++

ASSET MANAGEMENT AND MONITORING MANUAL

for water supply systems

ASSET MANAGEMENT AND MONITORING

for water supply systems

The pathway to business-driven, affordable & quality water supply services in rural and peri-urban areas

Authors: Ilja van Kinderen
Bart-Jan Kouwenhoven
Judith de Bruijne

Version 3.0 June 2023

Practica foundation
Geulweg 16 – 3356LB Papendrecht – The Netherlands
Tel: +31786150125
info@practica.org
www.practica.org

FOREWORD

This manual has been developed under the WASH SDG Programme by PRACTICA Foundation as a member of the WASH Alliance International (WAI), a partner of the Dutch government-funded WASH SDG Consortium and its program. The manual has been developed for water professionals working with communities and operators of rural or peri-urban water systems in the global South.

Special thanks to the WAI partner *Centre for Urban Integrated Development* (CIUD), which has played a vital role in building capacity and testing the asset management approach with various water user committees in Nepal. Through this practice, they have been able to develop improved templates for asset management planning with clear instructions. They have been inserted as appendices to this manual. Also thanks to WAI partner, *AidEnvironment / RAIN* who developed templates for asset management monitoring, which have been adjoint to this manual too.

Next to the improved (3rd) version of this manual and paper-based templates for asset management, the WASH SDG Program (Phase 2), resulted in the development of simple Asset management software for small-scale or medium-sized water systems in the global South. These are open-source, free-to-use digital tools to develop and monitor water systems asset management plans. Through a web-based configuration panel, one enters a maintenance plan, and with help of a mobile app one can monitor data on-site. All collected data, both expected and actual, will be automatically displayed in a web-dashboard. The software package also consists of an e-learning environment with three modules for different target groups. The e-learning environment contains similar information as this manual but has additionally: supporting pictures, animated videos, case studies, practical assignments, quizzes, and a serious game. This with the objective to generate applied learning possibilities at the community level (module 1), for supporting field staff of regional governments and NGOs (module 2), and for water professionals (module 3).

Free logins for these applications and the connected user manuals can be requested at the software developer SmartTech Solutions: info@smarttech.com.np

CONTENTS

INTRODUCTION

With the establishment of SDG 6 in 2015, the required increase in access to safe drinking water gets considerable attention in the WASH sector. Nevertheless, despite the many water infrastructure projects that took place in Africa during the last decade, within 5 years about 25 to 30% of the hardware is no longer operational (*Source: What's working where and for how long, 2016, RWSN*). A similar picture can be observed in other parts of the global South. This mostly has to do with the fact that the maintenance of water systems is neglected.

Investments are solely being put aside for creating access to safe water, but the recovery of recurrent costs is often forgotten or assumed that operation and maintenance can be done on the basis of voluntary community-based management. Rural water systems, especially small-scale or medium-sized piped water systems, are often complex and require substantial budgets for proper management. Ignoring cost recovery thus results in the early breakdown of water systems, and by this, service levels decline.

Asset management is an approach to overcome the naïve picture of 'just building systems is enough'. It is a method to systematically optimize the use of various components (or assets) of (water) systems over their whole life cycle. It has the objective of providing the best balance between the costs involved and the level of service provided to its users.

Practica Foundation is convinced that asset management is one of the critical elements to ensure technically and financially sustainable water systems. It is complementary to other important policies and commonly promoted activities in rural water supply nowadays, like inclusive participation, climate resilient design, water safety planning, and hygiene promotion.

Commonly, asset management is used to:

- record assets and develop a maintenance plan for them – to ensure technical sustainability;
- develop a financial prognosis – and analyze the financial sustainability of water payments versus costs;
- optimize the asset planning by finding the optimum between financial and technical sustainability in relation to the service level;
- monitor assets and evaluate their management to avoid breakdowns and long downtimes in the most effective and efficient way.

The objective of this manual is to gain a general understanding of the principles of asset management and how one can apply it to small or medium-sized (piped) water systems. It should be understood that asset management is a tool. Not the solution itself. Making an asset management plan has little added value if it is not put into practice. It often comes with a structural behavior change. This is widely accepted to be the most challenging part. Continued attention to it, follow-up, monitoring, support and guidance are key for a successful implementation.

1 THE BASICS OF ASSET MANAGEMENT

1.1 DEFINITION OF ASSET MANAGEMENT

An **asset** is a resource, or in simple words a 'thing', that is expected to provide future benefit to a person or company. A water system is a valuable object for people, thus an asset. It provides a service to customers – in the form of water supply – and it generates income by selling this water.

Assets, such as water systems, will need **maintenance and management** in order not to break down. Think of a pump that stops working or solar panels that are not kept clean or get vandalized. If this happens, the system will not provide water which results in people without safe water and a loss of income. To prevent this from happening, one will need a plan to maintain the asset and set up a management structure to ensure that somebody timely undertakes necessary inspections, repairs and replacements.

The quality of the delivered service is called the **service level**. Service levels can be adjusted to fit the needs or requirements of the water users, the government, and/or service providers. For example, by expanding the system with extra household connections or adding features to it such as chlorination systems. This will have an influence on the number of customers one can reach (quantity) and/or customer satisfaction (quality). And therefore, how much income is generated.

Asset management is thus ***the activity of achieving and maintaining the wished-for service level during a certain period of time.***

1.2 BENEFITS OF ASSET MANAGEMENT

Asset management for (rural) water systems comes with three main benefits:

1. First of all, it serves as a tool for **improving financial and technical sustainability and thus the lifetime of a water system**. It allows water users committees (WUC) and/or water entrepreneurs to understand where their assets are located and how they function. It provides a framework for maintaining and replacing them in a timely and effective manner. By identifying the most critical assets and establishing a plan for their maintenance and replacement, a WUC or water operator can ensure that its assets are being used efficiently and effectively, which can help to extend their lifespan.
2. Secondly, it **improves decision-making and financial management**. If data is collected systematically over a longer period of time, it provides decision-makers with an exact overview of the financial and operational status of their infrastructure. Resulting in more informed decisions on future interventions to improve water systems' functionality: what is needed where and what is the best approach? In this way more informed decisions about allocating resources and budgeting for future expenses. This can help the WUC or water operator to manage its financial resources better and make sound financial projections.
3. Thirdly, it creates **trust and transparency** if shared openly. Stakeholders know what is the plan and where money is being spent on. In this way, it is more likely that users are willing to pay for water.

Other connected benefits often mentioned are:

- More **systematic manners of collecting and storing data** on the water systems, through asset inventories and risk assessment.
- The service level, and its associated costs and revenues, are **fixed and formalized** with the water users. There is thus no room for misunderstandings.
- An **improved emergency response**, since an asset management plan helps to identify and assess potential risks beforehand. By identifying these risks, you can minimize or mitigate them and protect the system.
- The data can also be used to **attract external funding**. Funders are more prepared in investing in evidence-based cases that come with little risk, rather than a patchy approach where no long-term and sustainable strategy is in place.
- Maintenance, or asset management in general, is often seen as a cost. A good asset management plan, however, will avoid unnecessary long downtimes (=system not supplying water due to failure) and therefore ensure **continued optimized income** from the water system. It results rather in profits than costs.

1.3 WHEN TO APPLY ASSET MANAGEMENT

It is important to make an asset management plan before installing a system or applying it to optimize or rehabilitate existing infrastructure. It provides the operator, in sufficient detail and based on ambition and set agreements with users, the expected costs of maintaining and operating the system.

These costs will need to be recovered. Income to cover these costs comes in the form of water revenues. If the revenues can't cover the expected costs either one has to find optimizations by for example lowering the ambition (service level) or increasing the water price. Therefore, developing an asset management plan and negotiating the water price is a very important process that needs to be done upfront, before installing or rehabilitating the system. Starting a negotiation when the system is already in use will confront you with an already settled price and service level expectations – both from users as well as regulating institutions. It sets your system up for failure.

1.4 READERS GUIDE

This manual consists of the following chapters to define an asset management plan in a step-wise approach:

1. **Joint assessment & service level determination**: chapter explains how to start up a process of Asset Management planning by involving the right stakeholders and determining the level of service to be delivered to the water users.
2. **Cost and risk-based maintenance planning**: based on the service level and an insight on what maintenance is, one can define the maintenance plan. A maintenance plan sums up all actions needed, and their related costs, to maintain the service one wants to provide.
3. **Income and optimization**: income, generated by water sale, is needed to pay for the expenses. An estimation of the income is made. Based on the financial model one can explore if financial and technical optimization is possible.
4. **Monitoring and evaluation:** in reality, things often work out differently than planned and therefore plans need adjustments. Monitoring & evaluation is therefore needed to ensure continued and/or adjusted operation.

2 JOINT ASSESSMENT & SERVICE LEVEL DETERMINATION

The first step in an asset management plan is involving various stakeholders and making a joint assessment. With this information, you can start the process of setting a commonly agreed service level.

2.1 PARTICIPATORY APPROACH & JOINT ASSESSMENT

Like with every planning process, it is vital that key stakeholders come together to discuss how to develop a plan and who will take the lead. Key stakeholders in asset management planning could be owners/ managers of the water system, water (scheme) operators / entrepreneurs, water user committees, local government, maintenance technicians, financial planners, social mobilizers from concerned district/provincial/national governmental departments or supporting NGOs and/or technical assistance providers. An **inclusive, participatory approach** is vital to make asset management planning and monitoring a success. This implies meaningful participation of all types of people, including women, children, socially excluded groups, and people with disabilities. This is in order to ensure that everybody gets equal rights in decision-making and water services, even those living remotely or socially excluded, as water is a fundamental human right.

From these key stakeholders, a team could be formed that will develop a **situation analysis** of the water system and undertakes a **joint site visit**. The analysis should include the location and history of the water scheme, the current quality and quantity of water being distributed, its actual capacity, demand quantity, maintenance history, and other relevant existing information about the water system assets.

Next to a technical analysis of the system, it is important to map **social and financial aspects too**, like its current financial balance of costs and income, the willingness and capacity to pay for water among the community, and governmental plans and resources.

2.2 SERVICE LEVEL DETERMINATION

As part of this first step, it is important to define a (preliminary) envisioned service level. Or in other words, the quality of the delivered service. This means that, as a water operator, one sets the goal of how the water system should perform. This starts with defining what service level you want to provide to your customers. This should be done for the asset as a whole.

Setting the ambition has a direct impact on the maintenance plan, you will develop in the next steps of your asset management planning process. If one wants to provide a very high service, it may mean that more staff is required or more spare parts are to be held in stock. Lowering ambition has the opposite effect.

When setting these goals, it is important to keep the water users / prospective customer in mind and to talk with them directly. Some customer groups may want to pay extra if they agree on a high service level. Some may be happy with a very basic service level. Consult the customers first to create a starting point and some initial agreements on what the service level should be – one will see in the later steps of the asset management planning process that the service level might change during optimization.

Be aware that government regulations need to be taken into account too.

Key parameters to be determined for setting a service level are:

- **Reliability**: How often do we allow the system to break down and how quickly do we repair it?
- **Availability**: during which hours per day should water be provided?
- **Water quality**: what is the quality of water provided?
- **Water quantity**: how much water should be provided each day?
- **Accessibility & safety**: how do we ensure that everybody can reach the water?

Setting this goal should be as concrete and exact as possible. For a water system this may look as follows:

General Service definition	
Realize safe, accessible and reliable water provision.	
Parameter service level	**Performance Goal or specification**
Level of reliability	• The water system should be operational 95% of the time, during operating hours. • If critical parts of the system break down (meaning the system doesn't provide any water) it is repaired within one day • If noncritical parts of the system break down (meaning a part has broken but the system can still supply water) it is repaired within three days.
Level of Availability	• The water system shall be operational between 7:00 AM and 7:00 PM on Monday – Saturday • The water system shall be operational between 10:00 AM and 6:00 PM on Sunday
Level of water quality	• The water quality should be within Government regulations • Water should always be chlorinated with a free chlorine residual of at least 2.0 mg/L
Level of water quantity	• The system should provide at least 4 m^3 each day
Level of affordability, accessibility & safety	• Queuing time should be less than 10 minutes. • The water tap point should have a ramp, so it can easily be accessed by physically challenged people. • The slabs should be in good condition to ensure children, elderly and other vulnerable can access the water point without the danger of physical harm. • People without an income in the community should receive access to the governmental subsidy on water for poor.

