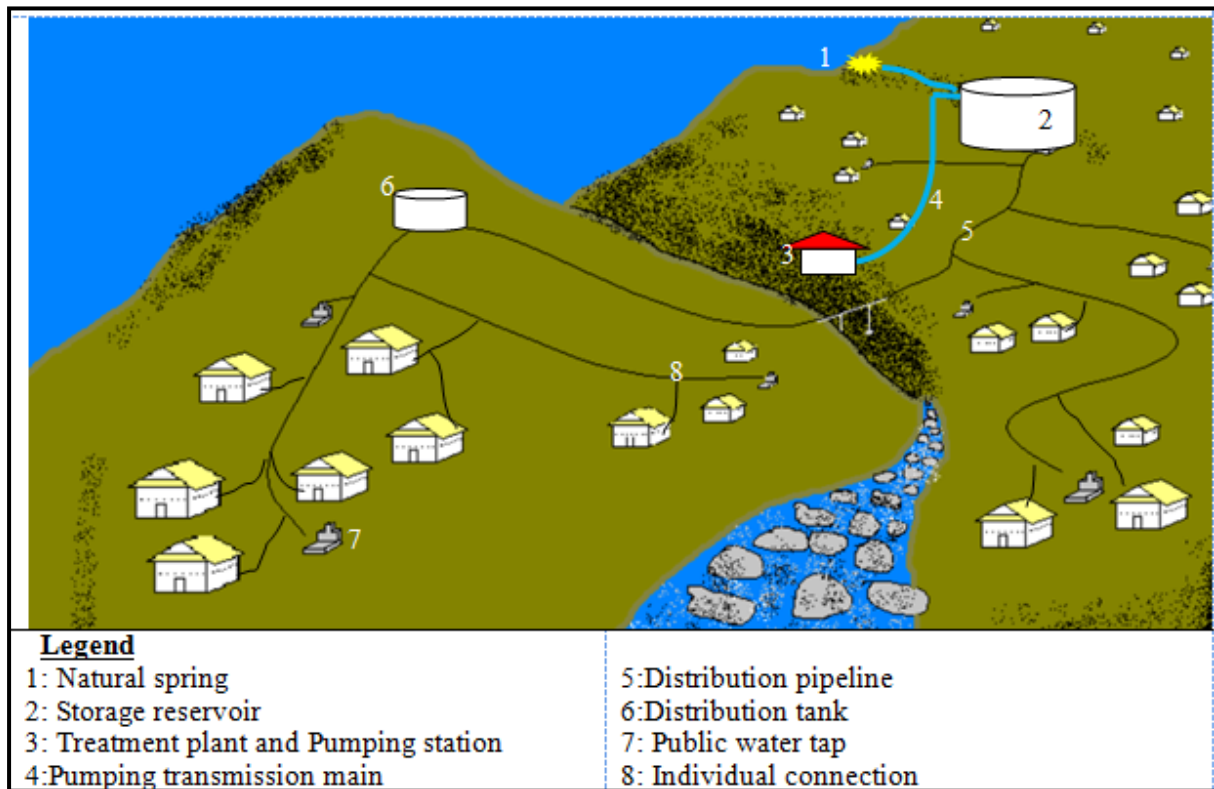
1 General

1.1 Component of a typical water supply scheme

A piped water supply scheme comprises of the following main units:

- Source / Intake arrangements
- Raw water storage
- Transmission line
- Treatment unit (Chemicals addition, flocculation, filtration and disinfection)
- Pumping station
- Balancing reservoir
- Distribution system
- Chambers (washout chambers, collection chambers, air release chambers, valve chambers, etc.)

The following picture outlines a typical water supply scheme.



(Picture adapted from Rich Rotto 1997)

Figure 1: Sketch of a typical piped water supply system

2 Concept of Operation and Maintenance

2.1 Operation

Operation is defined as the everyday activities of running and handling of a water supply facility (Davis, Brikké, & Boesveld, 1995). Operation of a water asset has the purpose of continuously conveying up to the consumers, the water of safe quality, in the satisfaction of desired quantity and service pressure.

2.2 Maintenance

Maintenance is a collection of those activities required to sustain the water supply in a proper working condition (Davis et al., 1995). The author has distinguished 3 categories of maintenance which are:

- i. Preventive maintenance: regular inspection and servicing of a water system without any observed problem, in order to preserve assets and minimize further breakdowns.
- ii. Corrective or curative maintenance: minor repair and replacement of damaged and worn out parts for maintaining the water infrastructure under safe working condition.
- iii. Crisis maintenance: unplanned responses to emergency breakdowns and user complaints to restore a failed supply.

In our case we will combine corrective and crisis maintenance in the category of curative maintenance.

2.3 Planning and organizing the operation

In order to continuously maintain the sustainability of the water infrastructure and deliver safe and enough water to the consumers, the operator should adequately plan for the required actions, the procedures and strategies for implementation. Planning is the responsibility of the managers. They thus make provisions for:

- Timing and frequency of actions along a work day, week, month, term and a year.
- Types of Operation and Preventive maintenance required such as the General System Inspection, Pumping equipment operation, Chlorination ...
- Procedures and strategies
- Budget, tools and materials
- Decide and assign responsible actors for each action.

2.4 Work day

Working hours a day for operation and maintenance will be at least 9 hours. The example of the daily schedule is displayed in the following table.

Table 1: Example of daily working time table

Time	Activity
06:30 - 07:00	Arrival and check before starting operation
07:00	Start operation and services
07:00 – 12:00	Operation, preventive maintenance and curative maintenance
12:00 - 13:00	Lunch rest
13:00 - 17:00	Operation, preventive maintenance and curative maintenance
17:00	Stop operation and services
17:00 – 17:30	Checking after stopping operation

(FEPEAR, 2014)

2.5 Activity of daily operation

- Add chemicals to the water
- Start and stop operation of a pump
- Discharge water into the network
- Manipulate valves
- Adjustments for balancing the flow discharge across the distribution network
- Managing the hydraulic functionality of the whole water network
- Fill the buckets at the public tap
- Reading water meter
- Recording result of operation and maintenance

2.6 Activity of preventive maintenance

- Inspection for the system
- Change oil and filters for engine
- Put grease in rotating parts of a motor
- Flush a distribution system without complaints
- Cleaning inside of the operator room
- Re-paint the fittings connecting the mains to a reservoir
- Inspect the condition of meters

3 Water Intake

3.1 Water source

3.1.1 Types of sources

The main sources of water are rain from which precipitations accumulate over and under the earth surface, thus giving rise to:

1. Surface water sources rivers, streams, lakes, ponds, dams
2. Sub surface sources: natural springs
3. Ground water sources: wells including open wells, dug wells and boreholes

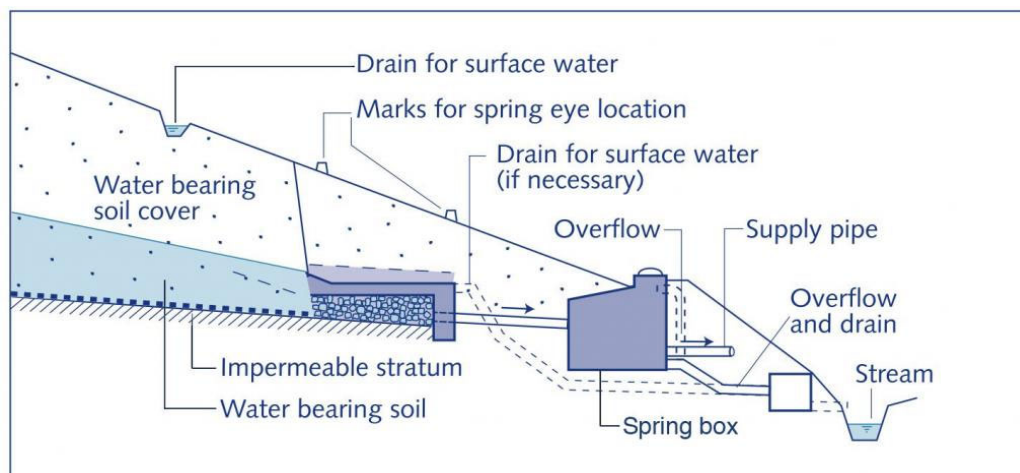
There are 3 features of a source such as quality of water, the quantity and reliability which are the most interesting during the appreciation of an appropriate water sources.

3.1.2 Intake arrangements

An Intake is a device or structure placed on a water source to permit withdrawal of the water from that source and to discharge into a water system (Gol, 2013). There are various catchment arrangements depending on the types of the sources. The following pictures show a typical intake arrangement of a natural spring:

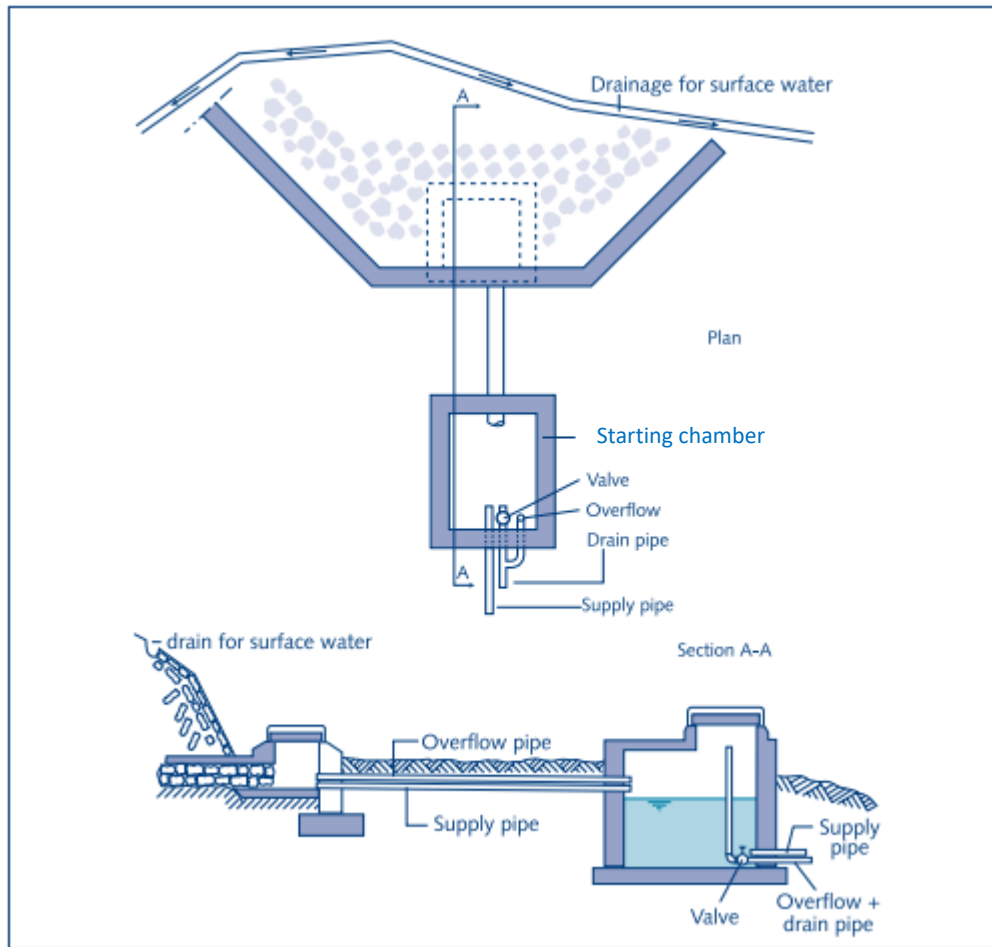
3.2 Natural springs

A natural spring is an opening where water from an aquifer emerges to the soil surface and spread continuously in the nature. Mostly the quality of springs' water is safe and people are used to develop a catchment arrangement to the openings of the springs and transfer that water to the places of use through pipes water systems. The figure below depicts sample technique of springs' water catchment:



(Smet & Wijk, 2002)

Figure 2: Lay-out of a spring water collection area



(Smet & Wijk, 2002)

Figure 3: Low cost option for collection area

During harnessing of a natural spring, the spring eyes are dug from the ground, cleared and collected first into gravels filter medium then directed into a spring box. The purpose of the spring box is to collect water from different springs, allow settlement of suspended particles and to discharge the water into the transmission main.

3.2.1 Main issues of the sources

- Seasonal or gradual fluctuations in water production
- Turbidity during rainy seasons due to erosion bringing about transportation of deposits, debris
- Pollution
- Leakages
- Clogging
- Damaging / collapse of the catchment arrangement due to external destruction actions or aging
- Conflicting uses between various consumers such as animals, people, irrigation, fishing, boats...)
- Growing of trees in the catchment

3.2.2 Preventive O&M of a natural spring

- Catchment protection: Protection of the catchment has two main objectives: (i) to improve the recharge of the aquifer, and (ii) to prevent contamination of the groundwater. This requires activities such as:
 - Planting lawn grasses to mitigate erosion
 - Controlling for growing and uprooting potential trees in catchment zone
 - Cleansing of the surface water drain or protection ditch
 - Fencing of the catchment zone (about 50 m radius)
 - Tracking the quality of water
 - Controlling the yield of the source
 - Respect standard of protection of source

Table 2: Schedule of operation and preventive maintenance activities in the catchment zone

Components	Actions	Frequency
Lawn grasses	Trim, replace and adds plants	Once a month
Growing trees in the catchment zone	Cut and uproot any trees growing over the catchment trenches.	As required
Springs marks	Maintain the location and repaint in red and white the springs marks (concrete sticks)	Once a year
Fence	Renew or reinforce the fences posts, lattices Trim uneven growing trees	Check once in three months and perform as required
Drainages / Protection ditch	<ul style="list-style-type: none"> • Clean off mud, sediments and deposits • Cut grasses and trees growing in the trenches. 	<ul style="list-style-type: none"> • After heavy rains • Once in three months
Surrounding catchment area.	Fight Erosion through: <ul style="list-style-type: none"> • Maintain land cover and runoff barrier • Develop water retaining and infiltration trenches 	Check one a year and perform as required
Check the quality of water	<ul style="list-style-type: none"> • Taking the water temperature with a thermometer 	Every day
	<ul style="list-style-type: none"> • Testing the turbidity of water 	More often during rainy season
Yield of the source	<ul style="list-style-type: none"> • Measuring the source discharge 	In the beginning, in the middle and at the end of every season.

3.2.3 Estimating the spring yield

The measurement of the flow rate of a spring is conducted by two persons. And it is expressed in liters per second.

For a non develop spring, the material required include a plough, shovel, a piece of pipe, a graduated bucket or a container, pile of clay, few stones, a block note and pen and a chronometer.

