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**Water and
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Regional Peer-to-Peer Exchange on Non-Revenue Water management/ Standard Operating Procedure: Calculating a Water Balance

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WATER AND ENVIRONMENT SUPPORT IN THE ENI SOUTHERN NEIGHBOURHOOD REGION

The "Water and Environment Support (WES) in the ENI Neighborhood South Region" project is a regional technical support project funded by the European Neighbourhood Instrument (ENI South). WES aims to protect the natural ressources in the Mediterranean context and to improve the management of scarce water resources in the region. WES mainly aims to solve the problems linked to the pollution prevention and the rational use of water.

WES builds on previous similar regional projects funded by the European Union (Horizon 2020 CB/MEP, SWIM SM, SWIM-H2020 SM) and strives to create a supportive environment and increase capacity all stakeholders in the partner countries (PCs).

The WES Project Countries are Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, Libya, Palestine, Syria and Tunisia. However, in order to ensure the coherence and effectiveness of EU funding or to promote regional cooperation, the eligibility of specific actions can be extended to neighboring countries in the Southern Neighborhood region.

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ABBREVIATIONS

CARL	Current Annual Real Losses
DMA	District Metered Area
ENI	European Neighbourhood Instrument
ILI	Infrastructure Leakage Index
IWA	International Water Association
KPI	Key Performance Indicator
NRW	Non-Revenue Water
SIV	System Input Volume
SOP	Standard Operating Procedure
UARL	Unavoidable Annual Real Losses
WES	Water and Environment Support

1 INTRODUCTION

This document outlines the Standard Operating Procedure in the context of water supply and Non-Revenue Water (NRW) management for the "Water and Environment Support (WES) in the ENI Neighbourhood South Region" project. The project is a regional technical support project funded by the European Neighbourhood Instrument (ENI South). WES aims to protect the natural resources in the Mediterranean context, improve the management of scarce water resources in the region, and primarily address issues related to pollution prevention and the rational use of water.

Historically, water supply systems have played a crucial role in enhancing living conditions, namely by supporting public health and economic growth through the provision of water. As societies have developed and urbanized, the demand for water has risen, placing increased pressure on water utilities to maintain efficient and sustainable distribution systems. Utilities encounter a range of losses, and it is critical that losses are managed effectively for a several reasons, in particular system efficiency, as well as for economic and environmental purposes. Recognizing the vital role of water and the water supply systems in fostering healthy and prosperous communities, efforts to manage losses have become paramount. The calculation of the Water Balance is the first stage in water loss control. This will provide an overview of the source and magnitude of the losses, and aid in creating an overview of the financial and resource implications of these losses.

As part of the WES project workplan for the third year (2021-2022), a regional training combined with a study tour and a peer-to-peer exchange are planned, all addressing the same topic of NRW management. The regional training and study tour took place in Athens, Greece, while the peer-to-peer exchange takes place online. Up to two peers from each partner country engage in the peer-to-peer activity. The hereby document is a result of the effort of the peer-to-peer group and the group’s facilitators, through a series of meetings: kick-off meeting, working session and a formal exchange with the peer group.

The purpose of this regional activity is to build the capacity of the partner countries on NRW Management and the connected interventions. With a NRW level of more than 50% in most partner countries, significant NRW reduction measures are necessary.

The objective among peers is to facilitate meaningful dialogues and the exchange of experiences among participating practitioners. This aims to foster the sharing of valuable insights, Standard Operating Procedures (SOPs), and effective practices related to Non-Revenue Water (NRW) management. The activity encourages the exchange between practitioners from different regions, and sharing of practical examples, all to collectively enhance NRW management strategies. As an outcome of the activity, participants should lead and contribute to the implementation of cost-effective NRW management and reduction interventions.

1.1 ENABLING WORKS BEFORE STARTING TO CALCULATE A WATER BALANCE

The following recommendations have been provided by Mr. Marwan Bdair, Director Water Monitoring of Quality Service department, Water Monitoring Directorate, Palestinian Water

Authority. The recommendations are regarding steps that must be taken before starting to calculate a Water Balance. The authors fully support these excellent recommendations.

"To reduce levels of NRW it is fundamental that the scale of the problem is defined; and that the location of areas with the highest levels of NRW can be identified. This can only be achieved if we have a sufficient and accurate method to account for inflow and outflow from distinct bulk and service water supply systems of sufficiently small size to pinpoint problem areas through these:

- Water utilities/providers should ensure the correctly sized and calibrated flow meters, capable of recording instantaneous and bulk flow are installed at the point of purchase of bulk water, in and out of reservoirs and at booster pump stations.
- Distribution networks should be sub-divided into district metered areas, with correctly sized meters capable of accurately measuring instantaneous and bulk flows (minimum night flows and estimated peak flows).
- Water utilities/providers should ensure that customer revenue meters are installed at all points of sale, including all consumers, municipal and religious buildings. Water utilities/providers shall replace old and inaccurate meters.