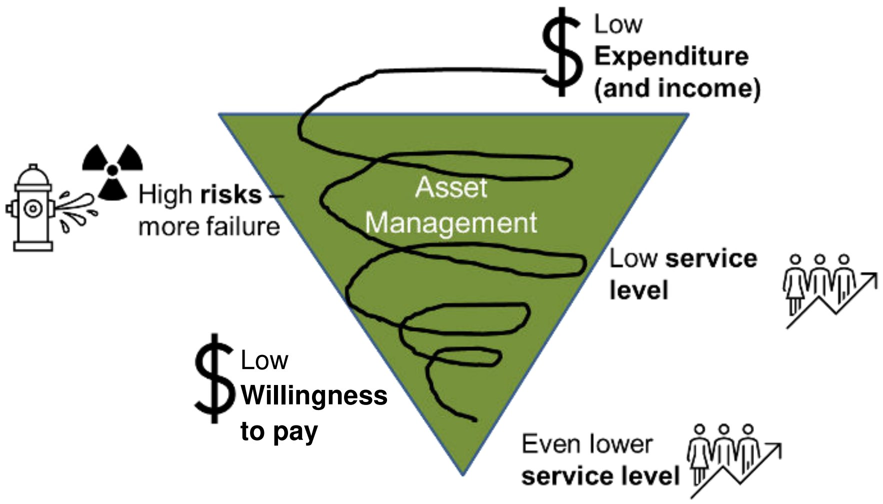
3 RISK & COST-BASED MAINTENANCE PLANNING

This chapter will start with the importance of maintenance and various maintenance strategies, before it demonstrates how to develop a risk- and cost-based maintenance plan.

3.1 IMPORTANCE OF MAINTENANCE

Maintaining an asset means ensuring its ability to fulfill its functions and tasks to make sure the required service level is reached. It is used to increase the reliability of the hardware and thereby reduce the risk to the water service provider. It is the whole process of inspecting the system, predicting when components may break down or have an unwanted effect on the service level, and based on this replacing and repairing different parts.

In the case of water systems, this means that one ensures safe water is continuously provided to the customers. Customers are happy with good service and are therefore willing to pay for the service provision. The money generated ensures that the system can be maintained, thereby making it reliable. Which, again, has a positive effect on the customer's satisfaction. Not maintaining a water system will have the opposite effect. This can be demonstrated by **the Asset Management downward spiral**.



A downward spiral could start if the community agrees to a high level of service but fails to pay for it in time. In this case, the operator cannot perform maintenance without a budget, which increases the risk of failure. Often, it starts with small steps. For example, if the operator lacks income, he is less likely to keep the water point clean and might ignore minor repairs regularly. The community sees the place becoming dirty and water flowing less smoothly. Thus, people start complaining and are no longer willing to pay full price for water. Because the operator is being paid even less, he decides to skip inspections and preventive maintenance. Eventually, a severe failure occurs, and the water system can no longer function properly. The service level completely drops to occasional supplies. During that time, the community may still not be interested in paying the operator, and within a few weeks or months, the system is completely non-functional.

Maintenance of piped water systems is an activity that is often neglected or overlooked. It is often wrongfully assumed that operators know how to take care of their assets or that voluntarily community-based management will do. This is a naïve picture.

Maintaining a water system requires systematic attention but is not too difficult. It comprises a sound combination of technical skills, planning, setting ambition levels, financial management and entrepreneurial skills.

3.2 TYPES OF MAINTENANCE

Different parts will need different types of maintenance. Also, there are three different approaches to maintenance. The question is how to decide what type of maintenance one should use for various water system components.

First of all, **causes of failure** can vary considerably. And they will differ for each component of the system. One can think of temperature (e.g. overheating), attachments (e.g. loose bolts), dust/moist/water, unwanted visits from animals (mice, insects), vandalism or theft, natural effects (such as lightning or earthquakes), the lack of regular inspection, incorrect installation, dirt on the solar panels etc. This also influences your maintenance strategy.

There are different methods to maintain assets and avoid a reduction in service level. The following types of general maintenance approaches can be used:

- **Reactive maintenance**: a more technical term is **'**Failure Dependent Maintenance'. One reacts when something breaks down or fails. It is basically the simplest form of maintenance, but it has an impact on the level of service or reliability of a system. More often than favorable the maintenance approach of water systems is "failure dependent maintenance". Many systems could benefit to also adopt the following two strategies.
- **Preventive maintenance:** generally referred to as 'Use Dependent Maintenance'. This maintenance is done when certain specified parameter (a parameter is something you can measure) reaches a certain value/level. These parameters can be lifetime, amount of water sold or volume, how often or frequent a part is used, etc. For example, when 5.000.000 liters of water is sold then the water meter is replaced to prevent it from breaking down and losing sales. Or the water tower is repainted every 3 years to avoid it will rust and break down.
- **Inspection-based maintenance:** it is also known as 'State dependent maintenance'. One uses inspections to determine the state of the assets and based on the outcome of the inspections maintenance is done. For example: you visit the site every 2 weeks and based on this inspection you decide to clean the solar panels and do minor repairs to the concrete slab.

To make the decision about which of the three strategies one will use, one needs to determine the likelihood of the part breaking down and what will happen if it breaks down. If it stops the water sales completely or to a large extent, it is called '**critical**'. If it has a minor effect on water sales, it is called '**non-critical'**.

One should keep in mind that this risk of breaking down will change over time. With a pump in mind, one could say that the risk profile of a pump is high at the beginning of the installation, then during a period of time this risk decreases to an acceptable level. And increases when the pump reaches its expected life span.

With the changing risk profiles over time and as a rule of thumb one can state that:

- **Reactive maintenance** should only be applied on parts of the system that are non-critical to the envisioned service level. Such parts represent a **low risk.** For example, this could be a crack in a concrete slab. When a slab starts to crack the water provision itself is not directly at risk. Reactive maintenance can be used in this case to prevent further deterioration.
- **Preventive maintenance** is used when the **risk of failure** of a **critical element** of the system **increases over time**. For example, when it is known that the likeliness of a pump to break down increases significantly after 7 years, one can decide to do preventive maintenance or even replacement of the pump when the pump approaches that age.
- If the failure rate of an element is constant – so is has a **constant risk profile** which does not increase over time - one can apply **inspection-based maintenance**. If the part is considered critical one can regularly inspect it. If it is non-critical one can increase the intervals between inspections.

This rule of thumb doesn't apply to all situations and logical thinking should be used at all times. For example, lightning strikes are hard to predict and can cause considerable damage to the system. This would suggest either preventive or inspection-based maintenance. Yet the most logical form of maintenance would be reactive maintenance. In this example, risks of long-term non-functionality can be reduced by having spare surge-protectors (the part that breaks when lightning strikes) available when this happens. Also, some parts may be maintained through a combination of strategies. For example, you may want to maintain expensive parts during their life very well by repainting, cleaning or greasing them (preventive), and only replace them when they have truly broken down (reactive) so that you have to buy these parts as few times as possible.

3.3 DEVELOP A RISK AND COST-BASED MAINTENANCE PLAN

A **maintenance plan** is a plan that records and sums up all components (hardware and software) that need maintenance. The plan determines what type of maintenance is needed based on its risk level, including frequency of tests or inspections, what this will cost and who will do it. These actions will depend on the service level one wants to provide.

Asset management is the activity of achieving and maintaining the wished-for service level during a period of time. A maintenance plan is therefore a part of an asset management plan.

There are different approaches to making a maintenance plan. In this manual, the following approach will be used:

1) **Asset Inventory**: Define all your existing assets.
2) **Risk Assessment**: Define all elements of the system and their risk profile;
3) **Risk Mitigation**: Define ways to prevent the failure or how one can repair/replace/improve the element and define who will do what and when.
4) **Cost Estimation**: Define the cost of these measures

Maintenance never stops and new insights are generated when experience grows. Therefore, a maintenance plan needs continuous reviewing and can be updated according to new insights and experiences. In other words: ***The maintenance plan needs maintenance as well.***

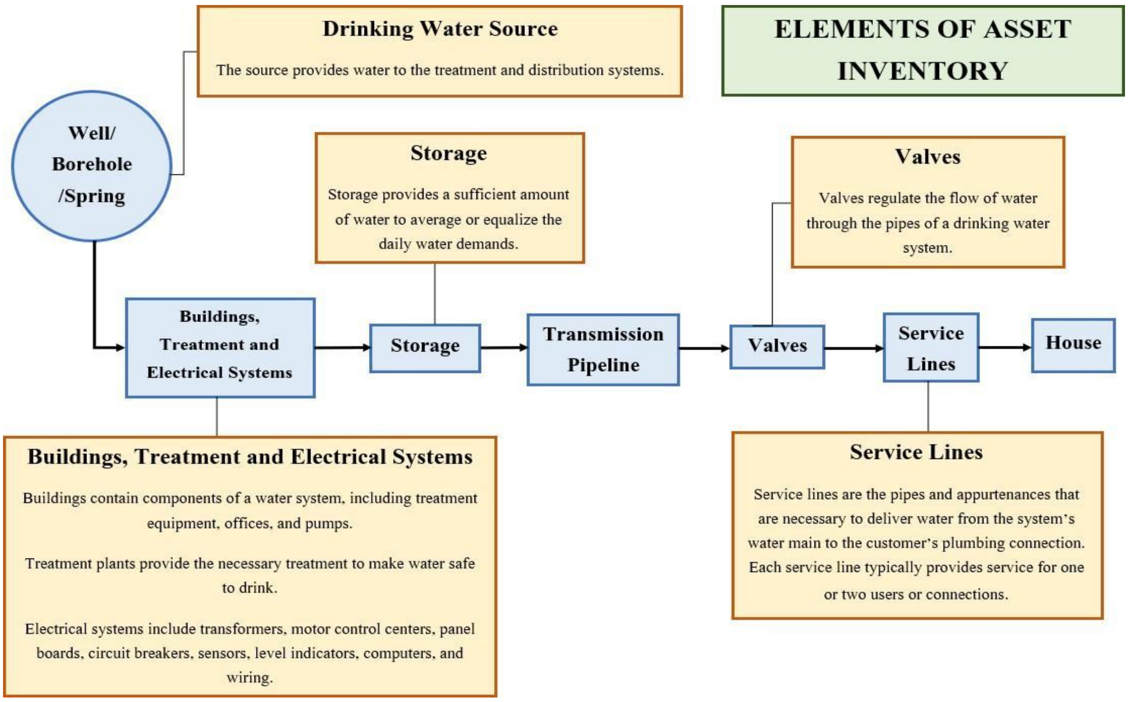
Note: in the appendices of this manual blank templates are provided to make a maintenance plan – including graphs. They allow users to make a plan without using a computer. If a computer with Excel is available, it is advised to make the plan with help of a computer. This will speed up the process and allow adaptations over time.

The WASH Alliance International has developed also open-source, free-to-use digital tools to develop and monitor asset management plans. Through a web-based configuration panel, one enters a maintenance plan, and with help of a mobile app one can monitor data on-site. All collected data, both expected and actual, will be automatically displayed in a web-dashboard. A free login for this application and the connected user manuals can be requested at the software developer SmartTech Solutions: info@smarttech.com.np

Step 1: Asset inventory

The first step in making a maintenance plan is to list all elements of the system. This what one calls in an **asset inventory**: making an inventory of all assets, like pipes, pumps, towers, couplings, solar panels. Keeping track of assets helps in knowing their present condition, their maintenance history and estimated useful life.

Normally, an asset inventory is split up in main categories/elements and sub-elements. As a first step could make a schematic overview of the **main elements**, see the example below in the blue boxes. The yellow boxes provide an explanation.



Elements of an Asset Inventory (EPA, 2004)

The next step would be putting the main elements/categories in a tabular format, and list for each category a number of sub-elements. For example, a well normally will have an intake as a sub-element.

For each sub-element it is recommendable to record a number of details in a so-called 'stock entry sheet'. An asset inventory normally at least indicates, the location of the asset, the date of installation, its current condition and the total amount of that specific asset (e.g. 4 valves). Other information that is recommended to add about the asset is: serial number, size, GPS coordinates of the location, expected useful lifetime, composition material, information of supplier/manufacturer, model type, service history details and design drawings.

An example of how such detailed stock entry sheet could look like, is displayed on page 15. A template and explanation how to fill out an asset inventory can be found in Appendix 1.

Note: It is important to realize that it is okay to start your asset inventory with just a few details. You might work with an old water system of which limited information has been stored. It should not become the main goal of developing your plan to invest all your time and energy in data collection. Keep it simple!

Step 2: Risk assessment

Once you have an asset inventory in place, one tries to list the possible failures of each component. As explained before, there can be different reasons why assets fail. It can be natural causes (overheating, mice invasions, storms) or human causes (ignorance, vandalism, theft). One asset could also fail in different manners.