Procedures

- Clear the site and channel the water through a unique water way.
- Construct an earthen dam to retain the water, using the clay and stones if necessary.
- Insert an outlet in the dam with the pipe piece.
- After construction let water flow for a time and stabilize (This may take more or less 15 minutes for a small source). The stability is achieved once the level of the water in the dam is no more changing.
- One person takes to the outlet a graduated bucket or a container of well-known capacity. The other person records with a chronometer the time it takes to fill the container. Repeat the experience 4 times and do the average of the time required to fill the container.
- To calculate the flow rate, take the capacity of the container in liters and divide the average time it has taken to fill it.

3.2.4 Curative maintenance of the natural springs

Common problems of natural sources are the following: Leakage, Turbidity after rain, Sudden change of temperature, Drop of production during dry season, pollution.

a) Leakage:

Leakage of a source can occur due to cracks in the catchment after a natural disaster such as land slide, an earth quake or uneven land settlement. Also collapse of catchment can occur due to aging, invasion of roots, rodents, construction defaults or inappropriate operation. Most of the time, remedying a leaking source requires opening the catchment trenches and redo the lining of the catchment trenches with the new clay. The following table proposes solutions for various failures of natural springs' catchments.

b) Turbidity

In general, the quality of spring water is good. That can be justified by a persistent colorless (no color) and constant temperature properties. If spring water changes color after rain or if its temperature changes along the day, it is a sign of poor or thin soil layers over the aquifer. Thus the purification of the recharge water from the rain while this water is infiltrating through the soil layers is not reliable.

Table 3: Issues and remedies of the natural springs

Failure	Possible cause	Remedy
Leakage:	Natural disaster like: land slide, earth quake or uneven land settlement	Redo the catchment
	Collapse of internal arrangement of catchment materials (clay, gravel, pipes, back filling)	Redo the catchment

Failure	Possible cause	Remedy
	Diverting of sources	Redo the catchment
	Trees or rodents intrusion	Inspect the damage by follow the pathway of intrusion. If the damage is still larger, seal it with clay. If the catchment is deeply affected, redo it.
Turbidity & change of temperature along the day	Thin soil layers during infiltration	Treat water before use Forbid use of the catchment zone for farmers activities
	Cracks in the catchment allowing external water intrusion	Redo the catchment
	Quality of bedrock	Let suspended materials in water settle down or treat it before distribution
	Collapse of catchment	Redo the catchment
	Clogging or Insufficient slope of intake pipe	Readjust the intake pipe
Dropdown of production	Leakage	Redo the catchment
	Trees invasion	Cut and uproot the trees in catchment zone and surrounding area
	Drought	Reinforce the source with other closer sources.
Pollution	Toilets and dump pit in surrounding areas	Close or relocate the existing pits. Ban digging of new toilet pits.
	Activities (grazing, washing ...) in catchment zone	Fencing
	Damaged catchment	Repair the catchment.

3.3 Surface water sources

Surface water sources include rivers, streams, lakes and ponds. The most common method of intake for the surface water sources are the dams.

3.3.1 Frequent issues of the dams

Seepage

Seepage is the flowing of water through the embankment of the dam. The main causes of seepage in the dams are the roots of trees, construction defaults and rodents invasion. Once the seepage has started, it grows progressively, thus opening wide and creates a water path tunnel. This phenomenon is known as piping. In the end that tunnel may bring out the collapse of the dam.

Overtopping

Overtopping is the flowing of water over, or around the dam. That happening causes the erosion the soil particles from embankment of an earthen dam. Overtopping occurs when the spillway has been under designed or if there are entrapped debris hindering an adequate evacuation of overflow water.

Structural failures

Common structural failures of the dams are slides, overturning, cracks and settlements. Those failures result from bad construction materials or poor design and implementation techniques.

3.3.2 Preventive Operation and maintenance of the dams

Table 4: Activities and schedule for preventive maintenance of dams

Component	Maintenance activity	Frequency
Embankment	• Vegetation control	Twice per year minimum
	• Rodents control	Check once per year, then perform as required
	• Minor earthwork, erosion repair	Check once per year, then perform as required
	• Erosion protection	As required
Principal spillway	• Vegetation control	Every six month
	• Minor earthwork, erosion repair	Check every six month, perform as required
	• Erosion protection	Check every six month , perform as required
	• Concrete repair	As required
Emergency spillway	• Vegetation control	Every six month
	• Minor earthwork, erosion repair	Check every six month
	• Erosion protection	Check every six month
	• Concrete repair	As required

Intake / Outlet structures	Trash rack cleaning *	After every major storm
	Mechanical operation	Once per year
	Internal conduit inspection	Once per year
	Concrete features inspection	Once per year
Masonry walls	Vegetation control	Every six month
	Missing stones	As required
Miscellaneous Safety and access Features	Vehicle / Pedestrian access road (s) maintenance	Once per year
	Fence, locks, signs inspection	Once per year

Table adapted from: (Rocque, 2001)

*A trash rack is a wooden or metal structure, frequently supported by masonry, that prevents water-borne debris (such as logs, boats, animals, masses of cut waterweed, etc.) from entering the intake (https://en.wikipedia.org/wiki/Trash_rack)



Image of a trash rack (AWMA Water control solutions

<https://www.awmawatercontrol.com.au/products/trash-screen-trash-rack/>)

3.3.3 Curative maintenance of the dams

Table 5: Types of failure and recommended actions

Types of Failures	Possible cause	Procedure for solution
Seepage/Piping	Seepage water exiting at abutment contact	<ul style="list-style-type: none"> • Study leakage area to determine quantity of flow and extent of saturation • Inspect frequently for Slides • Water level in the impoundment may be lowered to increase embankment safety
	Seepage water exiting as a boil in the foundation	<ul style="list-style-type: none"> • Examine boil for transportation of foundation materials, evidenced by discoloration. If soil particles are moving downstream, create a sand bag or earth dike around the boil

Types of Failures	Possible cause	Procedure for solution
	Rodents activity	<ul style="list-style-type: none"> Control rodents to prevent more damage. Determine exact location of digging and extent of tunneling. Remove rodents and backfill existing holes
Overtopping/Erosion	Blocked/inadequately sized spillway	<ul style="list-style-type: none"> Remove all trees and shrubs on and within 1meter of the embankment. Properly backfill void with compacted material. Control vegetative growth in spillway channel. Install log boom or trash rack in front of spillway entrance to intercept floating debris
	If riprap is broken down or missing	<ul style="list-style-type: none"> Re-establish normal slope. Place bedding and competent riprap
	If erosion was observed	<ul style="list-style-type: none"> Protect eroded area, compacted soil and re-establishing turf
Structural failure such as cracking, settlement and slides	Large cracks, slide, slump or slip	<ul style="list-style-type: none"> Measure extent and displacement of slide. If continued movement is seen, begin lowering water level until movement stops
	Wall displacement / open joints	<ul style="list-style-type: none"> Reconstruct displaced structure. Water-stops should be used at joints where feasible.
	Large cracks	<ul style="list-style-type: none"> Cracks without large displacement may be repaired by patching, in which case surrounding areas should be cleaned or cut out before patching
	Leakage through joints or cracks	<ul style="list-style-type: none"> Check area behind wall for paddling of surface water. Check and clean drain outfalls, flush lines, and weep holes
	Valve leakage	<ul style="list-style-type: none"> Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trash rack

Table adapted from: (Rocque, 2001)

3.3.4 Structure of boreholes

The structure of boreholes must be determined considering, besides the foreseen deepness, the pumping flow, the groundwater level, the water quality, etc.

Boreholes pump groundwater from the confined aquifer, that is why, unlike wells (artesian wells), the pumping flow is depending on perforation, diameter and deepness of it, as well as by the aquifers, the pump capacity, etc.

Generally steel pipes are used for the casing of boreholes, which thickness will be determined by the ground condition. However, when there is corrosive possibility for the water quality influence, the quantity of water or galvanic corrosion, there are cases in which thicker pipes are utilized, PVC pipes, stainless steel pipes, fibre reinforced pipes (FRP), etc., according to necessity.

The joints of casing pipes and screen pipes must be connected perfect, for example, welded, threaded or flanged joints.

For pumping groundwater from boreholes, submersible pumps are mainly utilized, which specifications are determined by the pump diameter, flow rate, total head, electric tension, frequency, pump performance, axis power, etc.

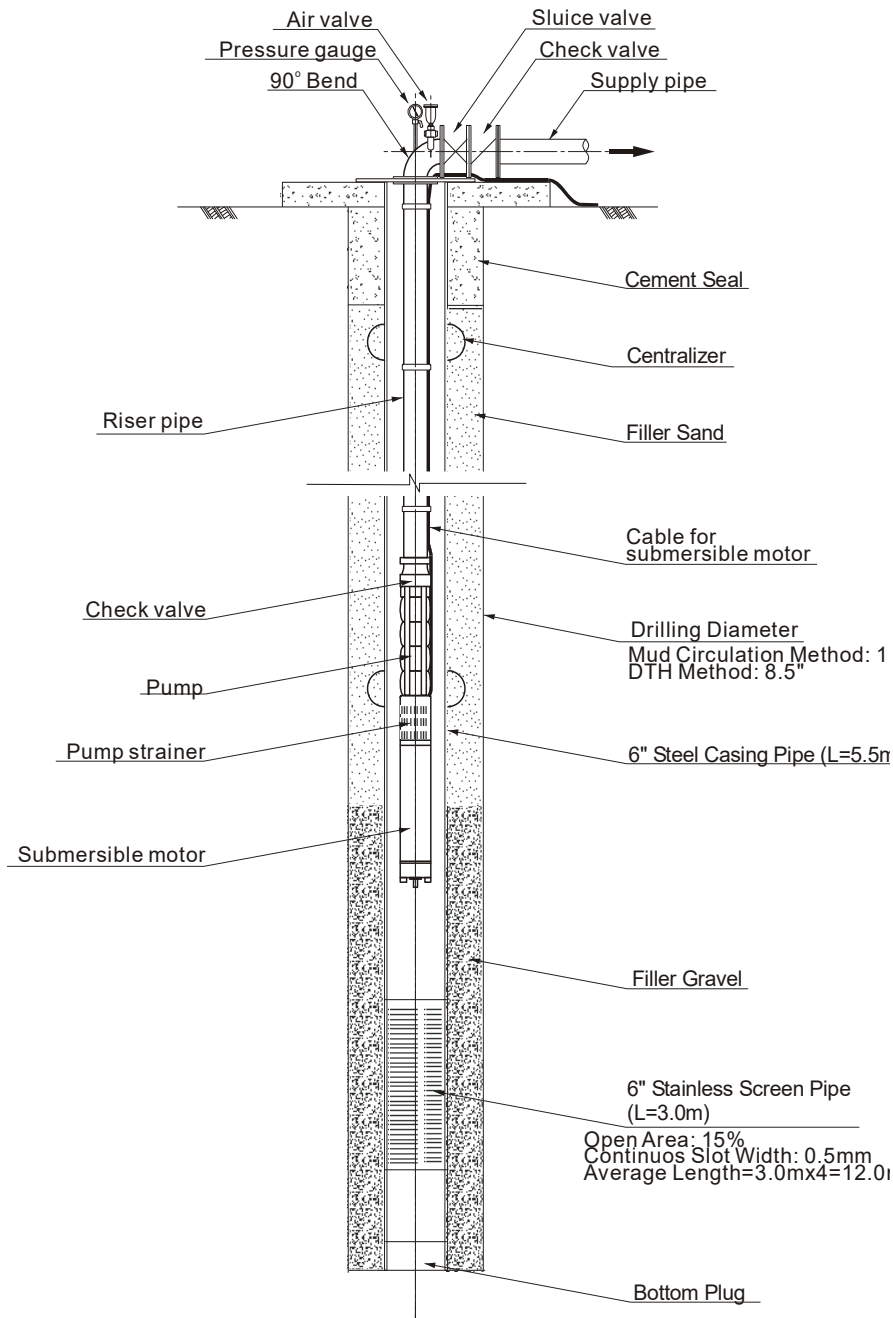


Figure 4: Example of the structure of borehole with submersible motor pump

3.3.5 Preventive maintenance of boreholes

The borehole has its maximum pumping capacity, in normal cases, at the moment to end its construction. The borehole capacity declines through aging, according to the passage of time, whether it is used or not.

The capacity decrease of the borehole during the pumping is mainly due to obstructions, though the water is not pumped, the convection inside the borehole conducts to oxidation right through the deepest part, being able to cause obstructions because of chemical reactions.

It is difficult to keep maintaining the initial pumping capacity. In the case of capacity declining, it is possible recovering it through rehabilitation works, etc.

There are 3 related factors with the functioning of the borehole:

- i) water quantity
- ii) water level
- iii) water quality

When the borehole functioning becomes worse, phenomena like water pumping volume decrease, water level lowering and water quality change might be occurred. Among these factors, the water quantity decrease and water level lowering appear at the same time. It means that for some reason the water level declines, and the water quantity. On the other hand, the water level decrease may affect the water quality. As one of the most representative cases, it is mentioned iron, salt, manganese, fluoride and other minerals should be found in boreholes depending on the geological condition. That is why it must be constantly measured the 3 aforesaid factors to diagnose the borehole.