Furthermore, the calculation of the Water Balance must be arranged step by step."

2 THE WATER BALANCE

2.1 IMPORTANCE

Effective water loss control leads to benefits for the water utilities implementing NRW measures. From resource management, with its environmental and financial gains, to the direct financial benefits obtained from an improved revenue recovery. These gains are reflected in the activity of water auditing as well, as it helps utilities respond to the obligations they have to customers and the other stakeholders in providing safe water, high quality and reliable services and efficient operation. The Water Balance calculation provides a framework for assessing a water operator's water loss situation and it brings a wide array of benefits. These are described below.

In terms of actual data, auditing reveals the availability of data, its reliability while also improving its accuracy and robustness. By comparing figures, discrepancies may be noted which can indicate inaccuracies or errors in data handling. When discrepancies highlight a leak, by comparing water input and output volumes in the area where the loss might be occurring, the leak can more easily be pinpointed, hence improving the data assessment. Furthermore, calculating the Water Balance allows for validation of consumption data. This may highlight customer meter reading or billing inaccuracies.

An accurate and sound database leads to an increased level of understanding of the distribution and metering system, and the process of auditing aids staff in increasing their knowledge of the systems. Hence, it can lead to faster reaction times and generate ideas for optimization. One of the main outcomes of the Water Balance calculation is the identification of leaks and losses, which raises awareness of the system's problems and supply issues in personnel. This, together with the knowledge of the system will lead to strengthened personnel performance.

Water utilities should use the results of the Water Balance calculations in their long-term planning. The Water Balance data can serve as a pillar in asset management and is necessary for decision-making and guiding improvement and investment measures.

The Water Balance is an essential NRW management tool that leads to the generation of Key Performance Indicators used for benchmarking, performance improvement, and comparison among water operators.

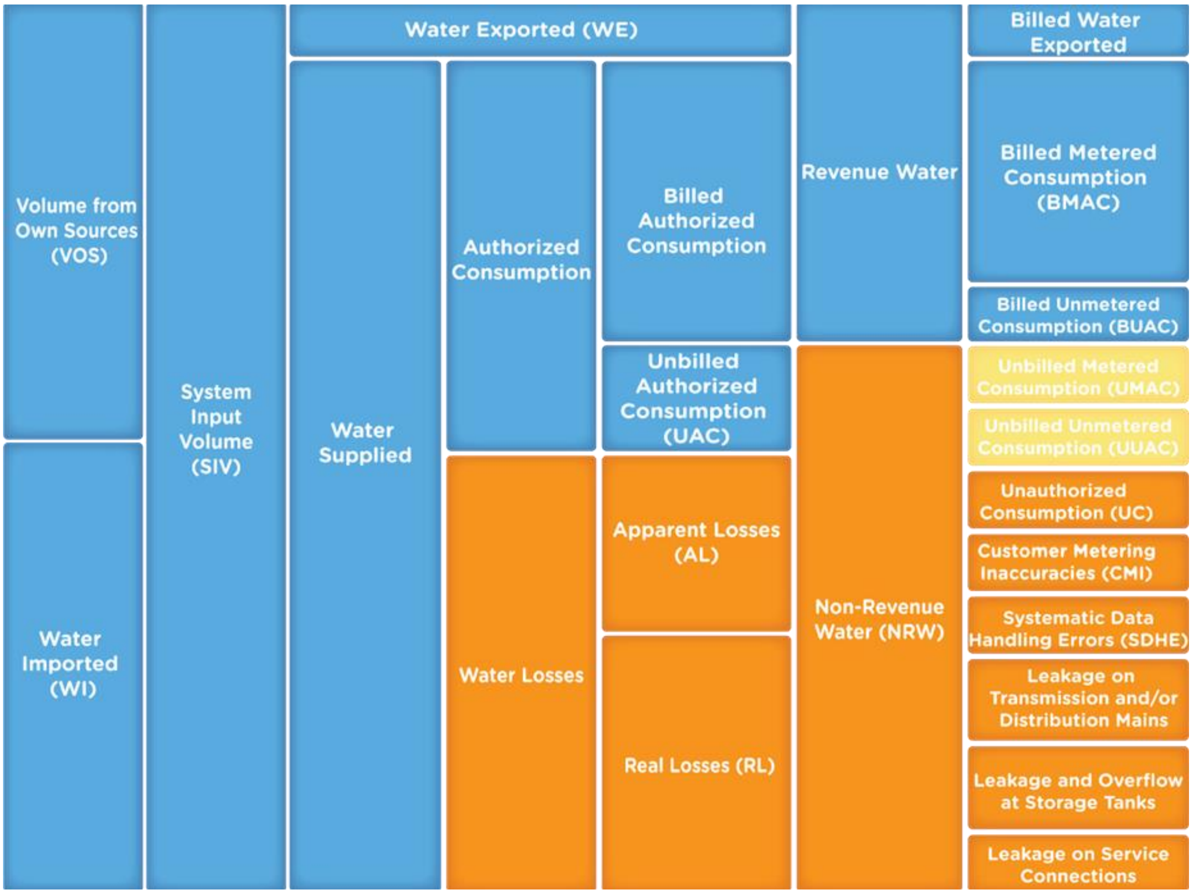
Accurate and detailed information on the water system brings forth transparency and build credibility. But moreover, it can help in complying with reporting requirements and regulatory compliance with different bodies.