More important than the cause, it is actually the chance that it will happen and once it happens what the impact will be. It is therefore important that one assesses the risk of each failure separately. The following formula represents what risk means:

Risk = **Probability or chance** that something happens X **Effect or Impact** when that happens.

The method of finding out what the criticality for each component to fail is called a **risk assessment**. The table on the next page shows how the risk of component failure can be assessed.

The left side of the table shows a column with 4 effects. If a part breaks down and it has hardly any effect on the service level it will be given a score of 1 (non-critical). If a breakdown would result in a complete loss of functionality of the system it gets a score of 4 (critical). Scores 2 and 3 are in between.

In the row below the table, the probability is assessed. A probability score of 1 is given if the risk of that part breaking down is very low, or minimal. If the part is very likely to break down a probability score of 4 is given. Scores 2 and 3 are in between.

Effect				
4 - Total loss of functionality	4	8	12	16
3 - Reduction of functionality of system	3	6	9	12
2 -Reduction of functionality of part	2	4	6	8
1 - Hardly any effect	1	2	3	4
	1 - Minimal	2 -Low	3 - Medium	4 - High
	Probability			

If one multiplies these two scores (the score on the effect **X** the score on the probability) one gets a risk score. The higher the score the higher the risk. The higher the risk, the more attention it will need to get. However, this does not mean that low-risk assets should not be given any attention, as ignoring them will cause failures and unsatisfied water users.

For example:

- If a pump breaks down the effect is that the water system as a whole doesn't function anymore. This means it scores 4 points on the effect scale. The likeliness that a pump eventually breaks down is high. This means it scores 4 points on the probability scale, as well. The risk profile of a pump can now be calculated by multiplying the two scores. The risk 'profile' of the pump is therefore (4x4=16) high. This means we will have to ensure the pump is always working.
- If a soaking pit is clogged due to dirt the effect on the system as a whole is limited. Only the soaking pit doesn't function anymore as it should do. Still, water can be sold. It therefore only has an effect on the part itself. One could give it a score of 2 on the effect. The likeliness of a soaking pit to clog depends on the situation. In this example, it is given a rating of 3 (medium). The risk profile of a soaking pit can now be calculated (2x3=6). This risk is considerably lower than the risk profile of a pump. It means we still have to look after it, but we can have a different approach.

The table on the next page provides an example of such an overview. The table above only lists a part of a system – a maintenance plan should contain all (sub) elements. Since one asset could face multiple types of failures with different risk levels, it is important to list them separately in your risk assessment.

An empty template of a risk assessment can be found in Appendix 1.

In the following parts of this manual, we will continue with this list of components. It is not complete as pipes, valves, prepayment technology, etc. are missing. Therefore, parts of the maintenance plan (e.g. adding chlorine) are missing. The number of items is limited to keep it readable. The principles, however, stay exactly the same.

EXAMPLE OF AN ASSET INVENTORY

Stock Entry Worksheet **Date Worksheet Completed/Updated: 10/11/2018**

ID No.	Asset	Quantity	Size	Location		Year of Installation/ Purchase	Expected Useful Life	Composition Material	Manufacturer Information	Model	Serial Number	Service History
				Longitude	Latitude							
1	Intake	1	3 (m^3)	85.050267	27.758658	2072	40 years	Reinforced Concrete	CARE Nepal	-	-	-
2	Pump	1	20 HP	85.050033	27.758653	2073	15 years	Steel	KSV Company	PP10	0023354	Rehabilitation (2076)

EXAMPLE OF A RISK ASSESSMENT

			Effect				Probability				Risk
Nr	Element/sub element	Description Possible failure	Total loss of functionality	Reduction of functionality of system	Reduction of functionality of part	Hardly any effect	High	Medium	Low	Minimal	
1	Water Tower		4	3	2	1	4	3	2	1	
a	Metal structure	Structural breakdown due to rust									8
b		Structural breakdown due to loose bolts									8
c	Foundation	Cracks - doesn't support the tower anymore - tipping tower due to wind									8
d	Slabs	Crumbling, Reduced access, leakages to surrounding									6
e	Soaking pits	Clogged, leakages to surrounding									6
f	Tank	Leakages due to age (UV degradation)									6
2	Solar panels										
a	Panels	Reduced output due to dirt									8
b	Panels	Broken due to vandalism									12
c	Cables	Broken cable as a result of vandalism									4
3	Pump & appendages										
a	Pump	Breakage due to age/wearing - doesn't pump water anymore									16
b	Cables	Broken due to vandalism									4
c	Surge protector(s)	Disfunctional due to lighting strike									12
d	PV disconnect	Breakage due to age - No power to controller/converter									4
e	Controller & converters	Breakage due to age or high temperature - no power to pump									12
f	Pressure sensor	Breakage - pressure in pipes no longer recorded									6

Step 3: Risk mitigation & roles

The next step is defining the **risk mitigation actions**. 'Risk mitigation actions' are actions taken to prevent or reduce the severity of the risk. They should be defined clearly and based on the risk profile. A good way to determine whether mitigating actions are well-defined is to use the SMART acronym to check:

SMART stands for:

- *Specific* target a specific area for improvement.
- *Measurable* quantify or at least suggest an indicator of progress.
- *Assignable* specify who will do it.
- *Realistic* state what results can be achieved, given available resources (make a cost estimate)
- *Time-related* specify when the result(s) can be achieved.

So, one defines what action is required based on a SMART analysis.

Ensure you read the manuals and warranty conditions of the different components purchased. They generally provide an overview of the maintenance needed to keep the components in good condition and to ensure one does not lose its warranty on the product.

From the example above one can see that each action is described separately and is based on the risk assessment. For example, a structural breakdown of the tower due to rust is assessed to be a considerable risk. To prevent this, we plan to repaint the tower every 4 years. This will assure as that we meet our service level.

A breakdown of a pump (3a) has the highest risk. However, it is quite difficult to know when the pump breaks down exactly. This can be in year 6 or year 10. Moreover, we know some pumps are hard to get. Therefore, we need to plan ahead to be able to react as soon as the signal arrives that the pump has broken down. In order to react as quickly as possible, we already stock a spare pump in year 6. This allows us to meet the service level which states we have to assure that when a critical part breaks down, we are able to replace it in one day. In order to prolong the life of the pump, we also plan to grease its parts regularly and inspect it to repaint rusty parts and tighten loose bolts so that we don't have to replace the pump often, as they are expensive and hard to get. This way, the pump is maintained through a combination of preventive and reactive maintenance.

The following step is to define who does what and how. This can be done depending on the type of maintenance. In this case the 'main responsible' person is defined.

An example can be found in the table below.

Type of maintenance	Manager	Technician	Description of activity and responsible person
Reactive	■		A telephone number of the manager is painted on each water point. If there is a complaint or breakdown this is reported via this telephone number. The manager contacts the technician. General repairs for non-critical elements should be done within 3 days. For critical elements it should be done in one day.
Inspection		■	The technician is responsible for an inspection every 2 weeks. This takes place on Mondays. If he observes malfunctions he reports this to the manager during a call that takes place after every inspection round. The manager decides the needed action and time frame depending on malfunction reported.
Preventive	■		Based on the maintenance plan the manager steers the technician in doing preventive maintenance. The technician provides input and feedback if the technician thinks, based on his inspection, preventive maintenance is needed earlier than planned.

In this plan it is important to ensure proper communication, timelines and ways that complaints can come to the manager. Providing a telephone number on the water points which customers can use to reach the manager can be a good and simple solution. The exact way of defining responsibilities will depend on preferences and local conditions.

The frequency of maintenance and the time it takes to respond should be based on the first table you made being the service level. A higher service level might increase maintenance (for example, painting it every 2 years) and reduce the allowed response time for repairs.

An empty template of a risk mitigation worksheet can be found in Appendix 1.

EXAMPLE OF RISK-BASED (OR RISK MITIGATION) MAINTENANCE WORKSHEET

			Mitigation		
Nr	Element/sub element	Description Possible failure	Reactive	Inspection	Preventive
1	Water Tower				
a	Metal structure	Structural breakdown due to rust			■
b		Structural breakdown due to loose bolts		■	
c	Foundation	Cracks - doesn't support the tower anymore - tipping tower due to wind		■	
d	Slabs	Crumbling, Reduced access, leakages to surrounding		■	
e	Soaking pits	Clogged, leakages to surrounding		■	
f	Tank	Leakages due to age (UV degradation)		■	
2	Solar panels				
a	Panels	Reduced output due to dirt			■
b	Panels	Broken due to vandalism	■		
c	Cables	Broken cable as a result of vandalism		■	
3	Pump & appendages				
a	Pump	Breakage due to age/wearing - doesn't pump water anymore	■		
b	Cables	Broken due to vandalism	■		
c	Surge protector(s)	Dysfunctional due to lighting strike	■		
d	PV disconnect	Breakage due to age - No power to controller/converter	■		
e	Controller & converters	Breakage due to age or high temperature - no power to pump	■		
f	Pressure sensor	Breakage - pressure in pipes no longer recorded	■		

EXAMPLE OF COST-BASED MAINTENANCE WORKSHEET

Water system		Cost estimate of hardware			Yearly cost breakdown														
Nr	Element/sub element	Description	Cost (euro)	(Expected) Interval (yr)	Year														
1	Watertower				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
a	Metal structure	Paint structure	150	4	0	0	0	150	0	0	0	150	0	0	0	150	0	0	0
b		Tighten bolts	5	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
c	Foundation	Repair	25	3	0	0	25	0	0	25	0	0	25	0	0	25	0	0	25
d	Slabs	Repair	25	1	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
e	Soaking pits	Clean	5	1	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
f	Tank	Replace	250	9	0	0	0	0	0	0	0	0	250	0	0	0	0	0	0
2	Solar panels																		
a	Panels	Clean weekly	25	1	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
b	Panels	Replace	150	5	0	0	0	0	150	0	0	0	0	150	0	0	0	0	150
c	Cables	Repair	35	6	0	0	0	0	0	35	0	0	0	0	0	35	0	0	0
3	Pump & appendages																		
a	Pump	Replace	2000	6	0	0	0	0	0	2000	0	0	0	0	0	2000	0	0	0
b	Cables	Repair	50	8	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0
c	Surge protector(s)	Replace	100	5	0	0	0	0	100	0	0	0	0	100	0	0	0	0	100
d	PV disconnect	Replace	150	8	0	0	0	0	0	0	0	150	0	0	0	0	0	0	0
e	Controller & converters	Replace	300	8	0	0	0	0	0	0	0	300	0	0	0	0	0	0	0
f	Pressure sensor	Replace	150	10	0	0	0	0	0	0	0	0	0	150	0	0	0	0	0
				Hardware (Sum of above)	60	60	85	210	310	2120	60	710	335	460	60	2270	60	60	335
				Cost of manager	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
				Cost of technician	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
				Overhead (transport, pen, telephone)	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5	7,5
				SUM of all cost	88	88	113	238	338	2148	88	738	363	488	88	2298	88	88	363
				Inflation correction (3%)	1	1,03	1,06	1,09	1,13	1,16	1,19	1,23	1,27	1,30	1,34	1,38	1,43	1,47	1,51
				Real cost	**88**	**90**	**119**	**260**	**380**	**2490**	**104**	**907**	**459**	**636**	**118**	**3180**	**125**	**128**	**548**

Step 4: Cost estimate

After having executed step 1 to 3, we now know what needs to be done and who does what. Based on this information we can estimate the ongoing costs of maintenance. Each item specified can be estimated separately. The table on the previous page shows the principle. For each cost item it is specified what the exact cost and what the interval of each mitigation action is. So, for example: To paint the tower every 4 years. Painting costs are 150 euro. There will therefore need to be a reserve of 150 euro in year 4, 8, 12, etc.

To keep it practical it is advised to limit the cost breakdown to maximum 15 years. Estimating it for a longer period is possible, but updating and making a new maintenance plan should be done within this period of time. Preferably the maintenance plan is reviewed every year.

In the bottom row the sum of all basic maintenance cost per year is specified, being the sum of all individual cost per element that year.

In addition to this, one will need to determine other costs expected, especially **operational costs**. These are the regular, running costs of your water system. This can be the salary cost of the manager, caretaker & technician, office rent, overhead costs, possible taxes or even cost of capital (repayment and interest). In our example we assumed we only have to pay the first 3 cost items.

An empty template to make a cost estimate can be found in Appendix 2. In this template, the cost estimate per asset and its maintenance interval integrated in one table.