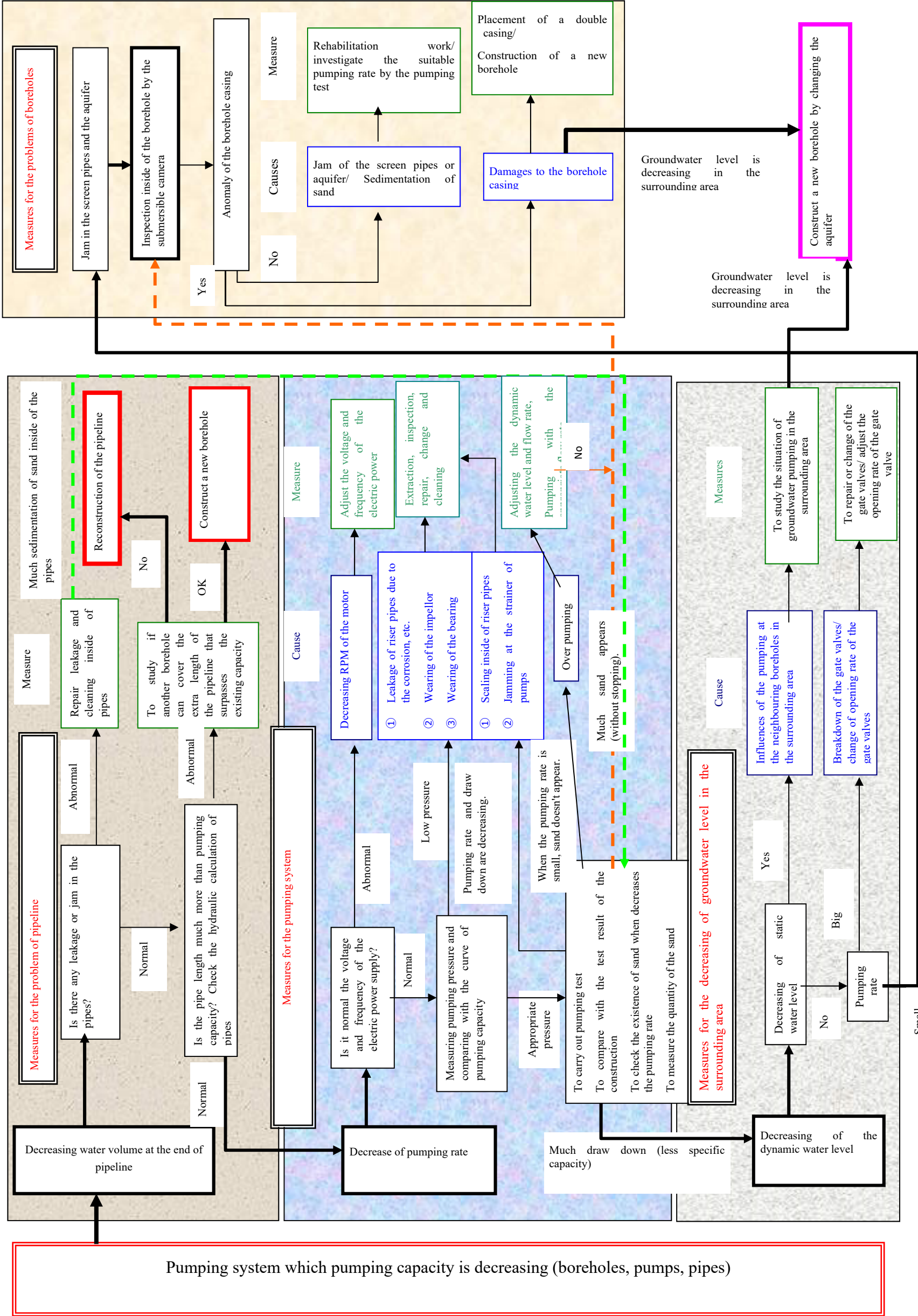


Figure 5: Diagnostic diagram of deep borehole

3.3.6 Curative maintenance of boreholes

Cause of reduction in well performance

There are many variables that contribute to reduction in well performance. That is to say,

- Pump damage or wear,
- Well screen and casing corrosion or incrustation,
- Incrustation of the aquifer,
- Structural failure of the well

These problems are often traced to factors such as poor well design or construction or improper selection of pump materials. Besides, hydrogeological conditions may contribute to reduced well performance. For examples,

- Reduced aquifer recharge,
- Over pumping of aquifer,
- Interference from nearby wells

Change in groundwater quality is also a significant factor in well performance decline.



Clayey material on the hand pump plunger caused by siltation



Incrustation on the well screen

Figure 6: Siltation and incrustation in the borehole

3.3.7 Method of curative maintenance of borehole

There are typical methods of curative maintenance for the borehole as follows;

- Air lifting method
- Mechanical bailing with a bailer
- Mechanical surging with a surge block
- High-velocity water jetting

It is recommended to refer to Table 6 when selecting the curative maintenance methods. Each method is outlined below.

Table 6: Applicability of Curative Maintenance Method by Type of Borehole

Type of Borehole		Applicability of Curative Maintenance Method			
Type	Material of casing and screen pipe	Air lifting	Mechanical bailing with a bailer	Mechanical surging with a surge block	High-velocity water jetting
Borehole with handpump	uPVC, dia. 4"	applicable	less applicable	inapplicable	inapplicable
Borehole with motorized pump	Steel or stainless steel dia. 6" - 14"	less applicable	applicable	applicable	applicable

4 Operation of the Pumping Cabin

4.1 Water pumps

4.1.1 Security and tidiness in the pumping cabin

A pumping station is a delicate place which deserves special tidiness and protection. Important actions, arrangements and procedures for operation and maintenance inside the pumping station are depicted in the Table 7.

Table 7: Security and tidiness in the pumping premises

Item to control	Reasons	Methods/ Actions/ Arrangements	Responsible persons	Frequency
01 Limit accessibility to workers and notified people	<ul style="list-style-type: none"> Protect the station (fragile material, valuable equipment, fuel reserve, tools); Protect people (risk of fire, burn, cut). 	<ul style="list-style-type: none"> Fencing the pumping premises Closing and controlling the entrance gates Hiring permanent guards 	<ul style="list-style-type: none"> Manager Guardian Care taker 	Always
02 Clean the pumping station	<ul style="list-style-type: none"> Avoid contamination of the quality of water Make attractive and motivating working environment Good impression to water consumers 	<ul style="list-style-type: none"> Washing and sweeping surfaces outside and inside Trim and weeding garden's plants Maintenance of lanes 	<ul style="list-style-type: none"> Cleaner 	Twice a week
03 Ensure safe storage/ use of substances	<ul style="list-style-type: none"> Avoid deterioration of reagents Avoid effect on human being Avoid accident including fire, corrosion ... 	<ul style="list-style-type: none"> Put bags of reagents on timber cases Maintain suffocating substances tightly closed Avoid humidity and excessive brightness in the storage medium 	<ul style="list-style-type: none"> Manager Team leader Workers 	Always
04 Guarantying Hygiene	<ul style="list-style-type: none"> Maintain safe and healthy working conditions 	<ul style="list-style-type: none"> Provide toilets, washing facilities and drinking water 	<ul style="list-style-type: none"> Manager Team leader 	Always

Item to control	Reasons	Methods/ Actions/ Arrangements	Responsible persons	Frequency
05 Implement emergency procedures – evacuation in case of fire or other significant incidents.	<ul style="list-style-type: none"> Maintain safe and healthy working conditions 	<ul style="list-style-type: none"> Provide wide open doors and windows and a ring for alarming 	<ul style="list-style-type: none"> Manager Team leader 	Always
06 Heavy noise from pumps	<ul style="list-style-type: none"> Preserve hearing 	<ul style="list-style-type: none"> Avoid long time stays in the pumping house Bear Headphones 	<ul style="list-style-type: none"> Workers 	Always
07 To prevent accidents and cases of work-related illness	<ul style="list-style-type: none"> provide adequate control of health and safety risks arising from work activities 	<ul style="list-style-type: none"> Distribute personal protective equipment such as Masks, gloves, helmets, working clothes... Provide enough training to the staffs Avail the first aid box containing ointments, adhesive bandages, Soaps, Gloves, Goggles, Alcohol pad, Scissors , Paracetamol , Plastic tweezers 	<ul style="list-style-type: none"> Manager Team leader 	Always
08 Precaution against small fire	<ul style="list-style-type: none"> Extinguish 	<ul style="list-style-type: none"> Provide extinguisher bottles Pile of sands and shovel 	<ul style="list-style-type: none"> Manager Team leader Workers 	Always

Source: Guidelines of operation and maintenance for PO and the Districts (Suswas, 2016) and (HSE, 2014)

4.1.2 Operation of the pumps

There are many types of pumps which can be grouped into 3 categories:

- Velocity / turbine pumps like centrifugal pumps;
- Positive displacement pumps like piston pumps.
- Direct lift pumps

The principle of function of a positive displacement pump is base in trapping a fixed amount of water and forcing that trapped volume into the discharge pipe.

Concerning the Direct lift pump, the liquid is enclosed in a container which is raised to a desired height. This is the case of the Bucket wheels, bucket chains and Archimedes screws.

Velocity pumps are the common type used for *potable water* pumping applications: For this type of pumps, kinetic energy is transmitted to the fluid by increasing the flow velocity. This increase in energy is converted into potential energy (pressure). Example of velocity pumps include the centrifugal horizontal pump.

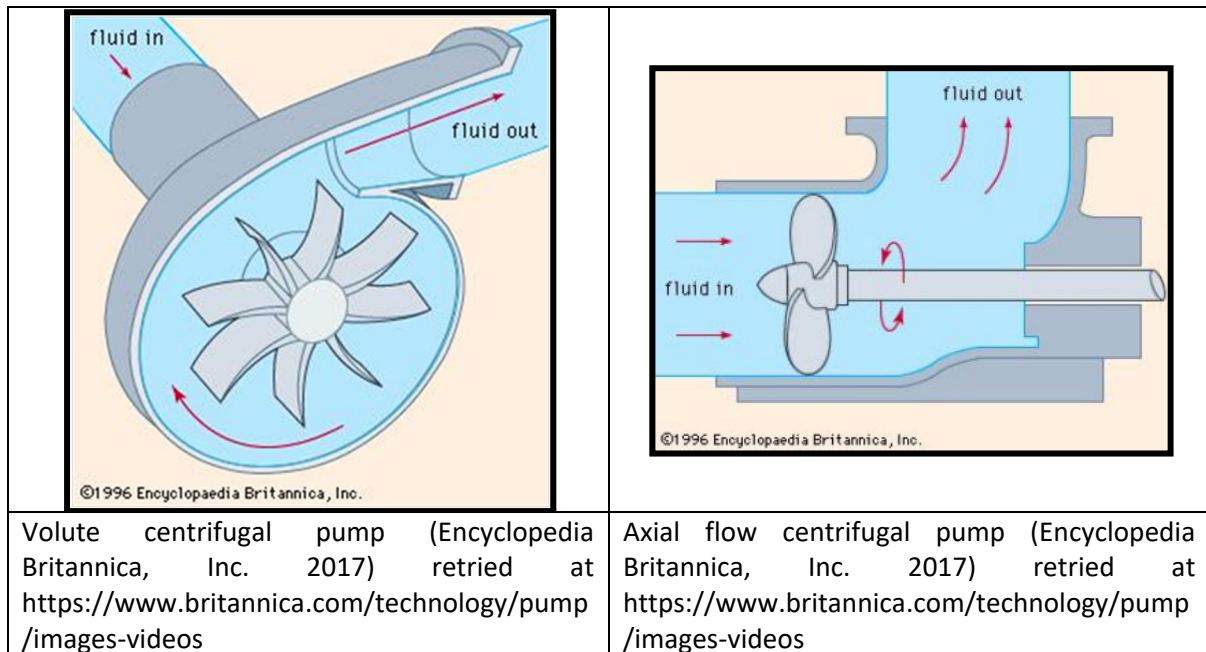


Figure 7: Radial vs. axial centrifugal pumps

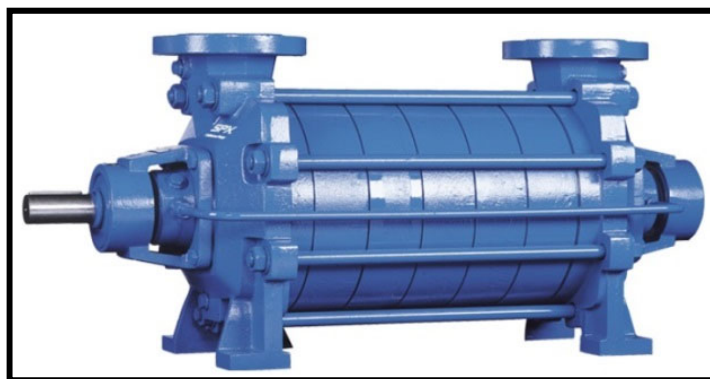


Figure 8: Multistage centrifugal pump

(Johnson Pump, 2017)

4.1.3 Starting and stopping water pumps

Every time, before starting pumps, the pumps operator should ensure that all installations are in healthy conditions to allow proper functionality of the pumps. For that reason, the following inspections need to be conducted.

a. Check the condition of the source of energy

Condition of the source of the energy shall be checked by the method shown in the Table below.

Table 8: Method of checking the condition of the source of energy

Item to inspect		Method
01	Power is available in all 3 phases	<ul style="list-style-type: none"> • Check voltage of each line with respect to ground using volt meter • voltage of each line with respect to ground is more or less same +/- 20 volt • If the source of energy is a generator, check the condition of the generator • Check the fuel and lubricant in the generator • Check the condition of the battery of the generator
02	All connections are properly thimble	<ul style="list-style-type: none"> • Closer observation
03	Trip circuit for relays is in healthy state	<ul style="list-style-type: none"> • In healthy situation all the contacts except protective relay contact are in close position.

b. Check the conditions of the pumps

Condition of the pump shall be checked by the method shown in the following table.

Table 9: Method of checking the conditions of the pumps

Item to inspect		Method
1	Check functioning of lubrication system of different pump elements	<ul style="list-style-type: none"> • Observation and manipulation
2	Check stuffing box to ensure that it is packed properly.	<ul style="list-style-type: none"> • Observation and manipulation
3	Check and ensure that the pump is free to rotate	<ul style="list-style-type: none"> • Observation and manipulation
4	Check if the pump is turning in the right direction	<ul style="list-style-type: none"> • Observation and manipulation

c. Check the availability of water

Availability of the water shall be checked by the method shown in the Table 10.

Table 10: Method of checking the availability of water

Item to inspect		Method
1	be ensured that the water level in the sump/intake is above low water level and inflow from the source is adequate	<ul style="list-style-type: none"> • Read the water level gauge • Open the trapdoor of the intake structure and observe
2	Check if the level of suspended material and the turbidity of water are acceptable in order to avoid abrasive sands or to pump useless water.	<ul style="list-style-type: none"> • Take a sample in transparent beaker and observe • Take sample to the laboratory if necessary

d. Records to be taken before starting pump operation

The following items shall be recorded before starting operation.

- Timings when the pumps are started, operated and stopped during 24 hours
- Index of electric meters including the current drawn by each pump-motor set and total current drawn at the installation
- Voltage in all three phases and the frequency of the current
- Readings of vacuum and pressure gauges
- Bearing temperature for pump and motor
- Index of water levels in reservoirs

- Readings on the pressure gauges
- Water level in intake/ sump
- Flow meter reading
- Any specific problem or event in the pumping installation or pumping system

e. Starting process

Procedure of starting operation of the pump shall be the followings.

- i. Open the suction valve
- ii. Open any recirculation or cooling lines
- iii. Fully close or partially open the discharge valve, depending on system conditions
- iv. Start the pump
- v. Slowly open the discharge valve until the pump reaches the desired flow
- vi. Check the pressure gauge to ensure that the pump quickly reaches the correct discharge pressure
- vii. If the pump fails to reach the correct pressure, perform these steps
 - Stop the pump
 - Prime the pump again
 - Restart the pump
- viii. Monitor the pump while it is operating
 - Check the pump for bearing temperature, vibration and noise
 - If the pumps exceed normal levels, then shut down the pump immediately and correct the problem
- ix. Repeat steps vii and vi until the pump runs properly

If the source of energy is an engine generator, the following action shall be taken.