2.2 COMPONENTS

The following Figure 1 presents the main components of the standard annual Water Balance, using the IWA/AWWA water audit methodology as a reference. The core information in all NRW reduction programs should be the Water Balance data specific to its distribution system. This information should be based on volume expressed, in thousand or in million m3 per year, since the percentage only plays a role in expressing inaccuracies. The use of latest information is crucial in obtaining accurate results.

Summary data is showing in the balance – it compares the SIV with the volume with sum of customer consumption and losses.

FIGURE 1– STANDARD IWA/AWWA ANNUAL WATER BALANCE.



The process of calculating a Water Balance is an effort of data collection, which indicates the need for guidance with respect to specifying the required information. Developing the water distribution system specific Water Balance for each distinct water distribution network within the service area requires demanding work to gather information and on data analysis and data quality improvements, while using a tool/software to compute the data is an easy task. Essential to the data collection process is the detailed definition of the constituent elements, which directs the efforts throughout the data gathering phase. The next paragraphs will expand on the main components of the Water Balance.

System Input Volume

The system input volume (SIV) is the volume of water input to a transmission system or a distribution system (Lambert & Hirner, 2000). It includes:

- Volume from Own Sources
- The volume of potable water introduced into the distribution system from the drinking water company's own production sites. This volume is measured using designated production meters (Waterbedrijf Groningen, 2017)
- Water Imported
- Water purchased wholesale from another system distributed in your utility’s supply system (Annual Water Audit Compilation). It refers to bulk transfer to your operating border (Lambert & Hirner, 2000)

Revenue Water

The components of System Input Volume that are billed and produce revenue. (American Water Works Association, 2009).

- Billed Water Exported
- Water provided wholesale to another system to be distributed in their utility’s supply system (Annual Water Audit Compilation). It refers to bulk transfers to another utility’s operating borders (Lambert & Hirner, 2000)
- Billed Metered Authorised Consumption
- Refers to standard billed water sales.
- Billed Unmetered Authorised Consumption
- Refers to flat rate customers.

Non-Revenue Water (NRW)

Refers to the difference between the System Input Volume and Billed Authorised Consumption (IWA 2000 Blue Pages). It includes:

- Unbilled Authorised Consumption
- Refers to the unbilled volume that is legitimately consumed, that is either metered or unmetered. This typically includes volumes used for operational purposes. These may be included or not according to local practice.
- Examples may include firefighting, flushing of mains and sewers, street cleaning, watering of municipal gardens, public fountains, frost protection, building water.

- Apparent Losses
- Consists of unauthorized consumption (theft or illegal use), and all types of inaccuracies associated with production metering and customer metering. (Lambert & Hirner, 2000)
- Real Losses
- Refer to physical water losses from the pressurized system, up to the point of customer metering. The volume lost through all types of leaks, bursts and overflows depends on frequencies, flow rates, and average durations of individual leaks. (Lambert & Hirner, 2000)

All calculations of leakage from standard Water Balances are therefore indirect assessments with limits of uncertainly, rather than direct measurements.

3 DATA COLLECTION

3.1 DATA REQUIREMENTS

The following data is necessary input for the Standard IWA/AWWA Annual Water Balance. Table 1 on page 11 presents the required data input for this water balance in tabular form.

3.1.1 QUANTIFICATION OF WATER SUPPLIED

- The Volume of water from Own Sources (VOS).
- The Error Adjustments on the Volume of water from Own Sources (VOSEA).
- The volume of Water Imported from outside sources or purchased from other water utilities (WI).
- The Error Adjustments on the volume of Water Imported (WIEA).
- The volume of Water Exported to outside water utilities or districts (WE).
- The Error Adjustments on the volume of Water Exported (WEEA).