After adding all the cost components one will get an idea of the yearly costs. However, as a result of inflation, cost of hardware and sometimes labour increases every year. To get an idea which funds are needed in reserve on each year, one will need to correct the figures calculated with an inflation correction factor. This factor is multiplied by the estimated cost (the SUM of all costs) resulting in the real cost. In our example, we use a yearly inflation rate of 3%. This means, that the cost will increase by 3% per year. A table in

Format for technical monitoring

*Note: For **frequency** and **responsible**, examples are given; these can be adapted to your own water system. For **water quality** indicators, the standards (maximum values) from the World Health Organization are given as a reference. It is recommended however, to follow the national standards, as can be provided by the Ministry of Health. For **accessibility and condition of assets**, both cleanliness and condition are given; cleanliness refers to the absence (or the acceptable presence) of dirt; condition refers to the functionality of the asset: when it functions well, the condition is good. Both the cleanliness and condition contribute to the expected useful lifetime.*

Indicator	Unit	(WHO) standards	Frequency	Responsible
WATER QUANTITY				
Water volume	M^3 or liter		Daily	Caretaker of WSUC
Water pressure on the system	Mbar		Daily	Caretaker of WSUC
Number of hours / days with running water supply	Hours / day or Days / month		Daily	Caretaker of WSUC
Exact timing of water supply during the day	Time slot / day		Daily	Caretaker of WSUC
WATER QUALITY				
Temperature	Degrees Celsius or Fahrenheit		Every 2 months	Caretaker of WSUC
pH (acidity)	Log H	6.5 - 8.5 (Not of health concern at levels found in drinking water)	Every 2 months	Caretaker of WSUC
Arsenic	µg / l	10 µg / l	Every 2 months	Caretaker of WSUC
Iron	µg / l	(Not of health concern at levels found in drinking water)	Every 2 months	Caretaker of WSUC
Chlorine	µg / l	5000 µg / l	Every 2 months	Caretaker of WSUC
Fluoride	µg / l	1500 µg / l	Every 2 months	Caretaker of WSUC
E. Coli	Number of colonies / cm^2	Must not be detectable in any 100 ml sample	Every 2 months	Caretaker of WSUC
ACCESSIBILITY				
Cleanliness of access path and water point	Descriptive		Every 2 months	Social expert of WSUC
Condition of access path	Descriptive		Every 2 months	Social expert of WSUC
Accessibility during times of flooding	Number of days / year		Every 2 months	Social expert of WSUC
RELIABILITY				
Number of service interruptions per year	Number per year		Every 3 months	Caretaker of WSUC
Water system losses / non-revenue water	Leakages per km pipeline / m^3 per year		Every 3 months	Caretaker of WSUC

	(difference between water sold and volume of water)			
AVAILABILITY				
Downtime during interruption (service restoration time)	Hours / interruption		Every 3 months	Caretaker of WSUC
CONDITION OF ASSETS				
Cleanliness of storage tank	Descriptive		Every 3 months	Caretaker of WSUC
Condition of storage tank	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pump	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pump	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pumping station	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pumping station	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pipelines (incl. joints, valves)	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pipelines (incl. joints, valves)	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of treatment plant	Descriptive		Every 3 months	Caretaker of WSUC
Condition of treatment plant	Descriptive		Every 3 months	Caretaker of WSUC

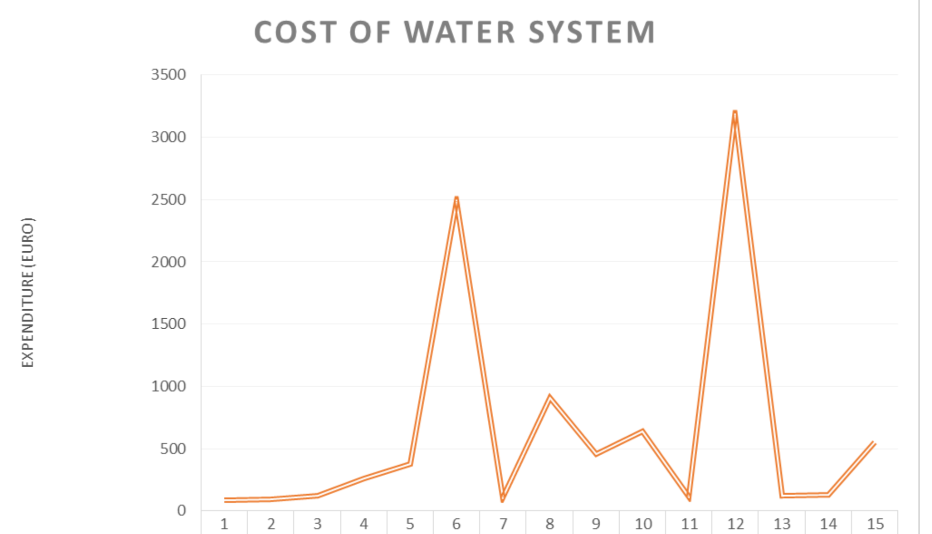
Format for a customer satisfaction monitoring

Note: For frequency and responsible, examples are given; these can / should be adapted to your own water system.

Indicator	Unit	Frequency	Responsible
WATER QUANTITY			
Sufficiency	Descriptive	Monthly	Social expert of WSUC
WATER QUALITY			
Taste	Descriptive	Every 3 months	Social expert of WSUC
Smell	Descriptive	Every 3 months	Social expert of WSUC
Colour	Descriptive	Every 3 months	Social expert of WSUC
Days of sickness of water users (because of bad water quality)	Number of days		Social expert of WSUC
ACCESSIBILITY			
Ease for disabled and elderly person or pregnant woman to access the water system	Descriptive	Every 6 months	Social expert of WSUC
Accessibility during times of flooding	Number of days / year	Every 3 months	Social expert of WSUC
AFFORDABILITY			
Price	Currency per jerrycan (20 l)?	Every 6 months	Social expert of WSUC
Affordability for poorest water system users	Descriptive	Every 6 months	Social expert of WSUC
% of income spent on water		Every 6 months	Social expert of WSUC
RELIABILITY			
Number of service interruptions per year	Number per year	Every 6 months	Social expert of WSUC
AVAILABILITY			
Suitability of time slot for access to water	Descriptive	Every 6 months	Social expert of WSUC
SAFETY / SECURITY			
Feeling of safety while fetching water	Descriptive	Every 6 months	Social expert of WSUC
Safety incidents while fetching water	Number / year	Every 6 months	Social expert of WSUC

Appendix 4: Inflation rate correction factor is provided if one wants to apply other inflation rates.

By having made an estimate of the maintenance costs, one can now get a clear picture on how the costs differ per year. This is shown in the following graph:



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Real cost (in Euro)	88	90	119	260	380	2490	104	907	459	636	118	3180	125	128	548

As can be seen, the costs of the system can vary considerably per year. This is a particular characteristic of piped water systems. In this case, the system can run without any trouble the first 5 years. However, in year 6 a significant expenditure can be expected. This is mainly caused by the replacement of a pump. Quite often this is the reason systems fail after so many years: this cost often comes as a surprise. However, knowing this cost will come enables the operator to be financially prepared.

Note that projected costs can be covered from generated income by water sales, but sometimes (local) governments have funds for larger repairs and replacements. It may be worth investigating this well before constructing the water point and integrating this into the cost estimation.

Another strategy could be to reduce maintenance costs. How this can be done is described in the next section.

3.4 HOW CAN ONE REDUCE NEEDED MAINTENANCE?

The paragraphs above mention what maintenance is and the types of maintenance. However, preventing maintenance costs is also essential. It will influence the costs of operations and therefore the financial sustainability of a system.

The amount of maintenance needed for a water system to function as intended can be reduced. The best moment to do this is during the design and construction phase of the system. This is the moment at which all components that need maintenance are defined and selected.

Examples of ways in which to reduce maintenance costs by taking it into consideration during the design and construction phases are:

- **The quality of material and components**: Optimize the selection of components and materials with the whole lifecycle cost in mind. Opting for a cheap pump might seem a good option during construction. If, however, this results in regular breakdowns and high downtime, one might be better off investing in a more expensive pump.

High-end products often come with (better) guarantees. It is important to understand that guarantees from suppliers are conditional – meaning one has to use the product in the intended way. Quality pays back, but one must obey all requirements under the guarantee! Studying guarantee leaflets may also be a good guidance when selecting hardware and during the development of a maintenance plan.

- **Suitability of design, materials and components**: Ensure that the characteristics & specifications of the design, materials and components fit with the working conditions.
    - ***Components:*** Components are designed for certain working conditions. Make sure the working conditions are similar to the specifications of these components. For example, pumps have a water temperature tolerance. Some pumps can only operate in low water temperatures, some only operate in high water temperatures. Make sure the water temperature matches the specification of the pump. Pipes have a pressure rating. The system will have much fewer failures if the chosen pipes match the required pressure range of the water system.
    - ***Design***: Ensure the design as a whole fits the field conditions. Simple design changes can affect the needed maintenance considerably. For example: screen the outlets of the tank as a preventive measure when there are a lot of bugs and insects. Prevent water/moisture and dust from coming close to the electronics. Make sure one can reach all the components easily – this will reduce the time it takes to do maintenance on these parts.
    - ***Materials***: select the right materials. For example, close to the ocean metal of a tower will rust quickly. To avoid this, one can opt for a concrete structure.

- **Availability of materials**: choosing for locally available materials will allow the operator to replace or repair components much faster than when transport of these components over long distances is needed. **Stock keeping** or critical components becomes essential when the hardware is not available on the local market.

- **Redundant design**: when a very high service level is envisioned with minimal downtime, one can design the system as such that critical components are placed in the design twice. It is referred to as a 'redundant design'. One can think of the example where 2 pumps are placed at a water intake. When one pump breaks down, the other pump can take over. Maintenance or replacement can be done while the system is still functioning.

- **Verification of construction and installation**. Correct and proper construction and installation of the water system will reduce the maintenance need. Examples are endless – correct welds on the frame of the tower, correct mix of cement/sand/gravel for the foundation, proper electrical connections, good and straight fitting work, installation of the pump at the right depth, etc.

During approval of the system (so the moment the builder of the system hands over the system to the entrepreneur) one will need to check all parts and elements and how they are constructed to ensure it has the quality you want to provide the service level envisioned. Checking upon handover to start operation (is it built to its requirements and specifications?) is called **verification.**

- **Validation:** A system may be well constructed and installed, but still not function properly. In this case, the functional design of the system has to be altered to make sure that a problem is not repeated in new releases of a piped water system. The process of monitoring against a set goal or purpose is called **validation.**

As part of proper maintenance practice, it is important to keep a log of all actions taken to maintain an asset. It can help with the validation process. And from analyzing logs one can learn to make better predictions for the future. This will help when one selects components, materials or makes a new design.

An issue and maintenance log ensures information is preserved. An **issue log** should be filled out when a problem or failure occurs on site. It describes the problem encountered, the likely cause of the problem and possible actions that can be undertaken to solve it. If possible repair or replacement costs are estimated.

Once resources are available to undertake the necessary repair or replacement, and the actually maintenance is undertaken, a **maintenance log** can be filled out. The maintenance log will describe the actual action undertaken and cost involved. The actual costs spent should be saved well in financial overview of the water system. This will help to improve future forecasts of maintenance costs

The following tables show examples of an issue and a maintenance log:

Issue log	
Date	
Component involved **(use good descriptors such as serial numbers or some other unique code)**	
Problem encountered & effect of problem	
Cause of failure	
Proposed maintenance action	
Estimated time required	
Estimated cost of action	
Submitted by	
Checked by	
Photos included of failure	

Maintenance log	
Date	
Component involved (use good descriptors such as serial numbers or some other unique code)	
Problem encountered & effect of problem	
Cause of failure	
Action undertaken	
Duration of action	
Cost of action	
Result	
Checked by	
Photos included of result	

4 INCOME AND OPTIMISATION

With the maintenance plan set one knows the expected costs. Two questions remain:

(I) Will the system generate enough water sales to pay for the expenses and
(II) Can we optimize the system?

For this manual, the calculations have been kept as simple as possible to make them easy to understand. The calculations can be used as a first good indication. Missing parts of this example calculations are, for example, interest & repayment of possible loans or funds placed on bank accounts against accrued interest. Adding these features may result in a more accurate calculation but they also add a considerable amount of complexity. Currently, rural piped water systems are often a donation – interest and repayment schemes are therefore often not included in a business case.

4.1 HOW TO CALCULATE YEARLY INCOME AND RESULT

To do maintenance one will need money and therefore income. The main income for a water system is generated by water sales. Generally, the customers pay per liter (or jerry can) or a fixed fee per connection. From a provider's point of view (and also for environmental reasons), it is advised to sell per liter. This will limit the consumption, reduce water spillage and spreads the cost over all the customers equally.