- Let it run without load for 3 minutes to heat
- Check volts and amperes dials (if any) and all indicator lights.
- Engage the pump.
- Monitor all lights and indicators.
- Attention should be paid to the sounds of machines.
- Check that there are no leaks of fuel or water.

f. Stopping a pump in normal conditions

Under normal circumstances, stop pumping takes place more or less by taking reverse actions at startup.

Normal stopping occurs when:

- The discharge tank is full;
- The water level of suction tank is at the limit;

- Time is up for stopping machines

g. Stopping procedures

- i. Monitor all lights and indicators. Attention should be paid to the sounds of machines. Check that there are no leaks of fuel or water and no overheating.
- ii. Close the delivery valve gradually (sudden or fast closing should not be resorted to, because it may give rise to water hammer pressures)
- iii. Stop the pump. If there is an engine generator the pump should be stopped first and then the engine generator.
- iv. Open the air vent in case of vertical turbine and submersible pump
- v. Stop lubricating oil or clear water supply in case of oil lubricated or clear water lubricated pump.
- vi. Record water meter reading, pressure gauges reading and stop time.
- vii. Check fuel, whether they are sufficient for the next day.
- viii. Check the cleanliness, clean the station and appliances

h. Pump stopping in emergency situation

The emergency conditions are all suspect or critical operating situations such as red light, heating, dials showing abnormal data, power failure or tripping. Those conditions require direct stopping. In case of power failure, precautions are necessary to prevent auto-restarting on resumption of power.

The emergency procedure should be defined case by case depending on the configuration of the station.

- It will be written and displayed in the station.
- All personnel on the station will be trained on it twice a year.

The following principles should be applied to define the procedure:

- An Operator's employee shall be permanently at the station while working.
- They need to know all the specific points that can trigger an emergency stop.
 - Abnormal noise;
 - Heating of device;
 - Red lights;
 - Loss of oil, fuel or water;

- Gauge that is not at its routine pressure;
- Voltage or amperage that is not normal (heat up and burn the control box);
- Safety Issues: heavy rains, thunderstorm with lightning, suspicious people.

Table 11: Rules to be respected during operation of a pump

Activity		Frequency	Method
01	Prime the pump before starting	If the pump has been out of use for a relatively long period of time	<p>Water needs to be flushed back into it and forced through in order for it to create enough pressure to begin pumping again.</p> <ul style="list-style-type: none"> • Turn off electrical power to the pump. • Locate a plumbing fixture that provides access to the pump system • Prepare a hose that can be connected to an independent water source • Flush the hose to remove any build-up. • Open any relief valves on the pump system • Insert the hose in the plumbing fixture • Turn on the water to the hose • Wait for water to enter the tank. • Turn off the water to the hose. • Restore power to the pump and turn on the pump system • Wait for the pump to finish its cycle • Repeat all steps until the pump is primed and functioning normally
02	Prevent dry running	Every time	<ul style="list-style-type: none"> • Fill the intake tank • Open the valves between intake and the pumps
03	<ul style="list-style-type: none"> • Avoid overheating of casing and pumps • Maintain the normal efficiency of the pumps 	Every time	<ul style="list-style-type: none"> • Respect the head-discharge characteristics of the pump. Don't pump near or beyond the shutoff head.
04	Maintain the voltage within the range of 10% of the pump design voltage	Every time	
05	Reduce starting load on motor	Every time	<ul style="list-style-type: none"> • Start a pump of low or medium specific speed against closed delivery valve

Activity		Frequency	Method
			Start a pump of high specific speed against closed delivery valve Normally the pumps used in water supply schemes are of low and medium specific speeds
06	Control sudden change in flow velocity which can cause the water hammer pressures	Every time	Operate gradually the delivery valve
07	For parallel operating pumps, the pumps should be started and stopped with a time lag between two pumps. In order to restrict change of flow velocity to minimum and to restrict the dip in voltage in incoming feeder.	Every time	Read the evolution of pressure on the pressure gauge to determine and maintain adequate time lag.
08	For the pumps operating in series, start and stop them sequentially, with minimum time lag.	Every time	<ul style="list-style-type: none"> • Next pump in sequence should be started immediately after the delivery valve of the previous pump is even partly opened • Due care should be taken to keep the air vent of the pump next in sequence open, before starting that pump.
09	Avoid idle pumps in the pumping station	Every time	<ul style="list-style-type: none"> • The running of the duty pumps and the standby should be scheduled so that no pump remains idle for long period and all pumps are in ready-to run condition • Unequal running should be ensured so that all pumps do not wear equally and become due for overhaul simultaneously
10	If any undue vibration or noise is noticed, the pump should be stopped immediately and cause for vibration or noise be checked and rectified	Every time	<ul style="list-style-type: none"> • Stop pump immediately after notification of vibration or noise •
11	Bypass valves of all reflux valve, sluice valve and butterfly valve shall be	Every time	Close valves.

Activity		Frequency	Method
	kept in closed position during normal operation of the pumps		
12	Frequent starting and stopping should be avoided as each start causes overloading of motor, starter, contactor and contacts. Though overloading lasts for a few seconds, it reduces life of the equipment.	Every time	Avoid frequent starting and stopping.

Source: Operation and maintenance manual for rural water supplies

During pumping operation "except for fully automated stations, all others must have a guardian at all times during pumping.

This may be the station's day or night guard, who has received specific instructions about what to monitor and how he can stop pumping (emergency procedure).

The Operator must be aware of the value of the pumping facilities, and his responsibility for their life span.

4.1.4 Preventive maintenance of the pumps

Method of preventive maintenance of the pumps is mentioned in the Table 12.

Table 12: Method of preventive maintenance of the pumps

Actions		Frequency	Method
01	Check for any abnormal bearing noise	Daily	<ul style="list-style-type: none"> Repeated hearing standing at different locations
02	Check belt tension. In case this is excessive it should immediately be reduced	Monthly	<ul style="list-style-type: none"> Push it with the thumb and estimate the flexion.
03	Examine oil in oil lubricated bearing for contamination by dust, grit, etc.	Monthly	<ul style="list-style-type: none"> This can be judged from the colour of the oil
04	Clean oil lubricated bearings and replenish fresh oil	Quarterly	<ul style="list-style-type: none"> Anti-friction bearing should have its housing so packed with grease that the void space in the bearing housing should be

Actions		Frequency	Method
			between one third to half.
05	Check tightness of cable gland, lug and connecting bolts	Quarterly	<ul style="list-style-type: none"> • Push it with the thumb and estimate the flexion.
06	Check and tighten foundation bolts and holding down bolts between motor and frame	Quarterly	<ul style="list-style-type: none"> • Push it with the thumb and estimate the flexion.
07	Check vibration level	Quarterly	<ul style="list-style-type: none"> • with instrument if available; otherwise by observation
08	Check air gaps.	Annually	<ul style="list-style-type: none"> • Put a hand closer an opening • Attentive hearing
09	Check resistance of earth connections	Annually	<ul style="list-style-type: none"> • Observation

4.1.5 Curative maintenance of the pumps

Prevalent failures and breakdowns of the pumps occur in pumps' efficiency, packing adjustment and misaligned head shafts.

a. Low pump efficiency

If the pump performance tests reveal that the pump is operating at significantly lowered efficiencies, the pump should be pulled out, inspected and repaired or reconditioned. This work is best referred for servicing to the manufacturer or a pump repair specialist.

b. Packing adjustment

The water flowing through the stuffing box should be maintained at a level just enough to prevent overheating. The gland nuts should be loosened or tightened one-quarter turn only to allow the packing to equalize against the pressure.

c. Checking and Adjusting Misaligned Head Shaft

Pump vibrations could indicate a misalignment of the head shaft. This can be checked by the following procedure:

- Remove the motor dust cover, motor head nut and key, and take out the motor drive flange.
- Check if the head shaft is concentric with the motor hollow shaft bore.
- If needed, adjust by using shims.

Other technical problems can be controlled guided by the Operational manual from manufacturer as in following table:

Table 13: Curative maintenance of jet centrifugal pumps

Trouble	Likely cause of trouble	Remedy
Pump Motor fails to start	Blown fuse or open circuit breaker.	Replace fuse or reset circuit breaker.
	Motor or starting switch out of order.	Inspect / repair. Refer to equipment supplier or experienced mechanic or electrician
	Break in wiring.	Repair circuit wires
	Stuffing box may be binding or tightly packed	Check packing by manually rotating shaft.
		Loosen packing nut just enough to allow a slow seepage of water and free the shaft.
Scale or sand in the impeller	Open pump and remove scale by acid treatment and/or sand.	
Pump runs but delivers no water	Pump lost first priming	Repeat priming. Follow manufacture's priming instruction.
	Pump repeatedly loses priming due to leaky drop pipe or suction pipe.	Pull out drop pipe and seal the leaks.
	No water at source due to over pumping	Reduce pumping rate or deepen the well.
	Collapse of well casing or screens	Replace with new one. If diameter of old casing is large, insert new casing inside the damaged casing. Consult driller.
	Clogging of well screens	Surging or acid treatment. Consult driller.
Pump runs but delivers only a small amount of water	Well not yielding enough water.	Do pumping test or deepen the well
	Air leaks in the suction pipe.	Pull the drop pipe from the well & seal leak
	Incrustation or partial clogging of well screen.	Surging or acid treatment. Consult driller.
	Impeller is worn out or lugged with scare or trash.	Open the pump and clean / replace impellers
	Foot valves may be obstructed	Clean foot valve
Noisy pump	Bearing or other working parts of pumps are loose or need to be replaced	Tighten or replace defective parts

Trouble	Likely cause of trouble	Remedy
	Pump motor is loosely mounted	Tighten mounting
	Low water level in well	Reduce pumping rate and regulate water level (lower and upper limit)
	Presence of air in suction line	Repair air leaks.

For submersible pumps common problems and remedy can be tackled as indicated in the Table 14.

Table 14: Curative maintenance of submersible centrifugal pumps

Trouble	Likely causes	Remedies
Pump motor fails to start	Motor overload	Overloaded contacts close automatically. Check cause of overload
	Low voltage	Check voltage
	Blown fuse, broken or loose connections	Check fuses, relays, electric condensers and all electrical connections
	Motor control box not in proper position	Ensure box is in right position
	Damaged cable installation	Locate and repair the damaged cable.
	Cable, splice or motor windings may be grounded or wet.	Check the ground by using an ohmmeter. If grounded, pull out the unit and inspect cable and splice. Cut the unit loose from the cable and check each part separately using an ohmmeter.
	Pump stuck by corrosion or abrasive	Pull out pump, examine and remove foreign matter.
Pump runs but delivers little or no water	Pump not submerged	Lower the unit into the well or replace by a smaller capacity pump
	Discharge pipe may be leaking	Examine discharge line by pulling out one joint at a time.
	Check valve may be clogged or corroded	Pull out pump and clean or replace check valve
	Pump badly worn-out by sand or abrasive	Replace pump. Clean well thoroughly of abrasive before putting the new unit in.
	Strainers or impellers clogged with sand or scale	Pull out pump unit and remove the scale / sand.

Trouble	Likely causes	Remedies
	Scaled or corroded discharge pipe	Replace pipe
Pressure valve fails to shut	Discharge pipe	Adjust or replace discharge pipe
	Switch may be defective or out of adjustment	Adjust or replace pressure switch
	Discharge pipe may be leaking	Raise unit one pipe joint at a time until leaks is found. Repair leaks.

Other common problems of pumps are treated in the Table 15.

Table 15: Most common problems of pumps

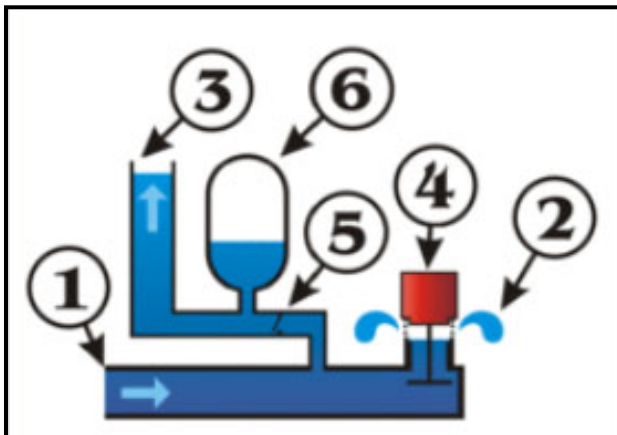
Problems	Reasons	Remedy
Corrosion	Different fluid properties can corrode the pump	<ul style="list-style-type: none"> Remove and replace the damaged parts Avoid aggressive water in the pump
Cavitation causing the damage of the impeller or the pump housing	<p>Cavitation is the result of inadequate suction pressure due to:</p> <ul style="list-style-type: none"> Suction water level of the supply was lower than normally expected. Upstream suction butterfly valve contributed to suction losses and turbulence Pumps operating head is considerably lower than the rated head. As a result the pumps is operating at considerably higher capacity 	<ul style="list-style-type: none"> Throttle the pumps so as to operate at a lower capacity wherein the Net Positive Suction Head Available (NPSHA) exceeds the Net Positive Suction Head Required (NPSHR) Trim the impeller to reduce capacity Add a Variable Frequency Drive (VFD) to reduce speed and capacity Replace impellers with ones constructed of more cavitation resistant materials. Replace pumps with new pumps better matched to the system head and NPSHA conditions
Wear of the Impeller	Can be worsened by suspended solids	Remove the pump and remove suspended solids.
Leakage	A wrong rotating shaft	Check and repair



Figure 9: Example of cavitation

4.1.6 Hydraulic ram

The hydraulic ram needs no external source of power. The ram utilizes the energy contained in a flow of water running through it, to lift a small volume of this water to a higher level. The phenomenon involved is that of a pressure surge, which develops when a moving mass of water is suddenly stopped. A steady and reliable supply of water is required with a fall sufficient to operate the hydraulic ram. Favourable conditions are mostly found in mountainous areas



Basic components of a hydraulic ram:

1. Inlet – drive pipe
2. Free flow at waste valve
3. Outlet – delivery pipe
4. Waste valve
5. Delivery check valve
6. Pressure vessel

Advantages

- No power sources are needed, and therefore no running costs.
- Suitable for low income area
- Simple design technology
- Protection of electro mechanical equipment

a. Starting an hydraulic ram pump

After installation of a new ram or when an existing ram has stopped, the following proceeding are performed in order to run it:

- Manually push down the waste valve already in closed position and put it open. If the flow is sufficient, it will then cycle at least once.
- If it does not continue to run by itself, repeat pushing down the waste valves several times until it runs.
- If the ram stops with the waste valve in the down (open) position, it must be lifted manually and kept up for as long as necessary for the supply pipe to fill with water and for any air bubbles to travel up the pipe to the source. Then it can be started manually by pushing it down a few times as described above. Having a valve on the delivery pipe at the ram makes starting easier.
- Close the valve until the ram starts cycling, then gradually open it to fill the delivery pipe. If opened too quickly it will stop the cycling. Once the delivery pipe is full the valve can be left open.

b. Maintenance of hydraulic ram pump

- Curative maintenance includes: "activities as replacement of the valve rubbers when they wear out, adjusting the tuning, and tightening bolts if they get loose. Occasionally the hydraulic ram may need dismantling for cleaning.
- Failure to deliver sufficient water may be due to improper adjustment of the waste valve, having too little air in the pressure vessel, or simply attempting to raise the water higher than the level of which the ram is capable.
- If the ram is broken due to climatic or mechanical problems, the damaged component can be removed and replaced by a new one or repaired through adjustment, welding, etc.
- If the recycling has stopped check the adjustment of the waste valve or the amount of water flow, then restart it manually.
- Check the sediments and debris in water which may clog the valves and prevent the cycling of the system. It is reasonable also to provide screen or strainer at water catchment.
- Check also the materials used during installation such as uniformity of pipes, the bending, etc.