The Error Adjustments should be based on validated inaccuracies of large volume (large diameter) water flow meters.

3.1.2 QUANTIFICATION OF AUTHORISED CONSUMPTION

- The volume of Billed Metered Authorised Consumption (BMAC).
- The volume of Billed Unmetered Authorised Consumption (BUAC).
- The volume of Unbilled Metered Authorised Consumption (UMAC).
- The volume of Unbilled Unmetered Authorised Consumption (UUAC)

3.1.3 QUANTIFICATION OF APPARENT LOSSES

- The volume of Unauthorized Consumption (UC). Either selection of the default value of 0.25 percent of the billed authorised consumption (BMAC + BUAC) or a best estimate based on analysing the most common occurrences of Unauthorized Consumption (i.e., illegal connections, open bypasses, and meter tampering). Refer to **Error! Reference source not found.**.

- The Customer Meter Inaccuracies (CMI), both for residential (small) meters and for industrial and commercial (large) meters, as a composite volume of all customer meter inaccuracies. These CMI should be based on validated inaccuracies of customer water meters.

- The volume related to Systematic Data Handling Errors (SDHE). Either selection of the default value of 0.25 percent of the billed authorised consumption (BMAC + BUAC) or a best estimate based on analysing the subcomponents: i) systematic data transfer errors, ii) systematic data analysis errors, and iii) policy and procedure shortcomings (i.e., related to customer account management). Refer to **Error! Reference source not found.**.

3.1.4 QUANTIFICATION OF SYSTEM DATA

- The Length of Mains in the distribution system (Lm).

- The Number of active and inactive service Connections (Nc). Refer to **Error! Reference source not found.**.

- The location of the customer water meter.

- The average Length of customer service connection Pipe (Lp).

- The Average Operating Pressure in the distribution system that is the subject of the water audit (AOP).

3.1.5 QUANTIFICATION OF COST DATA

- The Total Annual Cost of Operating the water system (TAOC) are an optional input. These costs include those for operations, maintenance, and any annually incurred costs for long-term upkeep of the drinking water supply and drinking water system.

- The Customer Retail Unit Charge (CRUC), representing the charge that customers pay for their water service. In case of a rate structure that includes a variety of costs based on class of customer, a weighted average of individual costs and number of customer accounts in each class should be calculated to determine a single composite cost that should be entered in the water audit.

- The Variable Production Cost (VPC), which depends on the local economic and water resources considerations. We expect that a water utility compiles all these costs and that the data is available. The VPC includes the basic costs to provide the next unit (e.g., thousand m^3) of water, which is typically the costs of treatment and power for pumping the water through the distribution system.

FIGURE 2 – CUSTOMERS VERSUS SERVICE CONNECTIONS.