If customers pay per liter one can determine the income by the following formula:

- **Income per year** = (estimated number of paying customers) x (average consumption per day per customer in liter per day) x (365) x (liter price)

Be aware that water consumption fluctuates over the year. During the dry season the consumption generally peaks. During the wet season the consumption will be less. It is therefore important you use the yearly average or to make a good assumption for the consumption pattern for each month of the year and enter this in the financial model.

If customers pay a fixed fee for access to water or a connection the income can be calculated using the following formula:

- **Income per year** = (estimated number of connections paid for) x (monthly fee) x (12)

It is possible that there are customers that don't pay. Therefore, in both equations, the estimated number of *paying* customers/connections (EPC) is used. As a water operator, it is important to limit the amount of 'non-revenue water'. **Non-revenue water** is water that is produced, but not being paid for. It is lost along the way due to leakages or due to water theft by consumers. Pre-payment technology for water points and/or disconnecting household connections is a way of dealing with nonpaying customers.

In the following example, it is assumed that users pay per liter. With a water price of 0.002 euro/liter, 100 paying customers and a daily average consumption of 8 liters per person per day we calculate the following income:

Income = (0.002 euro/liter) x (8 liters per person per day) x (365 days) x (100 customers) = 584 euro/year.

It is assumed to increase the water price by 2% each year to compensate for inflation. This inflation correction is needed to recover increasing costs over the years, also due to inflation.

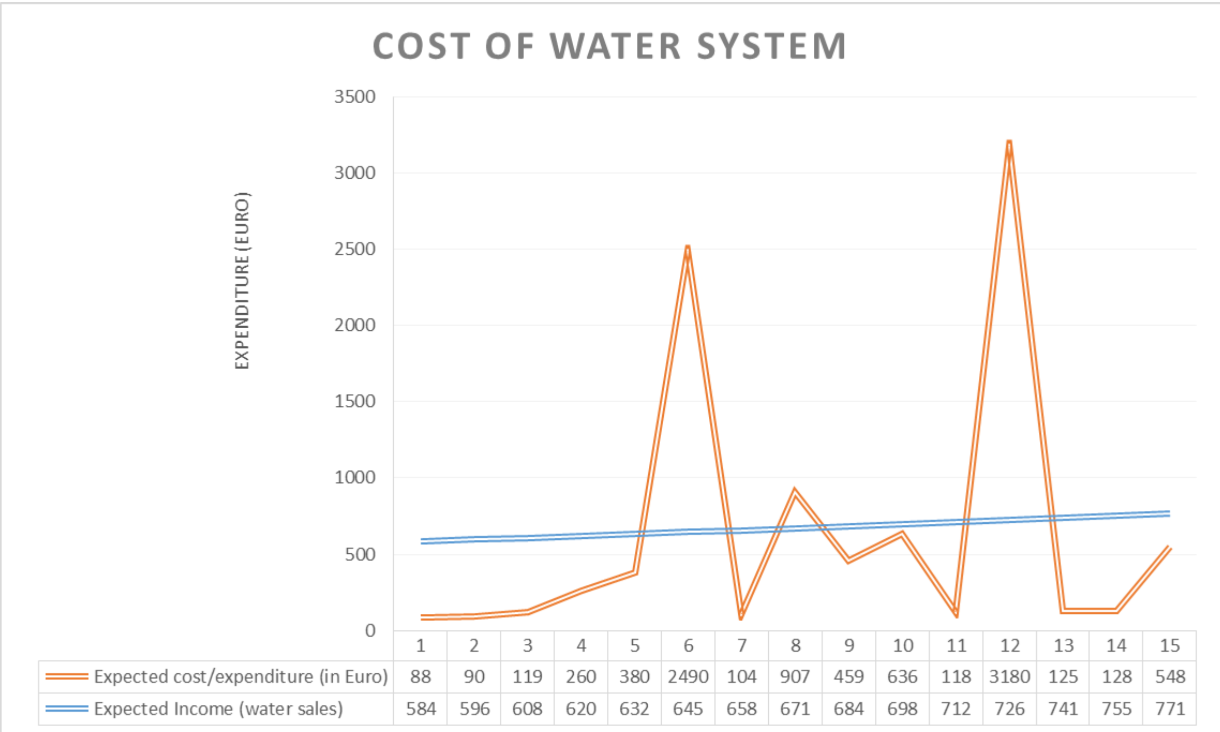
The following table shows the result:

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Expected cost/expenditure	88	90	119	260	380	2490	104	907	459	636	118	3180	125	128	548
Expected Income (water sales)	584	596	608	620	632	645	658	671	684	698	712	726	741	755	771
Yearly result	497	506	488	360	252	-1845	553	-236	225	62	594	-2454	616	627	222
Cumulative result (expected)	497	1002	1490	1851	2103	258	811	575	800	862	1456	-998	-382	245	467

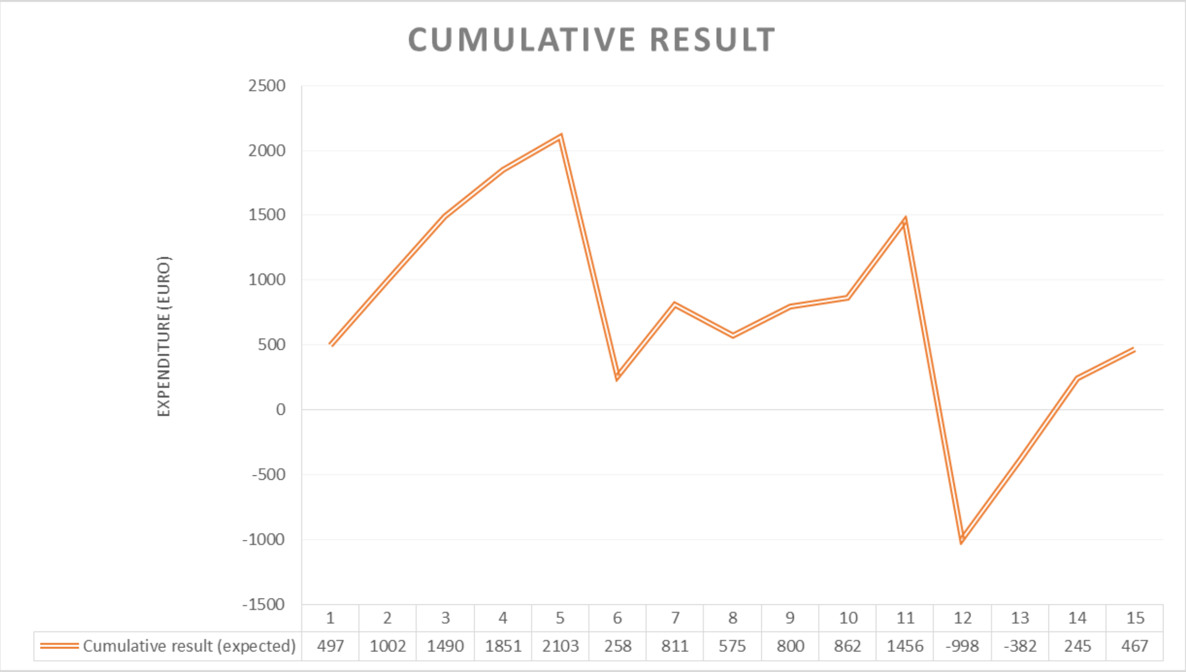
The table shows the following four lines:

- **Expected expenditure**: this is the cost as calculated in our example
- **Expected income**: This starts with the calculated 584 and increases each year with 2%.
- **Yearly result**: this is the income minus the cost. This means it is basically what you will be able to save that year. So, in year one this is (income-cost) = 584-88 = 496. Note that table shows 497. This is a result of rounding of numbers.
- **Cumulative result**: it is the sum of all the savings. So, in year one we saved 496 euros. In year two we saved 506 euros. The cumulative result is therefore 496+506 = 1002 euros.

The expected cost and expenditure can be seen in the following graph:



This graph shows a general trend observed for water systems. In the first years the income is considerably higher than the expenditure. However, after some years the entrepreneur will face high expenditure due to replacing costs. The question then is: did he/she save enough to be able to cover these cost? This becomes clear when reading the cumulative result as shown in the following graph.



Blank templates of these graphs can be found in appendix 3, as they will also serve for monitoring purposes (see next chapter).

The graph shows that nearly 2000 euro is saved when the big peak of costs in year 5 arrives. It provides enough to cover the costs. However, in year 12 the system will need to borrow money in order to pay for the expenses. One can see this because the line goes below zero. Even though after 2 years the result is positive again, it could mean the end of the water provision service because the negative cash flow was not expected.

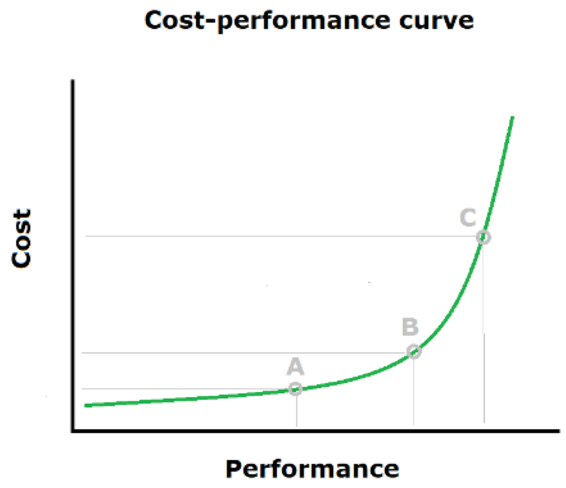
The following step, being optimization, is therefore critical to explore if the system can perform better than this model currently predicts.

4.2 OPTIMIZATION

Once we know the income and expenditure of a system one can explore measures that make the system function better.

This can be done by revisiting all the steps that one has made up to this point. This starts with the definition of the service level, and questioning if an adaptation in service level, design or maintenance approach might result in a net higher income.

In this quest, it is important to understand that setting service level goals has a direct cost and revenue impact. The more ambitious the goals, the more expensive the service can become. This relation is in many cases what they call 'nonlinear'. This means that the relation of cost and performance is not a straight line but a curved one. The following graph example shows the effect of this.

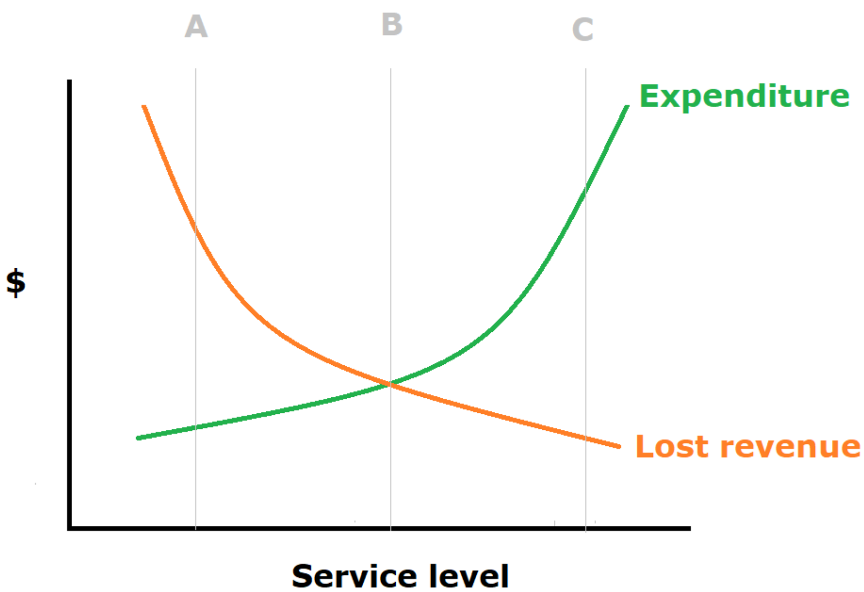


If one observes the curved green line in the graph above one can see that if:

- If you want to increase the performance with 50% from point A to B, the costs might double.
- If you want to increase the performance with 100% from point A to C, the costs might be 5 times higher.

A concrete example would be the **downtime** of a water system, meaning that the water system doesn't supply water anymore (or to a very limited extent). Ensuring that a system is operational for 90% of the time would, for example, cost 100 USD/month. Increasing this to 95%, would result in costs of 200 USD/month. However, a system with a 99.9% operational rate would increase the cost to 500 USD/month.

Providing the highest service possible is therefore not always the best option. Defining the service level from an entrepreneurial point of view should be done from a cost perspective. Given the example above, the entrepreneur will have to question whether the added 400 USD/month will create an equal of larger amount in revenue. The following graph shows this principle.