4.2 Power drivers

4.2.1 Diesel engine

Diesel engines have the important advantage that they can operate independently at remote sites. The principal requirement is a supply of fuel and lubricants and these, once obtained, can be easily transported to almost any location. Diesel engines, because of their ability to run independently of electrical power supplies, are especially suitable for driving isolated pumping units such as raw water intake pumps.

a. Preventive maintenance of diesel engine

In almost all cases, diesel engine prime movers are designed as standby units, these must be given proper care to prolong their life and for their efficient operation. In the absence of the equipment operating manual, listed below are suggested preventive maintenance practices.

Before start operation:

Operate the diesel engine at about 1,000 rpm for at least 5 minutes or until warm. This would allow the lubricant and coolant to circulate around the engine.

Every 8 hours operation:

Check coolant level, sump oil level, oil reservoirs, for oil, water or fuel leaks and clean oil bath cleaner.

Every 200 hours of operation:

- Drain and renew engine lubricating oil.
- Renew lubricating oil canisters.
- Check tension of drive belt.
- Clean fuel water trap.
- Lubricate dynamo rear brush.
- Clean air filter element.

Every 400 hours of operation:

- Renew fuel and air filter elements.
- Check hoses and clips.
- Clean lift pumps sediment chamber.

Every 2,400 hours of operation:

- Check and adjust valve clearances.

- Service injector units.

4.2.2 Electrical motor

Electric motors generally need less maintenance and are more reliable than diesel engines. They are therefore preferable as a source of power for pumping, if a reliable supply of electric power is available. The electric motor should be capable of carrying the workload that will be imposed, taking into consideration the various adverse operating conditions under which the pump has to work. If the power requirement of a pump exceeds the safe operating load of the electric motor, the motor may be damaged or burnt out. Attention must also be paid to the characteristics of the motor and the supply voltage.

There is sometimes a tendency to use general-purpose motors offered by the manufacturers without giving due consideration to the characteristics of the particular pump used. This results in frequent failure or burning out of the motor. The squirrel-cage motor is mostly selected for driving a centrifugal pump as it is the simplest electric motor manufactured.

4.2.3 General operation and maintenance for electrical motor

The most important items for good maintenance of an electric motor, aside from checking for bearing wear, are regular use, and keeping it warm (from operation), clean, and dry. Moisture is an enemy of insulation along with oil and dust.

Every motor should be operated for 5-6 hours at least every week. The longest useful life of a motor is obtained from a unit which is never shut down and cooled off, especially in a humid climate. Listed below are some maintenance tips.

Every Day:

- Check temperature of motor housing with hand.
- Check lubrication reservoir level.
- Check air vents for blockage.
- Check external wiring for frayed insulation or loose connections.
- Check voltage and current at each leg of the three phases.

Every Month:

- Check motor housing temperature.
- Check shaft alignment.
- Check input horsepower under load.

Every Year:

- Vacuum all dust out of windings and motor case.
- Drain lubricant, flush out oil reservoir with kerosene, and replace with factory-approved lubricant.

Every Three Years:

- Examine winding insulation for damage.
- Clean oil connectors and contact points with fine emery cloth.
- Inspect shaft and bearings for scour, wear or damage.
- Check input horsepower under load.

Table 16: General operation and maintenance of the motor

Description		Frequency	Method
01	Clean external surface of motor	Daily	<ul style="list-style-type: none"> • Blowing air • Wiping dust with a soft and dry tissue • Sweeping the dust with the brush
02	Examine earth connections and motor leads	Daily	Observation
03	Check temperature of motor and check whether overheated.	Daily	Temperature observation should be taken with Resistance Temperature Detector (RTD) or thermometer
04	Check the function of the oil ring lubricating bearing	Daily	Observation
05	Check for any abnormal Bearing noise	Daily	Hear the noise
06	Check belt tension	Monthly	Press the belt downward using the thumb and measure deflection with a ruler
07	Check insulation resistance	Monthly	Observation
08	Check condition of stator, stamping, insulation, terminal box, fan etc.	Annually	
09	Regular operation and maintenance records	Daily	<ul style="list-style-type: none"> • Record characteristics of the pump such as rating, model,

Description		Frequency	Method
			class of duty, class of insulation, efficiency curve <ul style="list-style-type: none"> • Record identity and address of the manufacturer • Record the date of installation and commissioning • Make records of monthly, quarterly, half yearly and annual maintenance and inspections about insulation level, air gap etc.
10	Checking the condition and maintaining the transformers, breakers, contactors and protection relays	Daily and Monthly	<ul style="list-style-type: none"> • Circuit diagram of breaker/relay circuit should be pasted on door of switch gear and additional copy should be kept on record. • Proceed to the regular maintenance and servicing of the components.
11	Check temperature of motor and check whether overheated	Daily	<ul style="list-style-type: none"> • Temperature observation should be taken with RTD (Resistance Temperature Detector) or thermometer
12	Wipe brush holders and check contact faces of brushes of slip-ring motors	Quarterly	If contact face is not smooth or is irregular, file it for proper and full contact over slip rings
13	Check insulation resistance of the motor	Quarterly	Observation
14	Clean winding of motor, bake and varnish if necessary	Half a Year	Clean, bake and varnish
15	In case of slip ring motors, check slip-rings for grooving or unusual wear, and polish with smooth polish paper if necessary	Half a Year	Check and polish
16	Clean and flush bearings with kerosene and examine for flaws developed, if any, e.g. wear and scratches	Annually	Clean and flush.

Description		Frequency	Method
	Immediately after cleaning, the bearings should be coated with oil or grease to prevent ingress of dirt or moisture		
17	Blow out dust from windings of motors	Annually	<ul style="list-style-type: none"> • Blow with clean dry air • Make sure that the pressure is not so high as to damage the insulation
18	<ul style="list-style-type: none"> • Clean and varnish dirty and oily windings • Re-varnish motors subjected to severe operating and environmental conditions 	Annually	Cleaning
19	Clean external surface of the motor.	Monthly	<ul style="list-style-type: none"> • Use air blower machine to remove dry dirty • In case of oil and sticky dirty, use appropriate detergent and soft cloth
20	Examine earth connections and motor leads	Daily	<ul style="list-style-type: none"> • Closer observation

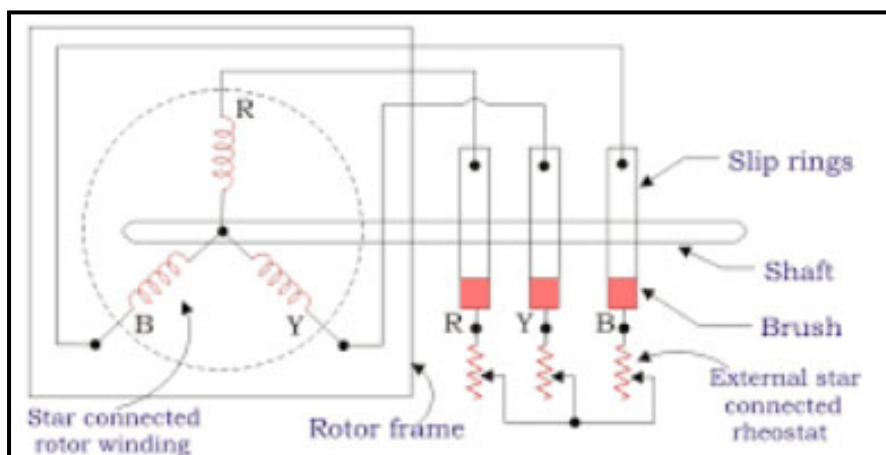


Figure 10: Image of a star connected rotor winding as part of electrical motor

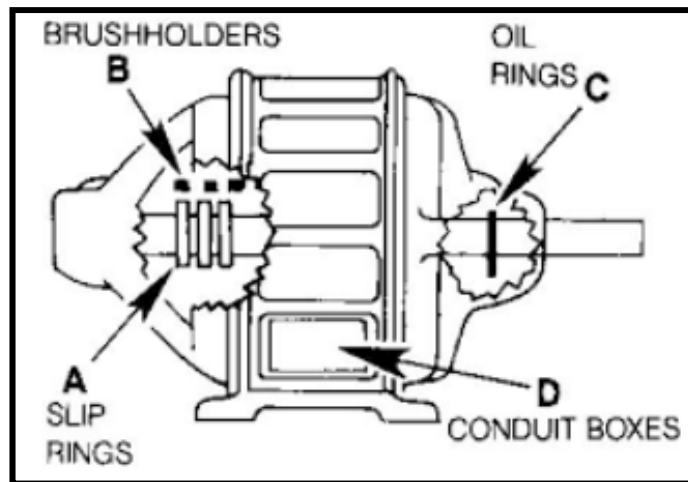


Figure 11: Slip rings and brush holders of electrical motor

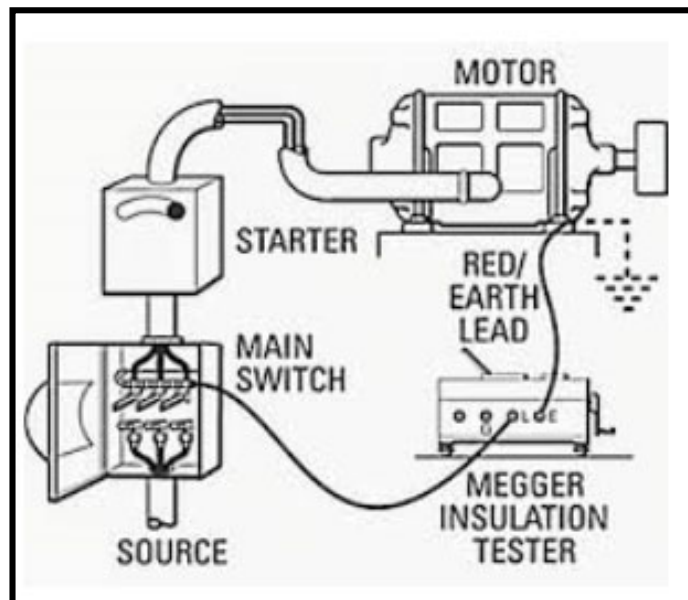


Figure 12: Motor insulation system

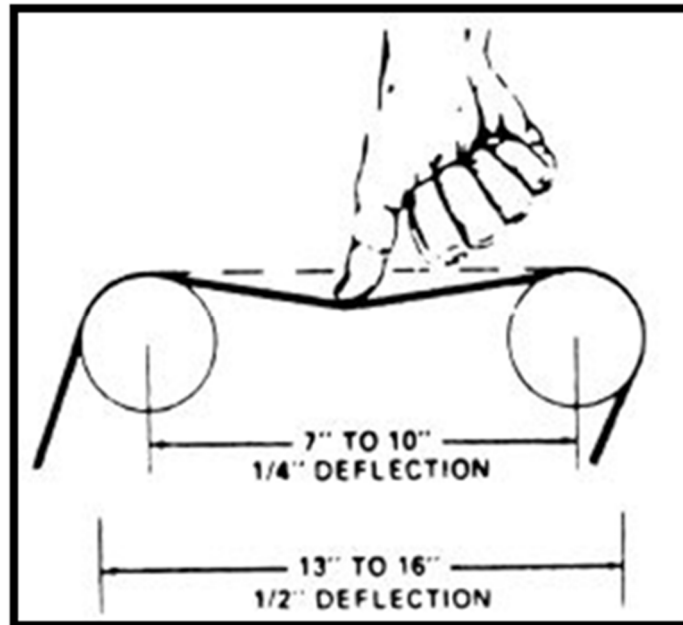


Figure 13: Checking of the belt tension with a thumb

5 Disinfection / Chlorination

Disinfection is the destruction (killing) or at least complete inactivation of harmful micro-organisms present in the water.

Drinking water is disinfected to kill bacteria, viruses and parasites, which may exist in the water and may cause illness and diseases like campylobacter, cholera, amoebic dysentery, giardia (beaver fever) and cryptosporidium. The disinfection of potable water is almost universally accomplished by the use of gaseous chlorine or chlorine compounds. Chlorine is easy to apply, measure and control. It persists reasonably well and it is relatively inexpensive. Other methods of disinfection are also available viz. ozone, ultra-violet light, chlorine dioxide, silver ionization etc.(Gol, 2013).

5.1 Methods

- Disinfection by chlorinated lime or bleaching powder ($\text{Ca}(\text{OCl})_2, \text{CaCl}_2, \text{Ca}(\text{ClO}_3)_2, \text{H}_2\text{O}$)
- Chlorination by gaseous chlorine
- Electro-chlorinator
- Chlorination by calcium hypochlorite
- Chlorination by sodium hypochlorite (HTH)

Solutions should have concentrations between 5 and 1% of free chlorine, the latter being the most stable solution. Some 10% of the chlorine remains in the settled sludge. The following table shows quantity required to prepare a solution 1% of free chlorine.

Table 17: Dosage for preparation 1% of free chlorine solution

Compound	Available chlorine quantity	Quantity to make a liter of 1 % chlorine solution
Chlorine gas	100 %	0
Calcium hypochlorite	70-74 %	14 grams
Bleaching powders	34-37 %	30 grams
Sodium hypochlorite (HTH)	12-15 %	80 grams

5.1.1 Disinfection by bleaching powder

- Fill clean water in the dosing vat of capacity suitable for 24 hours requirement.
- Add bleaching powder in the dosing vats full of water
- Mix manually or Turn on a motor-reduction gear operated slow speed stirrer

- Let mix for at least 1 hour
- Stop the mixer
- Let sediments settle down. The precipitates of calcium hydroxide settle at the bottom of the vat.
- Open the taps and drain the supernatant in a new dosing vat.
- Inject the solution (supernatant) in raw water for pre-chlorination, in the storage reservoir as for post chlorination or inject chlorine in distribution system as break point chlorination.
- The injection is made by opening a gravity flowing pipe or using special dosing pumps.
- For effectiveness of chlorination, contact period of at least 4 hours shall be maintained

5.1.2 Precautions

- The Operator should use hand gloves, aprons and other protective apparel, while handling and mixing
- The valves, stirrer, tanks, plumbing arrangements require renovation at every 6 months.