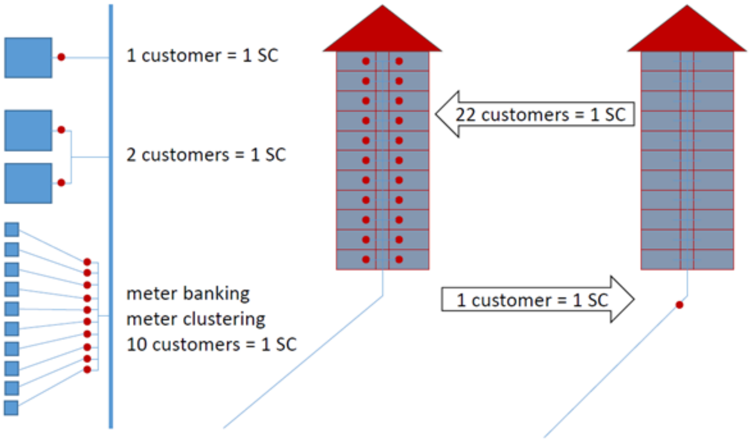
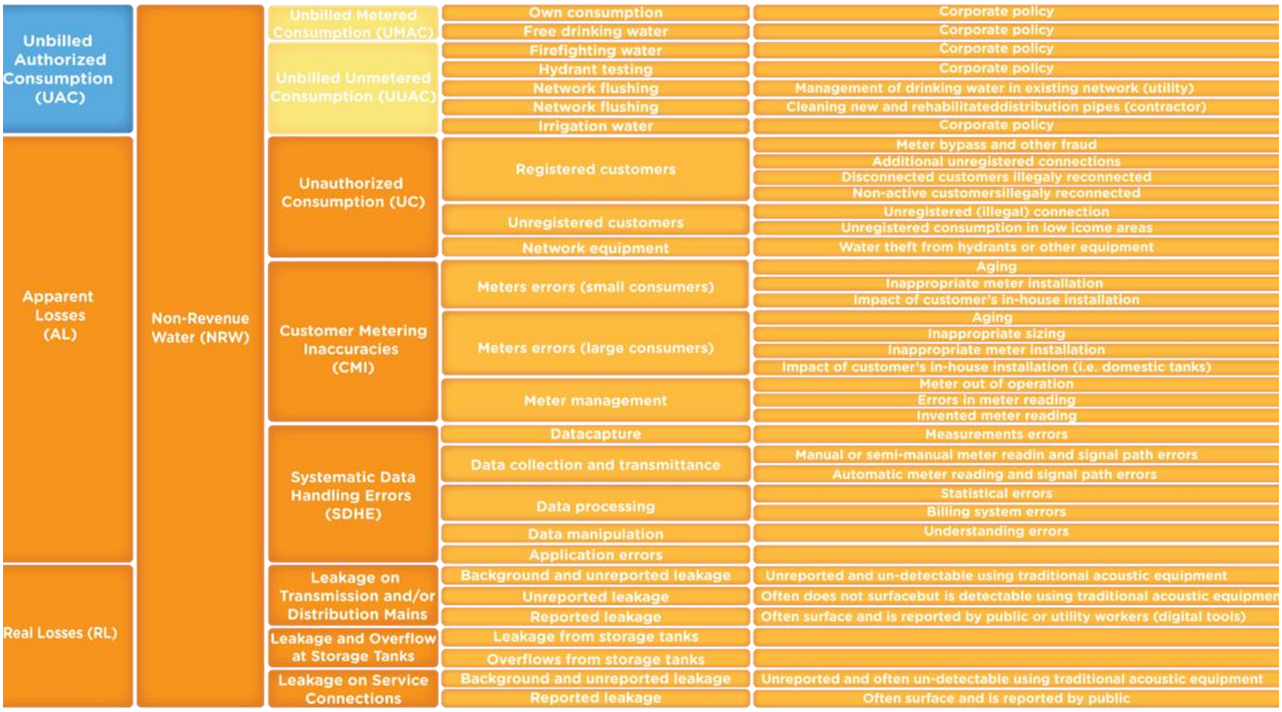


FIGURE 3– NRW COMPONENTS OF THE STANDARD IWA/AWWA ANNUAL WATER BALANCE.



Unbilled Authorized Consumption (UAC)	Non-Revenue Water (NRW)	Unbilled Metered Consumption (UMAC)	Own consumption	Corporate policy
			Free drinking water	Corporate policy
		Unbilled Unmetered Consumption (UUAC)	Firefighting water	Corporate policy
			Hydrant testing	Corporate policy
			Network flushing	Management of drinking water in existing network (utility)
			Network flushing	Cleaning new and rehabilitateddistribution pipes (contractor)
			Irrigation water	Corporate policy
Apparent Losses (AL)		Unauthorized Consumption (UC)	Registered customers	Meter bypass and other fraud
				Additional unregistered connections
				Disconnected customers illegaly reconnected
				Non-active customersillegaly reconnected
			Unregistered customers	Unregistered (illegal) connection
				Unregistered consumption in low icome areas
			Network equipment	Water theft from hydrants or other equipment
		Customer Metering Inaccuracies (CMI)	Meters errors (small consumers)	Aging
				Inappropriate meter installation
				Impact of customer's in-house installation
			Meters errors (large consumers)	Aging
				Inappropriate sizing
				Inappropriate meter installation
				Impact of customer's in-house installation (i.e. domestic tanks)
			Meter management	Meter out of operation
				Errors in meter reading
				Invented meter reading
		Systematic Data Handling Errors (SDHE)	Datacapture	Measurements errors
			Data collection and transmittance	Manual or semi-manual meter readin and signal path errors
				Automatic meter reading and signal path errors
			Data processing	Statistical errors
				Billing system errors
			Data manipulation	Understanding errors
			Application errors	
Real Losses (RL)		Leakage on Transmission and/or Distribution Mains	Background and unreported leakage	Unreported and un-detectable using traditional acoustic equipment
			Unreported leakage	Often does not surfacebut is detectable using traditional acoustic equipmen
			Reported leakage	Often surface and is reported by public or utility workers (digital tools)
		Leakage and Overflow at Storage Tanks	Leakage from storage tanks	
			Overflows from storage tanks	
		Leakage on Service Connections	Background and unreported leakage	Unreported and often un-detectable using traditional acoustic equipment
			Reported leakage	Often surface and is reported by public

3.2 DATA SOURCES AND ACQUISITION

Developing the Standard Annual Water Balance with a top-down approach is the recommended starting point to water utilities conducting their initial water audit. It is the initial desktop process of gathering information from existing records, procedures, data, and other information systems. It serves as a preliminary assessment, with a lower level of effort, which leads to a rough estimation of the losses and an overall understanding of the problem in monetary terms. it gives an insight into data quality and requisite improvements for fine-tuning. This stage requires two steps:

1. Quantification of consumption and loss components.
2. Water Balance calculation.

Leakage component analysis represents another auditing level, which can be applied to both real and apparent losses. But typically, it involves modelling of leakage volumes based on two factors: nature and duration of the leak.