If one observes the graph above one can see that:

- Situation A provides a very low service level (e.g. considerable downtime) as a result of limited maintenance expenditure. It is suboptimal; by spending extra in order to increase the service level one can increase the revenue. The costs in this case are lower than the additional income.
- Situation C is a situation in which the service level is very high, but this comes at a cost. Reducing the expenditure would result in a decrease of revenue. The reduced expenditure would however be higher than the reduction in revenue
- Situation B is an optimal situation from a cost-benefit perspective.

Customers should be placed central in this optimization step. Consult the customers with concrete proposals. For example: are you willing to pay X amount extra if you get 20% more water? Or are you willing to pay X amount extra if you get chlorinated water instead of untreated water? Making customers part of this decision ensures a more successful uptake: they have the opportunity to clearly specify their need within their budget. Ensuring the service provided fits their need.

A structured way of finding optimizations can be done by performing a '**sensitivity analysis'**. One can change certain values/inputs (like water price or number of customers) and it provides insight into the effect is has on the financial prognosis. One can see that changing some parameters have a much bigger effect on the outcome than others. When financially optimizing the system it is the most effective to look at the parameters that influence the financial performance the most.

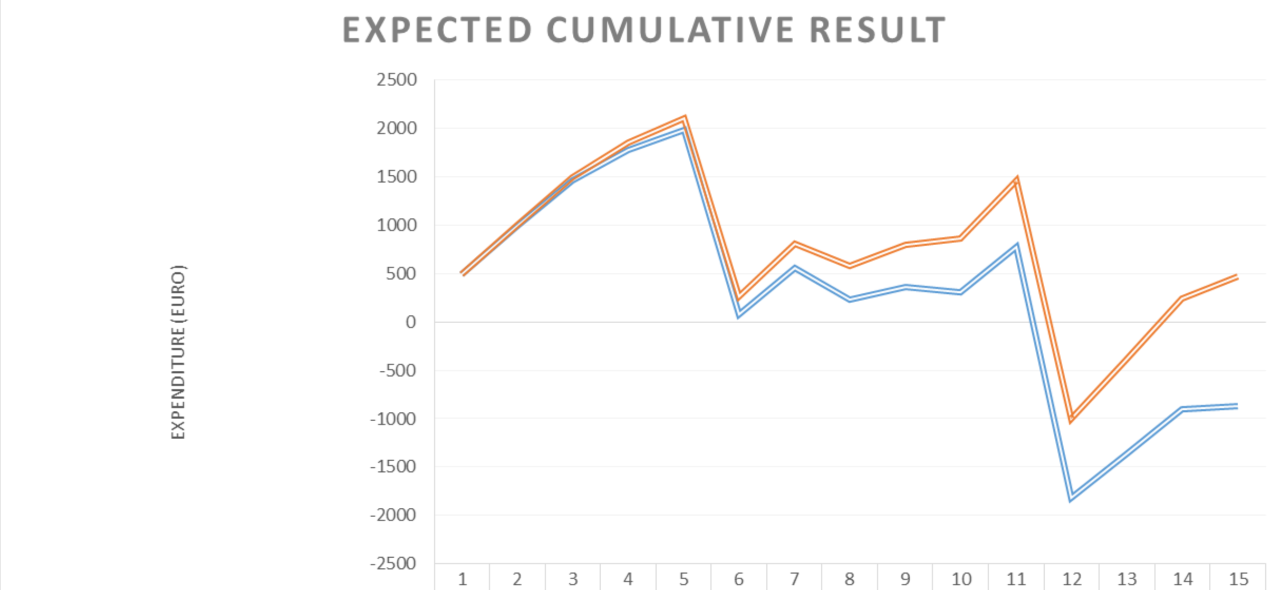
One should be aware that changing one parameter often has an effect on the plan as a whole. For example: added additional households do not only have an effect on the income (by generation extra income) but also on the maintenance plan as additional costs can be expected.

Common dominant parameters that influence the business case are:

- **Number of paying users**: increasing the amount of customers is often a measure that generates more income than it costs. Increasing the amount of household connections, placing water kiosks at strategic places or reducing nonpayment by means of using prepayment technology are alternatives that could be explored.
- **Water price and water price increase**: not surprising – the water price highly determines the financial sustainability. Starting off, from the start of exploitation, with the right water price is key. But equally important are price increases to counter inflation.
- **Fuel/electricity costs**: if a piped system is fed by a pump that runs on fossil fuels or electricity then there is a direct relation to the amount of water provided and the cost of fuel/electricity. A reduction of water quantity – particularly if one works with fixed connection fees – has a significant impact on costs while the income reduction might be limited.
- **Replacement cost of expensive, critical elements**: particular pumps are known to be a critical part that tends to be the cause of long-term downtime. Explore if cheaper (often less reliable) pumps should be favored above expensive (more reliable) pumps. Or if there are simple measures to protect the pump that ensure a longer lifespan. Dry run protection for submersibles is an example. Also, simple protection of expensive hardware (e.g. welding the bolts of solar panels fixed – to prevent theft) are cheap options that prevent expensive failure.

The optimization process is an **interactive process**. This means it consists of many steps that need to be repeated multiple times to get to the right answer. One will see that each system has its own characteristics – depending on the number of customers, technical setup, local price setting of labor and hardware, fuel prices, etc.

It is important to do this analysis and determine which parameters are critical in the business case that need constant attention to ensure a lasting service provision. The following graph shows, for example, what happens if we don't correct the water price by 2% to compensate for inflation.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cumulative result (expected - without inflation correction)	497	990	1455	1780	1984	78	558	235	359	307	774	-1823	-1363	-908	-872
Cumulative result (expected with inflation correction)	497	1002	1490	1851	2103	258	811	575	800	862	1456	-998	-382	245	467

We can immediately see the result: the system will be financially unsustainable for the long run.

Getting a grip on what is important to ensure financial sustainable also provides insight in critical parameters to steer on during the operational phase.

5 MONITORING & EVALUATION

An asset management plan is a plan with a projection only. The reality will be different. And a plan that doesn't result in any actions has very little value.

During operation of the water system it is therefore important to put the plan in practice and monitor and evaluate the performance. Monitoring means that:

- From a **financial perspective** one observes and keeps track of the cost and income. By comparing the expected cost and income with the real cost and income one can assess if changes in the business operations are needed.
- From a **technical perspective** one observes if the maintenance plan ensures technical continuity.
- From a **customer perspective** one observes if the intended service level is achieved and that the customers are satisfied with the situation.

5.1 MONITORING INDICATORS

Monitoring is always done based on **pre-defined indicators**: these are either quantities / variables that can be measured using units, or qualitative parameters that can be described. If you measure a **parameter**, it is called an indicator. An example of a quantity / variable is the content of iron, and its unit of measurement is μg / l (microgram / litre). An example of a qualitative parameter is the cleanliness of the storage tank.

In the service level agreement (see section 2.2), the key parameters of service are noted down, and what should be the minimum / maximum / average level of each parameter.

Some indicators could best be measured / monitored every week, other indicators only need to be measured twice a year. This is called the **frequency**.

Some indicators one can measure / monitor independently, e.g. the cleanliness of the water tank. For other indicators one needs some help, e.g. the content of iron: you can take a sample of the water, and then the actual measurement needs to be done in a laboratory by an expert.

In order to make monitoring useful, it needs to be done regularly over a long period. This can be done in a paper notebook or in a spreadsheet on a computer. To have a good idea of the functioning of the water system, you need to check both with the manager / operator/ water user committee and with the customers / water users. In the following section, examples of indicators are given for both these groups. Some indicators can be checked with both groups, other indicators need / can be checked with either the managers or the customers. The condition of assets is not a key parameter, but indicators on the condition of the assets are still included, as they influence the other indicators / key parameters.

Financial monitoring

The following data on expenditures and income need to be collected by the operator of the water system to ensure sound financial management. It is vital that yearly income will recover the costs made, so business operations can be secured.

The data collection for expenditures and income should be done on at least a monthly basis.

The next page contains an example of a format that could be used to simply collect data on operational and maintenance costs, and income from water sales.

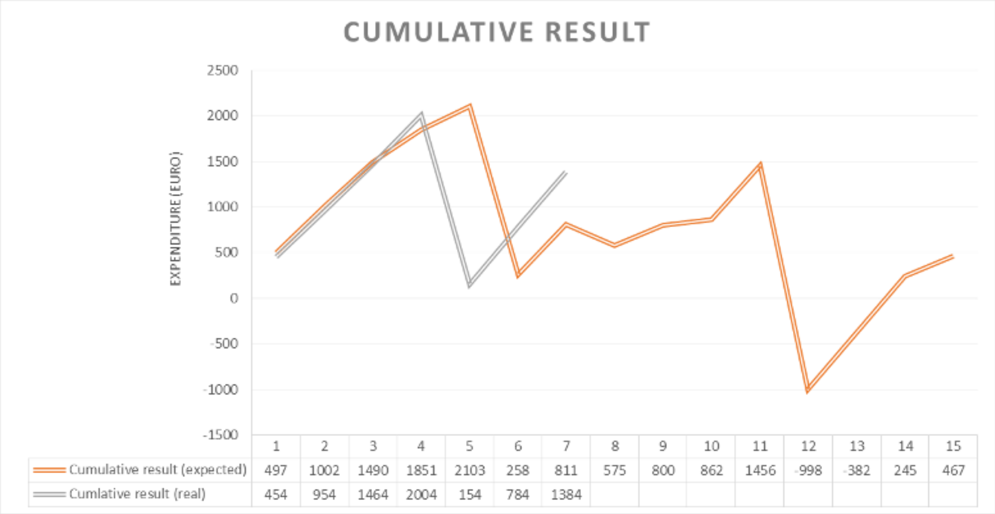
Expenditure						
Year	1					
System	Tower Papendrecht North, location 3					
Date expense (d/m/yr)	Description	Duration	Type of maintenance (reactive/preventive/inspection)	Type of cost (overhead/repair/replace/other)	Cost	Comment
3-3-2020	Water quality test	1 day	Preventive	Other	15	Government regulation
6-9-2020	Stolen solar panel	2 days	Reactive	Replace	10	Unexpected cost
15-9-2020	Leakage in main distributin pi	1 day	Reactive	Repair	20	Punctured by accident farmer
3-10-2020	Check loose bolts	1/2 day	Inspection	Repair	4	All bolts are ok
15-11-2020	Slab repair	1 day	Inspection	Repair	22	Less than expected
31-12-2020	Cleaning panels	weekly, 1 hour	Preventive	Repair	5	
31-12-2020	Salary manager	N.a.		Overhead	15	
31-12-2020	Salary technician	N.a.		Overhead	5	
				Total cost (SUM)	96	

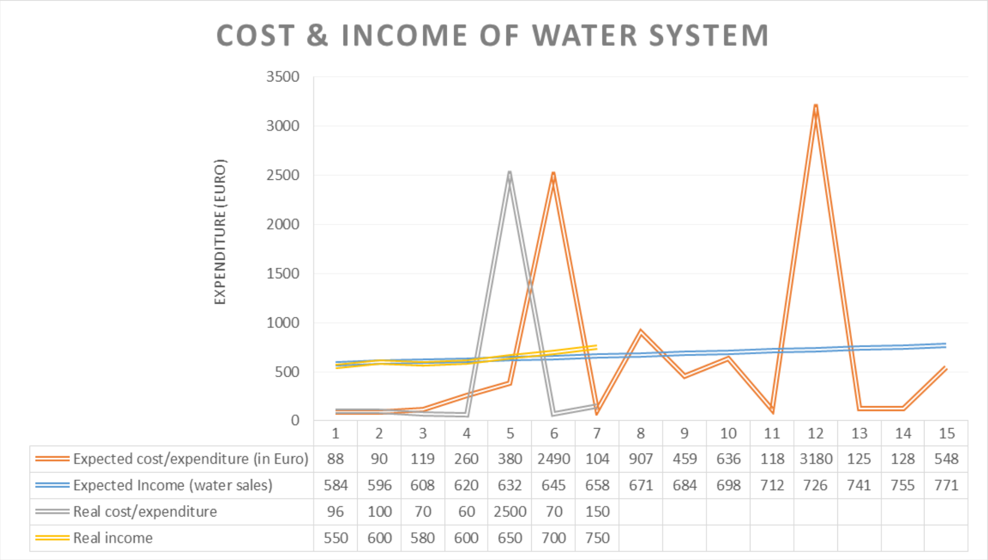
Income				
Year	1			
System	Tower Papendrecht North, location 3			
Month	Liters of water sold	Water price	Income	Comment
1	31500	0,002	63	Dry season
2	30000	0,002	60	
3	22500	0,002	45	
4	20000	0,002	40	
5	17500	0,002	35	Rainy season
6	15000	0,002	30	
7	17500	0,002	35	
8	18500	0,002	37	
9	22500	0,002	45	
10	24500	0,002	49	
11	27000	0,002	54	
12	28500	0,002	57	
		Total income (SUM)	550	

In our example we have collected data for 7 years – the data is filled in the templates and the results are used to make the following table:

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Real cost/expenditure	96	100	70	60	2500	70	150								
Real income	550	600	580	600	650	700	750								
Yearly result	454	500	510	540	-1850	630	600								
Cumlative result (real)	454	954	1464	2004	154	784	1384								

With these data we are able to compare the predicted income/expenditure with the real income/expenditure. In our case this would provide us the following graphs:





In this case we can see that our system is doing well – we had an expenditure peak earlier than expected, but due to lower costs and higher income than expected our total result is positive. It is even better than predicted.