5.1.3 Chlorination by gaseous chlorine

Normally, chlorine at a normal pressure is a toxic, yellow green gas, and is liquid at high pressure. Chlorine gas is released from a liquid chlorine cylinder by a pressure reducing and flow control valve operating at a pressure less than atmospheric pressure. The gas is injected in the water supply pipe where highly pressurized water is passed through a venture creating a vacuum that draws the chlorine into the water stream. Adequate mixing and contact time must be provided after injection to ensure complete disinfection of pathogens. It may be necessary to control the PH of water. A basic system consists of chlorine cylinder mounted with vacuum regulator, chlorine gas injectors, and a contact tank or pipe. Prudence or state regulation would require that a second cylinder and gas regulator be provided with a change-over valve to ensure continuity of disinfection. Additional safety and control system may be required.

5.2 Curative maintenance of DOSATRON

Curative maintenance of a DOSATRON is described table below.

Table 18: Curative maintenance of a DOSATRON

SYMPTOM	CAUSE	SOLUTION
Motor piston		
DOSATRON	The Dosatron is not on "ON"	Put the button on "ON"

SYMPTOM	CAUSE	SOLUTION
does not start or stop	Air has not been bled from unit	Bleed air from unit, by bleed button
	Maximum flow exceeded	<ul style="list-style-type: none"> • Reduce flow, restart unit • Return the Dosatron to your distributor
	Motor piston stalled or damaged	Return unit to your service center for repair
	Leak at the security	<ul style="list-style-type: none"> • Check or clean valve seal • Return the Dosatron to your distributor
No water at the outlet	Network pressure is not sufficient	Increase the pressure to more than 0.3 bar
Injection		
Water flowing back into concentrate container	Contaminated, worn or missing check valve parts	Clean or replace it
No suction of concentrate	The piston motor has stopped	See motor piston section
	Air leak (inlet) in the suction tube	Check the tightness between nut and suction hose
	Blocked suction tube or clogged strainer	Clean or replace it
	Missing or worn suction check valve seal	Clean or replace it
No suction of concentrate	Missing or worn plunger seal	Clean or replace it
Under injection	Worn injection stem	Replace it
	Suction of air	<ul style="list-style-type: none"> • Check the tightness of the nuts in the injection area • Check suction tube
	Dirty or worn check valve seal	Clean or replace it
	Maximum flow exceeded (cavitation)	Reduce flow
	Worn plunger seal	Replace it
	Worn injection stem	Replace it

SYMPTOM	CAUSE	SOLUTION
Leak		
Leak between motor part and injection part	Injection sleeve seal is damaged or positioned incorrectly	Replace it
Leak between the adjusting nut and the blocking ring	Injection stem seal damaged, positioned incorrectly or missing	Replace it
Leak between pump body and top cap	Top cap seal is damaged, positioned incorrectly or missing	Unscrew the top cap, clean the seal seating and replace or change the seal. Position correctly the top cap.

6 Transmission Line

6.1 Transmission by gravity through channels

6.1.1 Maintenance of unlined canal transmitting raw water

- All grass should be scraped and weed removed from the silted bed.
- Silt deposited should be removed.
- Bed should be levelled and their gradient regularized.
- Berms should be kept straight by trimming.
- Flow meters should be installed at the head and tail of canals at important points in between. Then the reading should be observed and recorded daily.
- Both edges of the bank especially the inner one should be neatly aligned and should be free from holes, weeds.
- Ensure there is no Seepage through the banks.

6.1.2 Maintenance of lined canals transmitting raw water

- Cavity or pockets or any activity detected behind the lining should be carefully packed with sand or other suitable material
- Care should be taken to ensure that the lining does not get damaged or displaced
- Damaged portion of lining should be removed and replaced with fresh lining of good quality by preparing a thoroughly compacted sub-grade before laying fresh sub-grade
- The cracks in the lining should be filed with standard sealing compound. An effective sealing may be obtained by cutting 'V' groove along the face of the cracks before filing with sealing compound
- Seepage through embankments if any should be observed from time to time and remedial measure should be taken.
- Silt deposition if any noticed should be flushed out when the water is silt free.
- Aquatic weed growth if observed below the supply level should be removed. Land weed growing over the free board should also be controlled.
- Canal banks should be inspected for seepage condition at the outer slope and for some distance beyond the toe especially in high fill reaches.

6.2 Transmission line in pipes

6.2.1 Frequent problems of transmission pipes

- Clogging
- Punctures and leakages
- Air entrapment
- Water Hammers
- Lack of documentation (Plans, history)
- Water quality deterioration

6.2.2 Preventive maintenance of the transmission line through pipes

Develop and conduct a surveillance programme for leaks in pipelines, pipe joints and valves.

- i. Develop and conduct a water quality surveillance programme.
- ii. Develop and conduct a programme for locating and repairing leaks including rectifying cross connections if any, arrange for flushing, cleaning and disinfecting the main transmission,
- iii. Establish procedures for checking and optimizing the safe water quality
- iv. Servicing of valves, expansion joints etc.
- v. Maintenance of valve chambers

The table below summarizes the schedule of main activities for the preventive maintenance of a transmission pipe line.

Table 19: Schedule of activities for preventive maintenance of a transmission pipe line

Description	Frequency	Methods
Scouring of pipeline	Monthly	<ul style="list-style-type: none"> • Flushing • Air scouring • Swabbing / pigging/ scrapping
Leakages control	Daily	<ul style="list-style-type: none"> • Work regularly along the pipeline and check if there is any leakage • Appoints informants to report eventual leakages • Replace aged gaskets • Control the acceptable pressure in pipelines

Description	Frequency	Methods
		<ul style="list-style-type: none"> • Check the erosion bared pipes and bury them in deep. Where not feasible protect them with a casing
Water quality monitoring	Daily	<ul style="list-style-type: none"> • Chlorine Residual Testing and injection
Records and reports	Daily	<ul style="list-style-type: none"> • Updated transmission system maps with alignment plans. Longitudinal sectional plans • Record of daily readings of flow meter at upstream and downstream end of pipeline • Pressure reading of the transmission system • Identification of persistent low pressure location along the pipeline • Record of age of pipes and fittings • Record on when the pipeline leaks were repaired or pipe changed and the cost of materials and labour cost thereof

a. Flushing method

Generating a flow of high velocity inside the pipe in order to washout the loose particles. The pressure to put in pipe depend on the nature of deposits to remove and the conditions of the pipes. The following table gives some recommendations:

Table 20: Recommended velocity and discharge during flushing through various pipes

Pipe diameter (mm)	Velocity (m/s)	Discharge (l/s)
50	1.3	2.70
75	1.6	7.20
100	1.8	15.00
150	2.2	41.00
200	2.6	83.00

(Trifunovic, 2014)

b. Disadvantages

- Large amounts of water used (particularly in large diameters pipes)
- The velocity increase in the pipe being flushed may disturb the flow and pressure pattern upstream of the cleaned section
- In areas with progressive corrosion, flushing offers only a partial improvement
- Not all parts of the distribution system may be equally suitable for the generation of high velocities (e.g. in low pressure areas) (Trifunovic, 2014)

c. Air scouring method

In situations where water quantities available for pipe cleaning are limited, air scouring can be used as an alternative method to flushing. By this method, compressed air is injected into a continuous flow of water. Pushed by the air, the water will form into discrete slugs forced along the pipe at high velocities. (Trifunovic, 2014)

d. Mechanical cleaning

This method includes swabbing, pigging or scrapping in which an abrasive object is inserted into a pipe and driven along by the water pressure, pushing the deposits ahead or a hard tool is used to strum off the sediments from the pipe.

6.2.3 Curative maintenance of the transmission pipe line

- Repairing of broken pipes
- Disinfection of pipeline in case of deterioration of water quality
- In case of air entrapment, operate the air valve located at that point if there is no air valve, washout the section affected and adjust the bed slope of pipes.
- If there are water hummers in the pipeline, it is an indication that the pipeline needs the installation of an anti-ram vessel or the installed anti-ram is not functioning correctly. One of the frequent issues of anti-ram is the inadequate air pressure. If this is the case refill the anti-ram vessel with the air.

7 Storage

7.1 Storages facilities

Different types of tanks are constructed in concrete, stones, bricks, metallic and polyethylene. The purpose of storing water is to meet the flow demand and to accommodate the period of interruption of production. Storage tank are normally located in relatively high points. They are equipped with a single inlet, but mostly outlets pipes are more, depending on the branches to serve.

7.2 Frequent problems of the storages tanks

- Accumulation of dirty on the bottom due to settlement of suspended materials
- Leakage due to cracks in the walls
- Leakages in the fittings
- Security of the access trapdoors

7.3 Operation of the service reservoirs

The activities of operating a water reservoir have the main objective of matching the storage capacity of that reservoir with the water demand in the command area.

The distribution of consumption over 24 hours is as follows:

- Between 11 pm to 4 am: in general, there is no consumption. This is the time to store more water.
- From 7 am to 10 am: the consumption is considerably increasing.
- From 11 am to 2 pm: the consumption decreases a little.
- From 5 pm to 8 pm: peak time. The consumption is at highest level.
- In general, we have 8 hours during the day where the consumption is high comparatively to production. This is the time the water system needs to use the storage water to supplement the water production.

Activities of operation of a water reservoir

- Opening, closing, handling, adjustment, settlement of inlet and outlet valves
- The maximum water levels to be maintained in the Storage Reservoir at each morning should be known to ensure that the system demands are met for the day. Usually water levels are read at the same time each day and the readings recorded.

Inspect regularly the quality of water in the reservoir. Reservoirs are good places to test the quality of water distributed in the network because they are open and then allow sampling and

naked eye observation for potential sediments, rust and chemical precipitates. The smell of water can also tackle from the reservoirs.

7.4 Preventive maintenances of storage reservoirs

- Handling and oiling trap doors
- Cleaning and washing the surfaces of the tanks
- Cleaning aeration chimneys and adjusting / replacing mosquitoes mesh
- Use the access ladder to climb over the tank instead of hooking and treading the fittings.
- Avoid prolonged stay of water in the tank as it putrefies and gives a bad odor
- Prevent access to lizards and rodents in tanks because after a time they swamp and die in the water.

The following table summarizes most performed action for preventive maintenance of the reservoirs

Table 21: Methods and strategies of maintaining the water reservoirs

SUBJECT	ACTION
GENERAL	Check if the name of the valves and piping such as washout, inlet, outlet, by-pass, overflow is be painted clearly and repaint if necessary.
TANK outside	Check the appearance and seals and clean if necessary. Check that there are no threatening erosions around the facility. Fix what does not need a mason, otherwise report and propose action.
MASONRY	Control the appearance and coatings and sealing; clean if necessary.
COVER / SLAB	Check corrosion and grease hinges if necessary. If corrosion propose action.
INLET Pipe, flow limiter, float valve	Check if there are no roots in the pipes, scrape deposits. Check inlet, the operation of float valve (adjust if necessary). Dismantle the coupling and clean up.
VALVES: Inlet, Outlet, By-pass	Check the operation and clean all valves and fittings.
VENTILATION	Verify the free passage of air and the prevention of access of water and detritus from the outside. If corrosion propose action.
OVERFLOW	Check free passage of water and protection against access of water and detritus from outside. Check status of fittings and valves.

SUBJECT	ACTION
DRAIN or WASH OUT	Check status. Maintain against erosion. Check status of fittings and valves
LADDERS	Check the condition and clean. Propose action if corrosion appears.
WATER METER (if present)	Calibrate the water meter at the discharge side of the reservoir by closing some time the flow to the reservoir and measuring the decrease in water level, multiply it with the surface of the reservoir and compare the volume with the registration of the water meter at the beginning and at the end of this operation. Alternative: calibrate the water meter with the help of calibration equipment if available.

7.5 Emergency maintenance of storage tanks

- Repairing the fissures in wall or in the base of the tank
- Scratch and remove the existing internal coating all along fissure
- Prepare a cement mortar of 350 kg/m³
- Apply carefully the mortar
- Smoothen the surface
- Keep the surface wet after one day

8 Distribution System

8.1 General

8.1.1 Common issues in the distribution systems

8.1.1.1 Intermittent System

A water supply system is intermittent when the supply is not continuous. This causes several problems such as:

- Storage structures which are not always wet are likely to experience cracks.
- Consumers are urged to store water in unsafe containers and that affect the quality of water
- Taps are left open and when the supply resumes unexpectedly, there is wastage of water
- Operators are confused for proper handle of valves in order to ration available water

8.1.1.2 Low Pressure in the network

There are various causes of low pressure in the network including:

- Inappropriate setting of valves
- Insufficient water flow due to production drop or the high peak consumption rate

8.1.1.3 Leakages

Leakages occur in failure of joints or broken pipes. That may be a result of poor quality materials, bad installation, aging, mechanical chocks, high or negative pressure, corrosion and vandalisms.

Leakages cause huge physical water losses, drop of pressure in pipes and water quality deterioration.

8.1.1.4 Unauthorized Connections

The issues with unauthorized connections are that:

- They disturb the normal hydraulic functionality of the network as they connect from inappropriate junction points.
- They don't save water then deprive water from authorized connections.
- They harm the water quality in pipelines
- They damage existing installation, breaking pipes and introduce materials of poor quality.

8.1.1.5 Extension of Service Area

Extension of services area leads to overloading of the previous pipes sections then the loss of pressure.

8.1.1.6 Aging

Aged pipes bring out several complications such as:

- Frequent punctures
- Metallic corrosion thus reducing the internal pipes 'section and polluting the water quality
- Difficult to repair and to fix new connections

8.1.1.7 Lack of records

The efficient maintenance of a water network is grounded on the information drawn from design, as built drawings, map, history of breakdown, repairs and maintenance, fittings arrangement, function schedule, transited discharge... however most of the time such kind of data are missing.

8.1.2 Field inspection

Inspection of a pipeline requires walking along it while observing conditions of pipelines protection structures (columns, anchor blocs, casings), potential leakages, vandalisms, unauthorized connections, erosions, land sliding, roots of trees, ponds of waste waters in the ways of pipes, and others elements which may hamper the condition of pipelines.

Normally pipes are laid deep between (1.00 m and 1.20 m).

In case of leakage, not always water flows at the ground surface. Sometimes the leaking water flows in ground and goes to find outlet far away from the leaking point. If you find an abnormal soil humid or coldness, introduce a soft wooden stick in soil and check if get wet. Also loss of pressure or the drop of flow rate are good indications of leakages in line.

If an obstacle or other object harmful to the function of the pipeline is found, plan to remove it as soon as possible.