The bottom-up approach involves a validation of the results obtained in the top-down analysis, with actual field measurements such as leakage losses calculated from integrated zonal, or district metered area (DMA) night flows. It includes physical inspections of customer properties and process flowcharting of customer billing systems (Ann water audit compilation)

3.2.1 PROTOCOL / STEPS IN THE TOP-DOWN WB CALCULATION

The Water Balance undertaking gives insights into the water supply's system problem, their location, nature (e.g., leakage or unauthorized consumption) and aids in the financial estimation of the losses. Furthermore, it can shed light into the losses generated by metering inaccuracies or data handling errors.

The approach to auditing described in this SOP relates to the IWA/AWWA auditing method and it focuses on the methodology of the top-down approach, which is described in detail below.

As overall principle, SIV has three final destinations:

- ➔ Water exported.
- ➔ Authorized consumption.
- ➔ Water losses (apparent and real losses).

3.2.1.1 Before starting the audit:

1. Identify system boundaries:
- ➔ Clarity must be provided in the assessment on where water enters and leaves the system.
- ➔ The process can be performed for sectors of the systems or for the entire distribution system.
2. Establish a time-frame:
- ➔ The water audit portrays the utility's situation in each time frame. The study period recommended by the AWWA is 12 months, for several reasons: to account for seasonal variation, account for lagged results from meter readings and to ensure record availability as records are archived over a calendar or fiscal year.
3. Establish measurement units:
- ➔ If your utility uses multiple units, ensure only one unit is used in the Water Balance calculations, for both supply and consumption volumes.
4. Gather data:
- ➔ Collect and assemble the available data into the water audit worksheet. All volumes need to be accounted for, regardless of their accuracy.
- ➔ Data is required on different levels, refer to section 3 for the prerequisite information to be collected.
- ➔ Tap into software information if your system makes use of SCADA or GIS.

3.2.1.2 The audit

0. Distribution system characteristics:
    - o Infrastructure data.
    - o Financial data:
        - ▪ Total costs for operating the water supply system.

        - Charged price to customers.
    - Operational data:
        - Does it operate throughout the entire year?
        - Is it always pressurized?

1. Determine Water Supplied:
    - Volume from Own Sources + Water Imported – Water Exported
    - Accuracy of large volume flow meters determines accuracy of Water Supplied
        1. Adjustments for metering inaccuracies.
        2. Adjustments for reservoir/storage level changes.
        3. Adjustments accounting for losses occurring before the distribution system.
2. Determine and/or estimate Authorized Consumption:
    - Billed Metered + Billed Unmetered + Unbilled Metered + Unbilled Unmetered

- Billed Consumption: ideally 12 months billing data (metered and unmetered).
- Get records of Unbilled Metered Consumption.
- Use realistic estimate for Customer Metering Inaccuracies or known meter under-registration.
- It is recommended to measure customer consumption using digital or analogue billing records. Consumption patterns are determined based on the customer type or use category. The total consumption for all customers and types of authorized connections must be then calculated for the entire study period.
- If metering is in place, the next step is to correct the volume, accounting for the possible lag time in meter reading.
- If no metering is in place, the consumption volumes need to be estimated by for instance, temporary metering of sampled groups for the different use categories and connection size. In any estimation a degree of error needs to be considered. The approach to the estimation must be documented for each audit.

3. Determine and/or estimate Apparent Losses:
    - Unauthorized Consumption + Customer Metering Inaccuracies + Systematic Data Handling Errors

- Use realistic estimate for:
    - Unbilled Unmetered Consumption, default %?
    - Unauthorized Consumption, default %?
    - Systematic Data Handling Errors, default %?

4. Calculate Real Losses
    - Water Supplied – Authorized Consumption – Apparent Losses
    - Accuracy depends on accuracy Water Supplied and Apparent Losses
5. Calculate Non-Revenue Water
    - Unbilled Authorized Consumption + Apparent Losses + Real Losses

- In the top-down approach, to accurately determine NRW, the calculation considers the remainder volume of water in the system after deducting the Billed Authorized Consumption.