Templates to monitor income and expenditures are given in Appendix 3.

Technical monitoring

The following indicators need to be checked by the manager or operator of the water system to ensure technical continuation.

- Water quality
- Accessibility
- Reliability
- Availability
- Condition of main assets

Templates on which parameters and indicators one could use for each category are given in Appendix 3

Customer satisfaction monitoring

The following indicators need to be checked with the customers / water users via customer satisfaction surveys or group discussions:

- Sufficiency of water supply
- Water quality
- Accessibility
- Affordability
- Reliability
- Availability
- Safety/security

Templates on which parameters and indicators one could use for each category are given in Appendix 3

5.2 OPTIMIZATION BY USING MONITORING DATA

Continuous monitoring of the whole system allows early adjustment of the chosen strategy if needed. These changes should aim for improvement. The optimization of a water system is therefore never a single action, but a continuous process that needs constant attention.

This type of information is important if one is considering expanding the system, building a new system in another location or comparing different designs and management models to see what fits best. Asset management should therefore be considered not only as a tool for one system, but as a way to optimize strategies, management and policies in the whole sector.

The information collected during monitoring thus can be used to optimize asset management. It is best to plan who to involve and what methods to use to ensure a proper optimization process. Consider a mix of stakeholders, various monitoring perspectives, and different data collection methods, like surveys and focused group discussions.

All service levels and other monitoring indicators must be considered in formulating these questions. An out-of-the-box manner of researching should be adopted to explore WHY and HOW behind the monitoring data outcomes.

Example questions:

- Can the low reliability of the water system be explained by the incompetence of the caretaker or by the poor quality of the spare parts put in place?
- Can the poor water quality of the samples taken this year to be explained by the fact that people are polluting the wells with waste more often or by the fact that another method was used to measure the water quality compared to last year?
- Can the higher water consumption be explained by more people moving to the village or by the fact that the existing villages are taking more frequent showers and baths?
- Can the higher expenditures be explained by more unexpected systems failures or because the market prices for spare parts increased?

One should not only think of external causes of why something is not functioning or has a different outcome than expected. Perhaps the monitoring method, or data have been inadequately analyzed or wrongly interpreted? This exercise could thus also result in formulating new indicators and new methods of monitoring and evaluation.

APPENDIX 1: MAINTENANCE PLAN TEMPLATES

Format for an Asset Inventory/ Stock Entry Worksheet

	Stock Entry Worksheet													
Date Completed/Updated:			Worksheet											
ID Number	Asset	Quantity	Size		Location		Year of Installation/ Purchase	Condition	Expected Useful Life (Years)	Composition Material	Manufacturer Information	Model	Serial Number	Service History
					Longitude	Latitude								

Using the Stock Entry Worksheet

Step 1: Enter the date

Circle whether you are completing or updating the worksheet and fill in the date.

Step 2: Identify and list your asset

Write in each of your system's assets with a unique ID number to identify them. Provide a unique ID number such as 1, 2, 3, and so on for the major assets, and use secondary ID numbers like 1.1, 1.2, 1.3, 1.4, 2.1, 2.2, 2.3, and so on to identify sub-components of the major assets.

Step 3: Provide the quantity/ number of your assets

Fill in the total quantity of your system's assets.

Step 4: Provide the size of your asset

Fill in the size of your system's assets depending on their nature and properties such as diameter, length, area, volume, flow rate, horsepower, etc., along with the units they are being measured with.

Step 5: Provide the location of your asset

Provide longitude and latitude to determine the location of your system's assets. Longitude and latitude can be easily taken with the help of smart phone.

Step 6: Fill in the year of installation/purchase

Fill in the year of installation or purchase of each of your system's assets.

Step 7: Describe the condition of your asset

Determine the condition of each asset. For simplicity, the condition of the asset has been broadly divided into seven categories such as Excellent (Like New), Good, Moderate/Fair, Excessively Used (MEICA Assets), Poor, Not Functioning, and Unknown. The focus of categorizing the condition is to obtain the adjusted useful life for each of the system's assets. You just need to select one option out of seven conditions from the drop-down list as provided in the Excel Workbook.

S.No.	Category	Condition

1.	Excellent (Like new)	For the assets that are in brand new condition or there is no deterioration even after being used
2.	Good	For assets that are comparatively new but have slight deterioration after use
3.	Moderate/Fair	For assets that have been used for quite some time and have gone through moderate amount of deterioration but have not redhead to the verge of breaking down
4.	Excessively Used (MEICA Assets)	Usually for Pumps and other mechanical/electrical components that are continuously run
5.	Poor	For assets that were in the verge of breakdown during the survey.
6.	Not Functioning	For assets that have stopped functioning while the survey for AMP was done
7.	Unknown	For assets whose conditions cannot be analyzed; for example: underground pipe lines, valves and gates that are underground.

Step 8: Fill in the expected useful life

Use the manufacturer's recommendation or the table presented below to enter the expected useful life for each asset.

Estimated Useful Lives of water system components

Components	Expected Useful Life
Wells and Springs	25-35 years
Intake Structures	35-45 years

Galleries and Tunnels	30-40 years
Pumping Equipment	10-15 years
Treatment Equipment	5-10 years
Storage Tanks	30-60 years
Transmission Structures/Distribution Pipes	35-40 years
Valves	35-40 years
Meters	10-15 years
Computer Equipment/Software	5 years
Transformers/Switchgears/Wiring	20 years

Electrical Systems	7-10 years
Buildings	30-60 years
Service Lines	30-50 years
Lab/Monitoring Equipment	5-7 years
Tools and Shop Equipment	10-15 years
Office Furniture/Supplies	10 years
Transportation Equipment	10-15 years

Note: The estimated ranges assume that assets have been properly maintained.

Step 9: Enter the composition materials of your asset

Fill in the composition material of your system's assets such as reinforced concrete, plain concrete, plastic, GI, HDPE, Aluminum, etc.

Step 10: Enter the manufacturer’s information

Provide the basic information of the manufacturer or vendor of your assets.

Step 11: Enter the model including the serial number

Provide the basic information of the model including the serial number for all your purchased assets.

Step 12: Describe service history

Briefly describe the service history of each asset. Include routine maintenance activities as well as any repairs and rehabilitations. List how often you have made repairs and rehabilitations.

Format for a Risk Assessment Worksheet

Risk Assessment Worksheet													
ID Number	Asset	Size		Description of Possible Failure	Effect				Probability				Risk
					Total loss of functionality	Reduction of functionality of system	Reduction of functionality of part	Hardly any effect	High	Med	Low	Minimal	Effect Probability
					4	3	2	1	4	3	2	1	

Using the Risk Assessment Worksheet

Step 1: List vulnerable and highly prioritized assets with ID number
List vulnerable and highly prioritized assets with their unique ID number, which was assigned to them while filling out the Stock Entry Worksheet.

Step 2: Provide the size of your asset
Fill in the size of your system's assets as filled out in the Stock Entry Worksheet.

Step 3: List out possible failures of the assets
List out possible failures that can affect the functionality of your system's assets. For each possible failure, a risk value needs to be calculated to determine the level of severity of risk associated with each failure. The following table provides an example of such an overview.

Step 4: Provide scoring for the effect and probability
Assign scores (1 to 4) for both Likelihood of Failure (Probability) and Consequence of Failure (Effect), where 4 is the highest level of likelihood and the highest level of consequence respectively.

The worksheet shows four columns with four different effects. If a part breaks down and it has hardly any effect on the service level, it will be given a score of 1 (non-critical). If it results in a complete loss of functionality of the system, it gets a score of 4 (critical). Scores 2 and 3 are in between. Similarly, the worksheet also shows columns with four probabilities. A score of 1 is given if it is very unlikely to break down (minimal). If the part is very likely to break down, a score of 4 is given. Scores 2 and 3 are in between.

Step 5: Calculate the risk
To calculate the risk associated with the failure of the asset, the score for the likelihood of failure (probability) is multiplied by the score for the consequence of the failure of the asset (effect). The higher the score, the higher the risk. This way, the risk score is calculated. The higher the risk, the more attention it will need to get. The risk is automatically calculated in the Excel Workbook based on the scores of "Effect" and "Probability" provided in Step 4.

Format for a risk-based (risk mitigation) maintenance plan worksheet

Risk-Based Maintenance Plan Worksheet											
ID Number	**Asset**	**Size**		**Description of Possible Failure**	**Risk Score**	**Risk Mitigation Type**			**Description of Risk Mitigation Action**	**Expected Interval (Years)**	**Person responsible**
						Reactive	**Preventive**	**Inspection**			

Using the Risk-based Maintenance Plan Worksheet

Step 1: Ensure the list of your assets along with unique ID number, their size, description of possible failures, and risk score are visible

Since the list of your assets along with unique ID number, size, description of possible failures, and risk score are automatically linked from the Risk Assessment Worksheet, please ensure that all the relevant information is visible in this worksheet as well.

Step 2: Choose the Risk Mitigation Type

Choose the type of risk mitigation between “Reactive” and “Preventive” depending upon the nature of the risks. The concept of both types is briefly explained above.

Step 3: Determine Risk Mitigation Action and Expected Interval

Determine the risk mitigation action plan for possible failures/risks identified. Based on mitigation action plans, determine the expected interval for carrying out maintenance work.

Step 4: Determine Responsible Person

Determine who is going to execute the Risk Mitigation Actions at the defined intervals. Depending on the type of action this could be a managerial person, a technician, a caretaker or an operator.

APPENDIX 2: COST ESTIMATION TEMPLATE

Maintenance costs				Description of Risk Mitigation Action	Quantity	Rate	Total Cost	Expected Interval (Years)	Yearly Cost Distribution														
ID Number	Asset	Size							1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Operational costs				**Description**																			
ID number	Type																						