It is advisable to regularly take the pictures because they give a memory of day to day site conditions, the location of an event, but also pictures may contain information that you couldn't discern before.

8.1.3 Routine operation of the distribution system

- Opening, handling, servicing and closing valves
- Monitoring and adjusting pressure in pipes for proper hydraulic functionality
- Releasing entrapped air
- Measuring, monitoring of transited flow rate and proper rationing

8.1.4 Preventive maintenance of the distribution system

Distribution system is the main way to transit water to the consumers. It thus deserves careful operation and maintenance actions. The frequency and technique used for maintaining distribution systems are described in the following table.

Table 22: Activities, frequency and techniques for maintaining a distribution system

Actions		Frequency	Methods
01	Mapping, design and drawings	When there is a change	<ul style="list-style-type: none"> • Collect as built documents from the District and make update every time there is a change • If maps and drawing are not available, conduct your own survey using GPS, theodolite and informants • All details to be depicted in the drawings including: <ul style="list-style-type: none"> i. Depth of pipes ii. Slope of pipes iii. Surface ground iv. Section and material of pipes v. Design flow and pressure vi. All connections vii. Other buried or exposed objects near the pipes viii. Location of flow meter, water taps, valves and pressure gauge.
02	Keeping the records	Every day	<ul style="list-style-type: none"> • Regularly site inspection • Write each observation, history, observations details regarding: <ul style="list-style-type: none"> i. Working or stopping hour ii. Flow rate and pressure iii. Break down iv. Repairs details v. New extension connected
03	Tracking the working or	Every hour	<ul style="list-style-type: none"> • Go and observe if there is water passing through

Actions		Frequency	Methods
	stopping hour of the network		<p>the water meter. Indeed, if figures in the water meter are not changing water is not passing.</p> <ul style="list-style-type: none"> • Watch if water is reaching the tank installed in the line.
04	Tracking the flow rate	Once a week	<ul style="list-style-type: none"> • Take the reading of the water meter (in litres) go and read again one hour later • Subtract the previous reading from the last ones. • The result that you obtain is the flow discharge in litres per hour • You also can use a bucket and a chronometer at the inlet of the break pressure.
05	Records analysis	Every day	<ul style="list-style-type: none"> • Information regarding flow rate and pressure should be compared to the requirements or appropriate standards in order to decide for further adjustment.
06	Control of low pressure	Every day	<ul style="list-style-type: none"> • Don't leave a line valve partially open. Open it completely • Avoid too low water level in the service tank • Avoid failure of the pumps feeding directly the line • Avoid too high velocity in small pipes
07	Control of high pressure	Every day	<ul style="list-style-type: none"> • Avoid sudden valves closing which generate water hammer • Do never over pressurize pipes with the pumps • Operate and set correctly pressure release valves • Do never bypass a pressure balancing chamber or a pressure break tank
08	Prevention of Leakages	Every day	<ul style="list-style-type: none"> • Routine inspection of the pipeline for identifying potential dangers likely to damage the pipes • Adjustment of unsafely laid pipes • Protecting, covering and casing exposed PVC pipes • Control and adjustment of proper pressure in pipes • Slow opening and closing of valves • Quick replacement of suspected fittings or pipes
09	Prevention of unauthorized connections	Every day	<ul style="list-style-type: none"> • Regular survey along the pipelines • Balance the quantity of water injected in the command area and water billed • Easy policy of private connection

Actions		Frequency	Methods
			<ul style="list-style-type: none"> • Arrange loans for implementing private connections • Sensitization about consequence on public health, sustainability of the infrastructure and fines • Informants
10	Dealing with aged pipes	Every 6 months	<ul style="list-style-type: none"> • Reducing excess pressure in pipelines • Inspection and control for potential abnormal pipes behaviors • Gradual replacement of most aged pipes
11	Dealing with intermittent system	Every 3 months	<ul style="list-style-type: none"> • Maintain a unique unchanged supply schedule and communicate it to consumers • Motivate the operators of valves in lines for appropriate setting of valves for maintaining equitable rationing • Check in idle hours if all taps are closed.
12	Servicing pipelines	After repair	<ul style="list-style-type: none"> • Cleaning and maintaining supports (anchors blocs and columns), casings and valves
13	Prevention of clogging	Every 3 months	<ul style="list-style-type: none"> • Control the strainers at the beginning of pipelines, • Make sure that water is free from suspended materials, debris and sediments. • Washing out

8.1.5 Curative maintenance of the pipeline

In case of breakage of pipes, leakage in joints, problems in water flow quick actions are necessary to maintain or resume the supply of water to consumers. The table below provides some hints to check and correct such technical problems in water mains.





Table 23: Repairs of various problems occurring in water mains

Failure	Cause	Solutions
Broken pipes	Crack due to excess pressure	Replace the pipe with the one of adequate Nominal pressure.
	External Mechanical chock or corrosion	Cut and remove the damaged section. Then provide spare pipes and repair the section having the problem.
Leaking joints	The rubber is broken, damaged or aged.	Replace the rubber with a new

Failure	Cause	Solutions
		one
	Wrong joint installation	Revise the pipes connection
	Slipping pipes due to excessive slope	Put anchor block to stabilize pipes.
Clogging	Deposits	Flush or washout pipes
	Invasion of trees' roots in pipes	Cut and uproots the trees, mostly the species of Eucalyptus surrounding the pipes. Repair the affected section of pipes.
	Bottle neck in glue joint	Dismantle pipes joint and redo it using small amount of glue
Flow anomalies	Entrapped air	Operate the existing air release valve, Check the need of an additional air release valve and install it.
	Inadequate control valves setting	Set the control valves appropriately.
Water hammer	Inappropriate provision of anti-ram	<ul style="list-style-type: none"> • Check and recharge the existing anti-ram vessel with air. • Install an anti-ram system if there isn't any.
	Sudden manipulation of flow control valves	Careful manipulation of the flow control valves
Collapse of pipes	Failure of support columns or anchor blocks	Reconstruct
	Casings of the pipes are broken	Provide new casings.
Unauthorized connections	Healthy installations without meter	Provide a water meter and record the connections
	Unhealthy installations	Cut the connection and redo it properly
Unearthing	Erosion and land slide transportation	<ul style="list-style-type: none"> • Dig again the trench according to the pipe size and regulation • Level the trench and make appropriate slope • Prepare the bed of the pipes with a layer of sand • Lay again pipes and back fill • Protect the area with erosion preventive grasses

8.1.6 Standard pipes repair procedures

- Identify or locate the vanishing point
- Dig out the pipes. The length to unearth should be enough to allow the movement of existing pipes.
- Determine the nature and the size of the pipe: if it is not mentioned on the map of the network one must measure it with a rule. Normally pipes may be made of Poly Vinyl Chloride (PVC), Poly Ethylene (PE), Galvanized Steel (GS), Ductile Iron, and Asbestos Cement (AC). Asbestos and Cast Iron pipes are uncommon.
- Determine pipe connection method and repair parts: Common repair methods use: rubber joints, Glue Seals, merchant couplings or weld repair sleeve for Galvanized Steel, repair clamps, dismantling joints for DI and other bigger pipes.

	
<p>Steel repair clamp</p>	<p>Steel repair sleeve</p>
	
<p>Merchant couplings</p>	

- Cut and remove the damaged section of pipe
- Carve both edges from either side of the cut pipes

a. For PVC glue joints

- Clean the edges of pipes as well as the inner sides of the repair socket with appropriate cleaner spirit
- Apply the glue around the edges of the pipes
- Let it exposed to the air for a while (5 minutes)
- Enter the edges of the pipes inside the repair socket
- Let it solidify for about 4 hours
- After solidification inject water inside the line to rest the tightness of the repaired section.

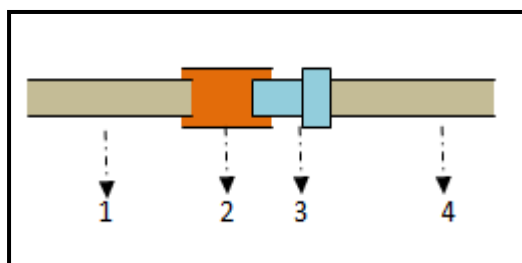
b. For rubber ring pipes

- Clean and lubricate the notches of the repair socket
- Lubricate and insert the rubber ring inside the notches of the fast repair PVC socket
- Push in the edges of the pipes inside the repair socket

c. For steel pipes using merchant coupling

- Thread both ends
- Wrap/ roll around the threaded ends with several layers of Teflon.
- Insert one threaded end of the pipes inside the merchant coupling and fix it
- Insert a union into the second end of merchant union
- Fix the other end of the union to the remaining threaded end of the pipes
- Using union during repairing of a Galvanized steel pipe is a cheap but not sustainable solution.
- The best solution is a dismantling joint or welding a repair sleeve.

Legend



1&4: Pipe to repair

1 : Merchant Coupling

2 : Union

Figure 14: Schematic illustration of a typical GS pipe repair using merchant coupling

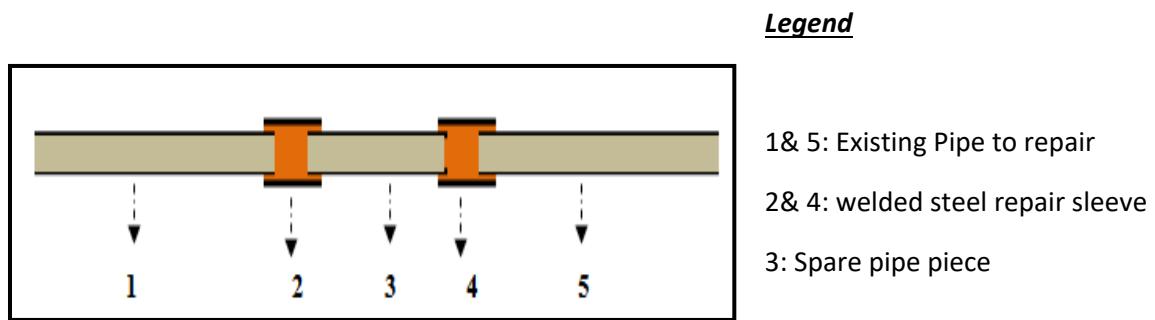


Figure 15: Schematic illustration of a typical GS pipe repair using a repair

d. Using dismantling or Johnson joint

Dismantling joints or Johnson joints are used to repair rigid pipes. Dismantling joints are recommended to repair larger size PVC pipes, larger size High Density Polyethylene Pipes, Steel pipes bigger than 2" and all Cast Iron pipes.

e. Process:

- Cut and remove the damaged section from the pipe to repair.
- Trim both ends of the cut pipes
- Cut a spare piece of the pipe to insert in the removed part. The length should be 2 cm shorter than the removed section.
- Rig out the spare pipe piece with the dismantling joints at both ends
- Put the spare pipe piece inside the empty space to repair.
- Slide the dismantling joint in the junction of the existing pipe and the repair part.
- Tighten the dismantling joint through fastening the screws.

Dismantling joint is an easy but expensive solution. Attention should be taken during carving of the broken pipes. Similarly, a small mistake in measuring the spare pipe piece may spoil the achievements to good result.

8.1.7 Optimum records information

- Updated map, drawing, fittings arrangement and operational manuals of the water infrastructure
- Readings of pressure and flow rate at various points
- Age and condition of pipes for various sections
- Planned actions for different sections of the pipeline
- Number of connections their descriptions and locations
- Identified unauthorized connections

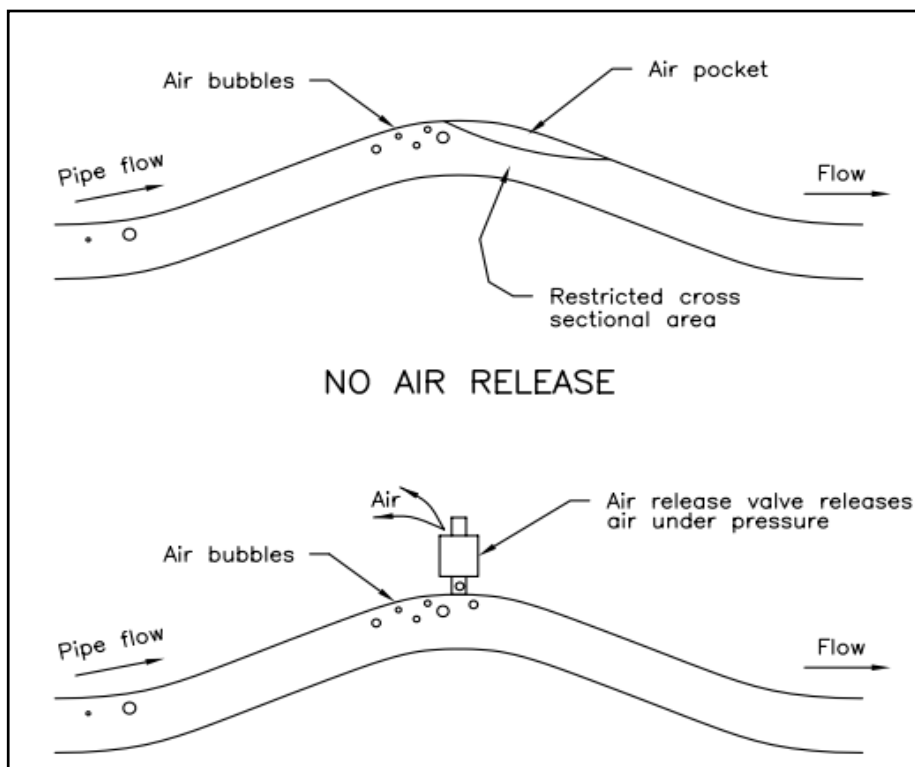
- Condition of water meter in private connections
- Repairs to be conducted in private connections
- Location of water meter and their conditions
- Leak points and causes
- Residual chlorine level in different points of the network
- Bacteriological quality as tested in different points
- Inventory of activities conducted separately for repairing and for inspecting the network as well as their respective costs
- Complaints from customers.

8.2 Air release valves

8.2.1 Necessity of air release valve

Air release valves or air relief valves are the devices installed in the higher point of the pipeline in order to enable the evacuation of the air pockets from flowing water. The exhaust of air from the pipeline is needed to avoid water hammer and to increase water flow efficiency.

The main origins of air in water are pumps, change of water temperature and change of pressure. Also during the drainage of the pipeline air enters into the line through the valve or different openings. The following pictures give scenario of air accumulation and releasing from pipes.



(Missouri Livestock Watering Systems Handbook)

Figure 16: Releasing air from the pipeline



Figure 17: Picture of an air release valve

8.2.2 Aging and breakage problem

Air valves should be inspected at least once a year. Given that some air valves are installed in remote and inaccessible places, they are exposed to the risks of vandalism damages and wear. Also some air release valves are buried so that during heavy rainfall they are flooded causing silting.