"The use of confidence limits in Water Balance calculations provides valuable insights into the reliability of the calculated components of NRW, and the priorities for action for improving the reliability of these calculations. Problems occur when %s of System Input Volume are used as a technical performance indicator for Non-Revenue Water or its components."

4 EXAMPLE CASE STUDY DMA HALMAT (EGYPT)

An excellent case study has been provided by the WES Partner Country Egypt. This case study provides the necessary data for:

Calculating the Annual Standard Water Balance.

Calculating the relevant Key Performance Indicators (KPIs) for Non-Revenue Water (NRW) reduction. The SOP Selecting relevant KPIs and Target Setting provides guidance on the selection of appropriate and relevant KPIs, and how to calculate them.

Table 1 presents the required data input for the Standard Annual Water Balance in tabular form. This table is filled with data for the Egyptian District Metered Area (DMA) Halmat for the three consecutive years 2020, 2021 and 2022. All volumes are expressed in m^3/year. Figure 4 presents the water balance for year 2020. Figure 5 presents the water balance for year 2021, and Figure 6 for year 2022.

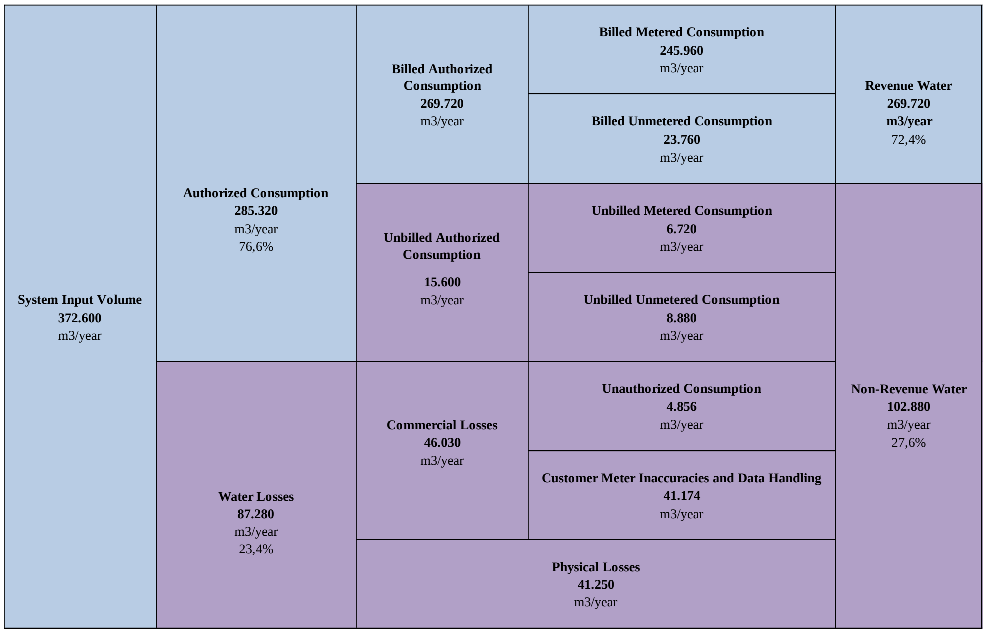
TABLE 1 – TABULAR FORM FOR REQUIRED DATA INPUT AND DATA FROM DMA HALMAT FOR A THREE-YEAR PERIOD (2020-2022).

Code	Description	Unit	2020	2021	2022
	Number of days	-	366	365	365
VOS	Volume from Own Sources	m^3	372 600	379 000	386 500
VOSEA	Error Adjustments on VOS	%	5	4.5	4.5
WI	Water Imported	m^3	0	0	0
WIEA	Error Adjustments on WI	%	0	0	0
WE	Water Exported	m^3	0	0	0
WEEA	Error Adjustments on WE	%	0	0	0
BMAC	Billed Metered Authorised Cons.	m^3	245 960	264 460	285 460
BUAC	Billed Unmetered Authorised Cons.	m^3	23 760	20 250	18 400
UMAC	Unbilled Metered Authorised Cons.	m^3	6720	6120	5845
UUAC	Unbilled Unmetered Auth. Cons.	m^3	8 880	7 840	6 980
UC	Unauthorised Consumption	m^3	4 856	3 450	2 588
CMI	Customer Metering Inaccuracies	%	12	11	10.5
SDHE	Systematic Data Handling Errors	%	7.8	7	6.5
Lm	Length of mains	km	15	15.4	16.3
Nc	Number of service connections	-	1 690	1 750	1 863
Lp	Length of customer service pipe	m	6.5	6.5	6.5