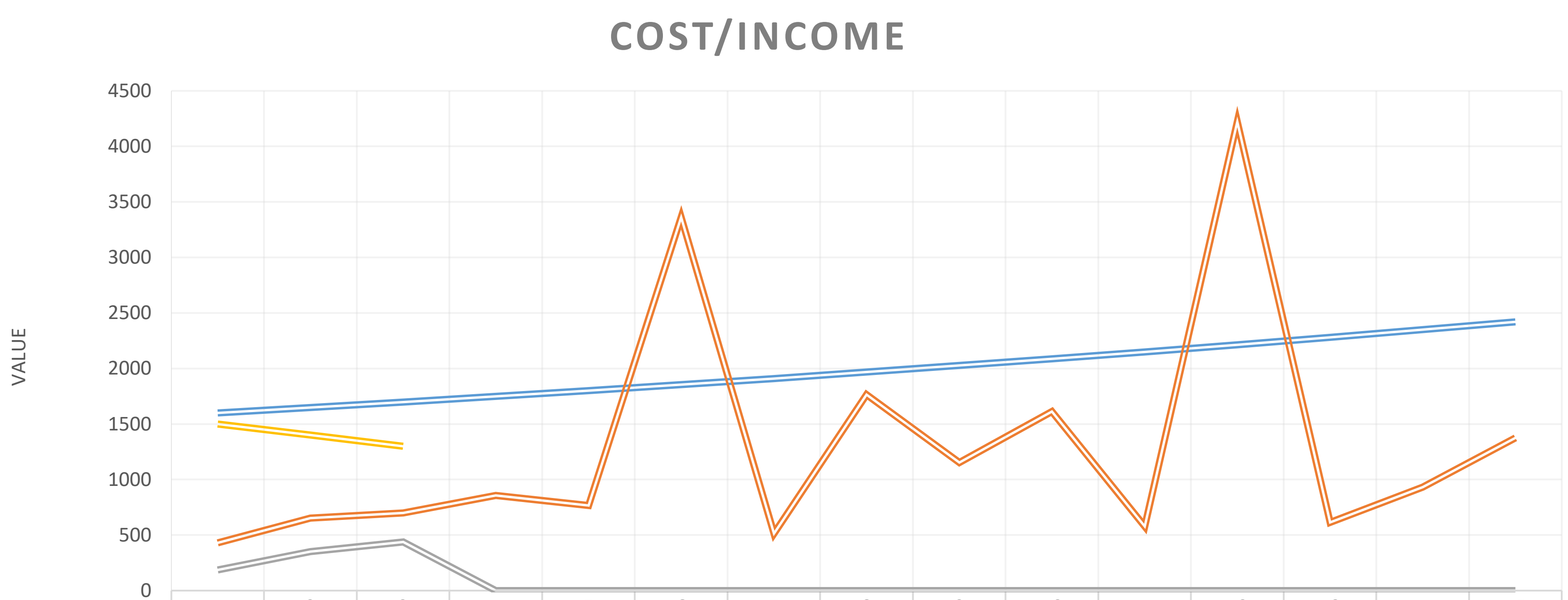
APPENDIX 3: MONITORING TEMPLATES

Formats for financial monitoring

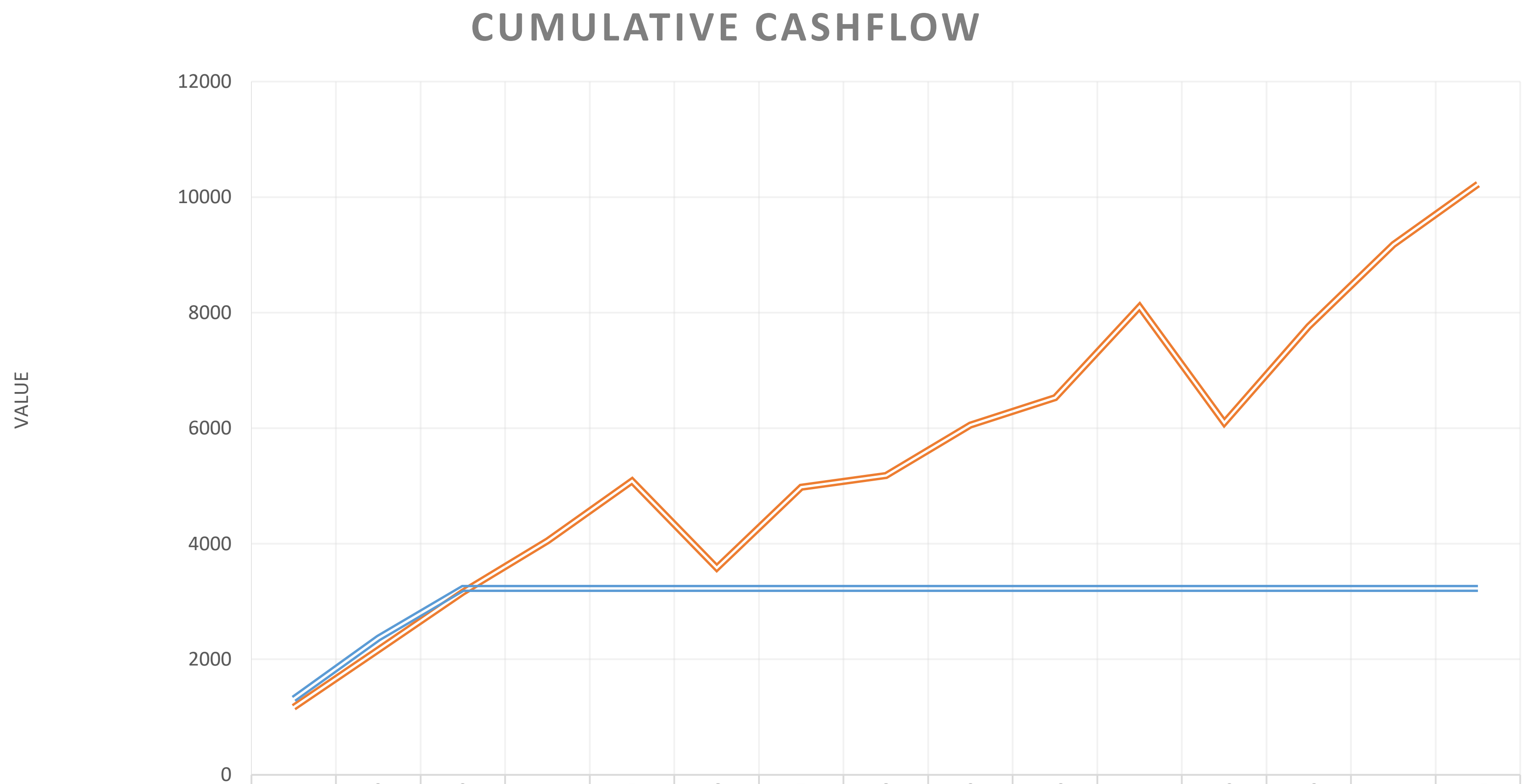
Income						
Year						
System						
Month	**A.Liters of water sold**	**B.Water price**	**C. Income water sales**	**D. Other income sources***	**E. Monthly total**	**Comment**
1			A*B = C		C+D	
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
Yearly total					SUM (1:12)	

*e.g. governmental subsidies, gifts, monthly general fees

Expenditure						
Year						
System						
Date (d/m/yr)	Description	Duration (days)	Type of maintenance (reactive/preventive/inspection)	Type of costs (e.g. overhead /consumable/repair/replacement)	Cost	Comments
TOTAL COSTS						



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Expected Income	1600	1648	1697	1748	1801	1855	1910	1968	2027	2088	2150	2215	2281	2350	2420
Expected cost	430	654	700	858	765	3362	513	1765	1153	1611	578	4222	613	933	1376
Real Income	1500	1400	1300												
Real cost	185	350	438	0	0	0	0	0	0	0	0	0	0	0	0



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Expected Cumulative cashflow	1170	2164	3161	4052	5087	3580	4977	5180	6054	6530	8103	6096	7764	9181	10225
Real Cumulative cashflow	1315	2365	3227	3227	3227	3227	3227	3227	3227	3227	3227	3227	3227	3227	3227

Format for technical monitoring

*Note: For **frequency** and **responsible**, examples are given; these can be adapted to your own water system. For **water quality** indicators, the standards (maximum values) from the World Health Organization are given as a reference. It is recommended however, to follow the national standards, as can be provided by the Ministry of Health. For **accessibility and condition of assets**, both cleanliness and condition are given; cleanliness refers to the absence (or the acceptable presence) of dirt; condition refers to the functionality of the asset: when it functions well, the condition is good. Both the cleanliness and condition contribute to the expected useful lifetime.*

Indicator	Unit	(WHO) standards	Frequency	Responsible
WATER QUANTITY				
Water volume	M^3 or liter		Daily	Caretaker of WSUC
Water pressure on the system	Mbar		Daily	Caretaker of WSUC
Number of hours / days with running water supply	Hours / day or Days / month		Daily	Caretaker of WSUC
Exact timing of water supply during the day	Time slot / day		Daily	Caretaker of WSUC
WATER QUALITY				
Temperature	Degrees Celsius or Fahrenheit		Every 2 months	Caretaker of WSUC
pH (acidity)	Log H	6.5 - 8.5 (Not of health concern at levels found in drinking water)	Every 2 months	Caretaker of WSUC
Arsenic	µg / l	10 µg / l	Every 2 months	Caretaker of WSUC
Iron	µg / l	(Not of health concern at levels found in drinking water)	Every 2 months	Caretaker of WSUC
Chlorine	µg / l	5000 µg / l	Every 2 months	Caretaker of WSUC
Fluoride	µg / l	1500 µg / l	Every 2 months	Caretaker of WSUC
E. Coli	Number of colonies / cm^2	Must not be detectable in any 100 ml sample	Every 2 months	Caretaker of WSUC
ACCESSIBILITY				
Cleanliness of access path and water point	Descriptive		Every 2 months	Social expert of WSUC
Condition of access path	Descriptive		Every 2 months	Social expert of WSUC
Accessibility during times of flooding	Number of days / year		Every 2 months	Social expert of WSUC
RELIABILITY				
Number of service interruptions per year	Number per year		Every 3 months	Caretaker of WSUC
Water system losses / non-revenue water	Leakages per km pipeline / m^3 per year		Every 3 months	Caretaker of WSUC

	(difference between water sold and volume of water)			
AVAILABILITY				
Downtime during interruption (service restoration time)	Hours / interruption		Every 3 months	Caretaker of WSUC
CONDITION OF ASSETS				
Cleanliness of storage tank	Descriptive		Every 3 months	Caretaker of WSUC
Condition of storage tank	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pump	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pump	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pumping station	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pumping station	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of pipelines (incl. joints, valves)	Descriptive		Every 3 months	Caretaker of WSUC
Condition of pipelines (incl. joints, valves)	Descriptive		Every 3 months	Caretaker of WSUC
Cleanliness of treatment plant	Descriptive		Every 3 months	Caretaker of WSUC
Condition of treatment plant	Descriptive		Every 3 months	Caretaker of WSUC

Format for a customer satisfaction monitoring

Note: For frequency and responsible, examples are given; these can / should be adapted to your own water system.

Indicator	Unit	Frequency	Responsible
WATER QUANTITY			
Sufficiency	Descriptive	Monthly	Social expert of WSUC
WATER QUALITY			
Taste	Descriptive	Every 3 months	Social expert of WSUC
Smell	Descriptive	Every 3 months	Social expert of WSUC
Colour	Descriptive	Every 3 months	Social expert of WSUC
Days of sickness of water users (because of bad water quality)	Number of days		Social expert of WSUC
ACCESSIBILITY			
Ease for disabled and elderly person or pregnant woman to access the water system	Descriptive	Every 6 months	Social expert of WSUC
Accessibility during times of flooding	Number of days / year	Every 3 months	Social expert of WSUC
AFFORDABILITY			
Price	Currency per jerrycan (20 l)?	Every 6 months	Social expert of WSUC
Affordability for poorest water system users	Descriptive	Every 6 months	Social expert of WSUC
% of income spent on water		Every 6 months	Social expert of WSUC
RELIABILITY			
Number of service interruptions per year	Number per year	Every 6 months	Social expert of WSUC
AVAILABILITY			
Suitability of time slot for access to water	Descriptive	Every 6 months	Social expert of WSUC
SAFETY / SECURITY			
Feeling of safety while fetching water	Descriptive	Every 6 months	Social expert of WSUC
Safety incidents while fetching water	Number / year	Every 6 months	Social expert of WSUC

APPENDIX 4: INFLATION RATE CORRECTION FACTOR

	Inflation Correction factor														
	Year														
Inflation rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1%	1	1,01	1,02	1,03	1,04	1,05	1,06	1,07	1,08	1,09	1,10	1,12	1,13	1,14	1,15
2%	1	1,02	1,04	1,06	1,08	1,10	1,13	1,15	1,17	1,20	1,22	1,24	1,27	1,29	1,32
3%	1	1,03	1,06	1,09	1,13	1,16	1,19	1,23	1,27	1,30	1,34	1,38	1,43	1,47	1,51
4%	1	1,04	1,08	1,12	1,17	1,22	1,27	1,32	1,37	1,42	1,48	1,54	1,60	1,67	1,73
5%	1	1,05	1,10	1,16	1,22	1,28	1,34	1,41	1,48	1,55	1,63	1,71	1,80	1,89	1,98
6%	1	1,06	1,12	1,19	1,26	1,34	1,42	1,50	1,59	1,69	1,79	1,90	2,01	2,13	2,26
7%	1	1,07	1,14	1,23	1,31	1,40	1,50	1,61	1,72	1,84	1,97	2,10	2,25	2,41	2,58
8%	1	1,08	1,17	1,26	1,36	1,47	1,59	1,71	1,85	2,00	2,16	2,33	2,52	2,72	2,94
9%	1	1,09	1,19	1,30	1,41	1,54	1,68	1,83	1,99	2,17	2,37	2,58	2,81	3,07	3,34
10%	1	1,10	1,21	1,33	1,46	1,61	1,77	1,95	2,14	2,36	2,59	2,85	3,14	3,45	3,80
11%	1	1,11	1,23	1,37	1,52	1,69	1,87	2,08	2,30	2,56	2,84	3,15	3,50	3,88	4,31
12%	1	1,12	1,25	1,40	1,57	1,76	1,97	2,21	2,48	2,77	3,11	3,48	3,90	4,36	4,89
13%	1	1,13	1,28	1,44	1,63	1,84	2,08	2,35	2,66	3,00	3,39	3,84	4,33	4,90	5,53
14%	1	1,14	1,30	1,48	1,69	1,93	2,19	2,50	2,85	3,25	3,71	4,23	4,82	5,49	6,26
15%	1	1,15	1,32	1,52	1,75	2,01	2,31	2,66	3,06	3,52	4,05	4,65	5,35	6,15	7,08