Other problems include: Leakage, clogging and admission of air into the pipe under low atmospheric conditions.

8.2.3 Operation and maintenance of air release valves

According to the Guidelines of operation and maintenance for PO and District, the following actions should be controlled for the optimum operation of an air release valve of a water scheme:

- Check outside masonry and inside of manhole.
- Ensure that water can infiltrate through the bottom into the sump.
- Check the status of the metallic cover / slab and good closure.
- Check if there are no leaks
- Operate the stop valve.
- Unscrew the cap on the head, to bring forth some water.
- Let out the air and dust.

- Close the cap

8.2.4 Curative maintenance of air release valves

Frequent issue of the air release valve is leakages: Leakage on the air release valve may be due to bad position of the ball, when the gasket is damaged or the cause may be abrasion of the ball itself. In both cases, the remedy is to replace the damaged parts.

8.3 Washout

Washouts are the points where water from the network can be forced out. This requires the manipulation of the valves provided for that purpose in order to reject water from pipelines towards artificial rejection basins, the natural streams or any other water ways.

8.3.1 Role of washouts in the network

Washouts are necessary as they help cleaning deposits thus contributing to the maintenance of water quality. In addition, washouts allow the elimination of solid intrusions that may hamper free flowing of water inside pipelines. Washouts are also required to facilitate the pipes repair and other operations on pipes, as they the water contained in the pipelines is exhausted through the washouts and the work is performed in a more flexible dry medium.



Figure 18: Soak away / tail end of a washout

8.3.2 Operation and preventive maintenance of washouts

According to the Guideline of Operation and maintenance for PO and District, the following actions should be controlled for the optimum operation of a washout of a water scheme:

- Check outside masonry and inside of manhole.
- Ensure that water can infiltrate through the bottom into the sump,
- Check the status of cover / slab and good closure.
- Ensure that the pipe toward soak away pit is in good conditions and well protected
- Control, clean and maintenance the structure at the drainage tail end.
- Test the condition of the pipes support for pressure balancing.
- Handle and manipulate regularly the valves of the washout. This will help to unclog the pipes, preserve safe water quality.

8.3.3 Curative maintenance of washouts

Frequent problems of the washouts include the clogging, give way of fittings or supports in concrete, rusting of valves, leakages, water stagnation, and collapse / cave-in of the chamber.

If the washout is clogged cutting the flow of water in the line, it may due to deposits in lower point. Thus, dismantle the valve and adjacent pipes clean them from dirty and deposits and install them again.

In case of rusting valves, handle it through repeated open and close exercises until you fill it is to perform 3 turns freely. If there is no success, remove and replace it.

Flooding or water stagnation: Most of washouts are constructed in lower point valleys, where water logging conditions are most likely to happen. In such hazards, execute an open trench to drain water from the chamber / box toward the existing water way.

Leakage in the washout may occur due to dislocation in the junction of the fittings or in the damage or failure of the valve. Check if the problem is dislocation in fittings and fix them properly, otherwise replace the valve.

As the washouts are constructed in lower valleys, they may be flooded or buried by runoff sediments thus causing collapse of the masonry box. In such cases, the masonry is to be reconstructed in hardcore not in bricks and coated with a strong mortar (1:3 cement sand mix ratio).

Due to high pressure in valley, the support anchors of pipes and fitting of washout may give way. It is recommended to regularly check the conditions of the supports in lower points with high pressure and reconstruct the new ones if the firsts are destroyed.

8.4 Pressure relief boxes with float valve

In rural areas, the pressure relief boxes of the water schemes implicate mainly;

(i) the reservoirs commonly known as balancing chambers which break pressure built-up inside pipelines due to drop in site elevation in limited cases.

(ii) the manholes harbouring the pressure control valves can be installed in the lines.

8.4.1 Operation and maintenance of pressure relief boxes

The operation and maintenance of a pressure relief box requires activities such as the general inspection of the condition of the reservoir as well as the free movement of installations every month.

- If there are leaks or broken parts, they should be repaired.
- Check the function of the float valve once per week.
- Clean dirty and deposits from components parts of the float valve in order to prevent blockage.
- Check the junction of the float valve to the inlet pipe at least once per month.
- If there are fissures in the walls, they are to be repaired with a mixture of one measure of cement per three measures of sand.
- The inlet, outlet and washout pipes and other connecting appurtenances should be controlled.
- In case any leak is detected, it should be repaired immediately.
- Ascertain if the float ball completely closes the valve. This can be ensured by handling it in open and close positions.
- Look if the float ball is water tight without any cracks or holes, so that water can't access inside the ball.
- The position of the ball on the rod can be enlarged or shortened by screwing in or unscrewing it from the rod.

8.4.2 Curative maintenance of pressure relief box

The main issue of a pressure release box is the functionality of the float valve mechanism.

- If there is leakage or blockage the reason can be corrosion, dirty or deposit. Thus it is recommended to dismantle the float valve, clean it and mount it again. Then repeatedly open and close the valve manually until a free movement is ensured.
- Puncture of the float valve: Seal it with glue paste. if the result is not good; replace it with the new one

- Distortion of the float beam: Check if the operating pressure fit with the manufacturer prescription. Straight it again with the help of adjustable and pipe wrenches
- Damage or loss of the hinge pin: Provide and install a new one.

8.5 Control valves

8.5.1 Types and role of control valves in the network

a. Control valves

Those are the valves which are installed wherever in the network to in order to regulate the flow and the pressure. They also are installed at the junctions where the branches or individual connections articulate to the mains. The purpose of such valves is to enable the control of supply or isolation of a connected branch / connection at any time required.

In most cases, the manholes harboring the connection control valves are larges in sizes depending on the number of connections hold in and the size of fittings installed. In general their internal dimensions vary from 0.80 m x 0.80m up to 2.00 m x 2.00 m.

b. Isolation valves

Sectioning valves are installed in the mainline to allow cut off of water flow for maintenance and repair, when there is breakage, water quality correction or any other works in the network.



Control valves box 1



Control valves box 2

Figure 19: Pictures of control valves installed in the water network

8.5.2 Operation and maintenance of control valves

- Cleaning for trash, mud, insects, rodents and stagnant water.
- The internal size of a valve control box must be enough (at least 0.8 m x 0.8 m for small dimension fittings up to DN 80) in order to allow the cleaning and operation activities.
- Handling and servicing the valves
- Check leakages
- Adjustment of the flow
- Security for locking the trap door

The following inspection should be regularly conducted on the valves:

- Locate the valve in the field.
- Check if the location is the same as shown on the drawing.
- Check whether the valve can be reached by men.
- Check if the key can be put on the valve to operate it.
- Control if the valve is in the right (open or close) position (the normal position).
- Check if the valve can be turned without excessive force.
- Check if the valve can be turned at least three times 360°.
- Preferably it is checked if the section (the part of the network which is bordered by two or more valves) can be fully closed (take into consideration that the customers have no water for some time).
- Valves operated manually should be opened all the way, then closed one quarter turn to prevent the valve from sticking in the open position
- Valves should be opened and closed slowly at an even rate to reduce the risk of water hammer
- Unless otherwise indicated, valves are opened by turning the hand wheel or key counterclockwise; and closed in the clockwise direction

8.5.3 Curative maintenance of control valves

Frequent problems in the valves boxes are due to the fault of the valves or the structure of the boxes themselves.

Leaving valves idle cause rust and blockage. It is advisable to check control valves at least once a month. In case of broken or blocked valve, replace it. The valve is considered as blocked if it

cannot turn 3 round without forcing. The valve is said broken, if it cannot close, it cannot open or if it is leaking. In all cases broken and blocked valves are to be replaced directly.

In water scarce areas, the control valves boxes are damaged. Trap doors are forced by vandalisms acts as some people want to keep themselves supplied regardless of the flow distribution that the operator has set. In case of such kind of vandalism, it is recommended to cover the boxes with heavy reinforced concrete blocks.

9 Customer Connection

9.1 Customer connection

9.1.1 Need for inspections

Individual connections deserve special follow-up by private operators because most of them are new with regards to water usage and management. They thus need guidance on handling water installations, saving water and safe care of water. Water meters, water faucet and service valves are weak and breakable fittings which once installed in the house hold require proper inspection for potential damage or breakage in order to avoid huge water losses. In addition, some individuals may be dishonest with low willingness to pay for water. They thus are attracted to install bypass pipes before water meter in order to draw free water. The purpose of inspection is to prevent such hazard in order to safely supply water at the satisfaction of the consumers and in the limit of affordable cost.

9.1.2 Major issues

- Illegal connections
- Water theft / robbery through bypassing
- Unmetered connections
- Unclear figures in the water meters due to opaque protection glasses
- Aged or faulty meters
- Poor installation in the junction to the main line
- Poor quality of materials or works during connection
- Unbalanced service pressure and flow rate among households
- Misrule in the process of request and implementation of the new connections

9.1.3 Routine operation and maintenance of customers connection

- Inspection for leakage and functionalities of junctions to the mainline and installation in the households
- Make sure that the meter and the water faucet are protected by a box in wood or metallic materials.
- Call users of each household to maintain tidiness of water faucets and water meters.
- Take users accustomed to inform for any leakage or other service problems.
- Keep update the meters inventory,
- Read records of all meters at least once a month.

- Test and calibrate suspected / inaccurate meters. To test a meter, one can use a gauged bucket and a chronometer. Several meters have a seep hand, 1 complete rotation equals 10 litres.
- Set / adjust connections control valves for governing the delivered quantity and pressure.
- Clean, and handle the Key hole boxes.
- Checking the illegal connections, bypass and water theft: Go in the connected water house. Open one taps and let water flow for a time. Check if the meter is turning. If the water is flowing and the meter is not turning. It may a proof of bypass connection or faulty meter. Explore the prevailing installation and the functionality of the meter.
- Check the installation of the water meters. Some customers, in the attempt cheat the water invoices, after the day of meter readings by the operator; they shift the installation of the meter and put it in reverse position. It is recommended to inspect the meter position unexpectedly.

9.1.4 Curative maintenance of customers connection

a. Low service pressure or quantity

Low pressure and insufficient flow to the individual connections may be due to;

- (i) improper adjustment of the control valve,
- (ii) the number of connections is overloading the design capacity of pipes or
- (iii) accumulation of deposits in the pipes.

The remedy is:

- (i) Readjust properly the control valves' according to the required pressure and quantity.
- (ii) Flush out deposits from the pipes
- (iii) Replace existing pipes with the pipes of the capacity matching the water demand.

If water is found dirty or inadequate quality (odor, contaminants) due to intrusion, pipe punctures, the solution is to washout the water from pipes for a while, let the pipes be cleaned and then resume the service.

b. Leakage:

Once a leakage is identified in at individual connection, the first step is to isolate the connection through closing the control valve at the junction to the main line. Repair the leakage using standard quality materials then open the control valve to supply again the connection. The first water must be flushed out as the quality may not be safe due to intrusions.

Here are steps for the correction of a dripping water faucet:

- a) Close the water flow with the ballcock.
- b) Unscrew with an adjustable wrench the superior crown of the water faucet.
- c) Check the gasket at the end of the stem. If it is worn out or torn, change it, take out the fastening screw and install a new gasket
- d) Place and adjust the crown with the item and verify its functioning opening the ballcock

9.2 Water meter

9.2.1 Introduction

Size of domestic water meters range from 3/4" to 2" while bigger size are for the meter installed in the main pipelines, at the pumping station and at the treatment plant to measure bulk water.

Problems of water meters may bring out to complete stopping, improper records, breakage and water quality deterioration.

9.2.2 Major issues of water meter

The main factors of problems are:

- Over aging: Normally the life span of a water meter is 10 years. Beyond that period water meters should be replaced.
- Wrong manipulation or purposefully reverse installation by users in attempt to cheat the water bill
- Darkness of the cover glass
- Clogging of strainers, rusting and solidification of component elements

9.2.3 Operation and maintenance of water meter

- Dismantle the water meter and clean inside to remove entrapped dirty and free the strainer from dirty every 6 months.
- Control the condition of the water meter (leakage, breakage, installation slope, ...) and replace damaged parts such as gaskets, protection glasses, strainer ... every 6 months. During such activities, handling the meter gently avoiding jerks, transport and store the water meter in a soft medium
- Meters should be protected. Aerial meter should be covered with wooden or metallic boxes and closed with a padlock. Ground meters should be harboured inside man holes chambers.

Those chambers are to be protected against flooding, seepage or water logging. Clean the chambers once in three months.

- Clean the meters, the cover glasses and the chambers once in three months
- Replace all meters aged over than 10 years
- Verify the installation of water meter once a month and adjust it if necessary.

9.2.4 Curative adjustment and reparation of water meter

Defected parts observed directly on site such as broken glass, cover, or wiper must be replaced.

If the meter has stopped working, remove it and take it to the appropriate meters repair workshop.

9.3 Padlocks, steps, handgrips, metal lids, etc.

Padlocks help for tightly closing the trap doors of the chambers, and water taps as well as the doors of the kiosks, the rooms in the treatment plants and in pumping stations.

Most of the padlocks vanish quickly as they are exposed to the outside rains and sun. Common problem with padlocks is the difficulty to open or to close.

The maintenance of a padlock deals with inspection of functionality. The inspection should be as frequent as once a month. At the time of inspection, proper lubricants such as motor engine oil or cooking oil should be applied to prevent blockage. During verification tour, vanished padlocks should be removed and replaced.

Steel Hand grips, Steps and lids are inserted in the walls of reservoirs and chambers to allow access. After a certain time, those steps take rust or they loosen from the walls holders. The condition of the ladders / steps should be checked every year:

- Check presence of rust and if it start attacking the metal clean it with the metallic brush, or sand paper and apply an anti rust paint.
- Check the firmness or strength of the steps in the wall. If some are loosening, reinstall them again.

9.4 Fast joint repair

9.4.1 Use of fast joints

Fast joints are used to repair the broken pipes in easy and quick ways. The fast joints are a solution for pipes laid in a location where it is difficult to dig such as in the streets and where a quick intervention is required after a pipe burst in order to resume the water supply.

a. Advantages:

- It is not necessary to discover long pipes section for carrying out the repair, especially when the pipe is larger than 2 inches of diameter and it is not needed so many persons to do the repair or digging the ditch.
- Less time is used to repair the damage in the pipes.

b. Disadvantages:

- Higher cost than the traditional method.
- It is not easy to find them in the local market or little municipalities.

9.4.2 Method and procedures for fast joint repair

- Dig out the broken section of pipe
- Cut and remove the broken section from the existing pipe.
- Trim and clean the ends of pipes to connect
- Prepare O-rings for the installation,
- Introduce the O-rings in the fast joint,
- Place the joint rapidly, first, placing it in an end and then living it up for joining both ends.

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