Code	Description	Unit	2020	2021	2022
AOP	Average Operating Pressure	bar	1.8	1.9	1.88
CRUC	Customer Retail Unit Charge [1]	EGP/m³	1.8	2.1	2.4
VPC	Variable Production Cost [1]	EGP/m³	1.2	1.63	1.9

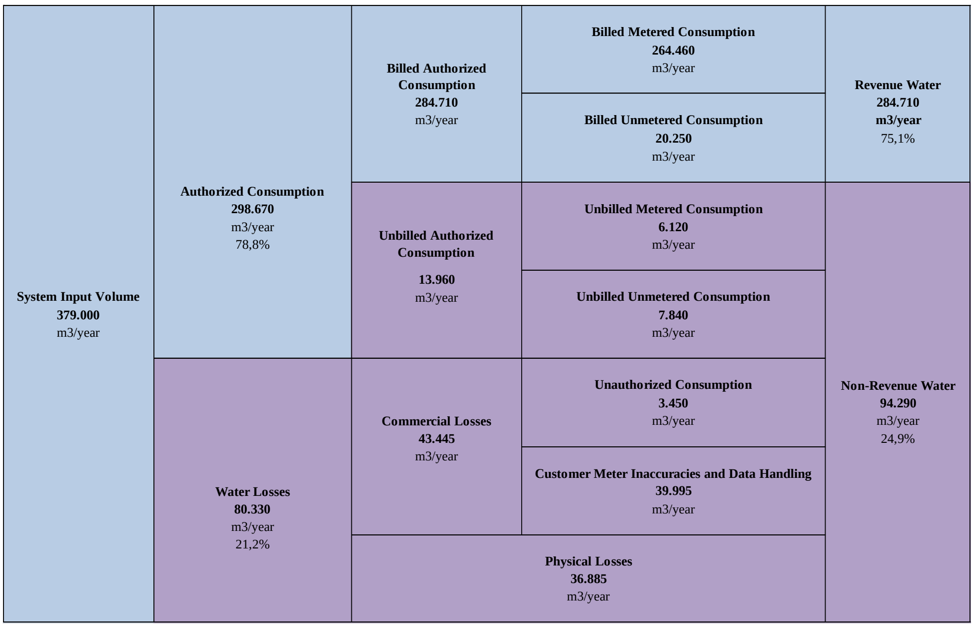
[1] The Egyptian Pound (EGP) has been used for this case study.

FIGURE 4 – STANDARD ANNUAL WATER BALANCE FOR DMA HALMAT IN EGYPT FOR YEAR 2020 (DATA FROM TABLE 1).



System Input Volume **372.600** m3/year	**Authorized Consumption** **285.320** m3/year 76,6%	**Billed Authorized Consumption** **269.720** m3/year	**Billed Metered Consumption** **245.960** m3/year	**Revenue Water** **269.720** **m3/year** 72,4%
			Billed Unmetered Consumption **23.760** m3/year	
		Unbilled Authorized Consumption **15.600** m3/year	**Unbilled Metered Consumption** **6.720** m3/year	**Non-Revenue Water** **102.880** m3/year 27,6%
			Unbilled Unmetered Consumption **8.880** m3/year	
	Water Losses **87.280** m3/year 23,4%	**Commercial Losses** **46.030** m3/year	**Unauthorized Consumption** **4.856** m3/year	
			Customer Meter Inaccuracies and Data Handling **41.174** m3/year	
		Physical Losses **41.250** m3/year		

FIGURE 5 - STANDARD ANNUAL WATER BALANCE FOR DMA HALMAT IN EGYPT FOR YEAR 2021 (DATA FROM TABLE 1).



System Input Volume **379.000** m3/year	**Authorized Consumption** **298.670** m3/year 78,8%	**Billed Authorized Consumption** **284.710** m3/year	**Billed Metered Consumption** **264.460** m3/year	**Revenue Water** **284.710** **m3/year** 75,1%
			Billed Unmetered Consumption **20.250** m3/year	
		Unbilled Authorized Consumption **13.960** m3/year	**Unbilled Metered Consumption** **6.120** m3/year	**Non-Revenue Water** **94.290** m3/year 24,9%
			Unbilled Unmetered Consumption **7.840** m3/year	
	Water Losses **80.330** m3/year 21,2%	**Commercial Losses** **43.445** m3/year	**Unauthorized Consumption** **3.450** m3/year	
			Customer Meter Inaccuracies and Data Handling **39.995** m3/year	
		Physical Losses **36.885** m3/year		

FIGURE 6 - STANDARD ANNUAL WATER BALANCE FOR DMA HALMAT IN EGYPT FOR YEAR 2022 (DATA FROM TABLE 1).

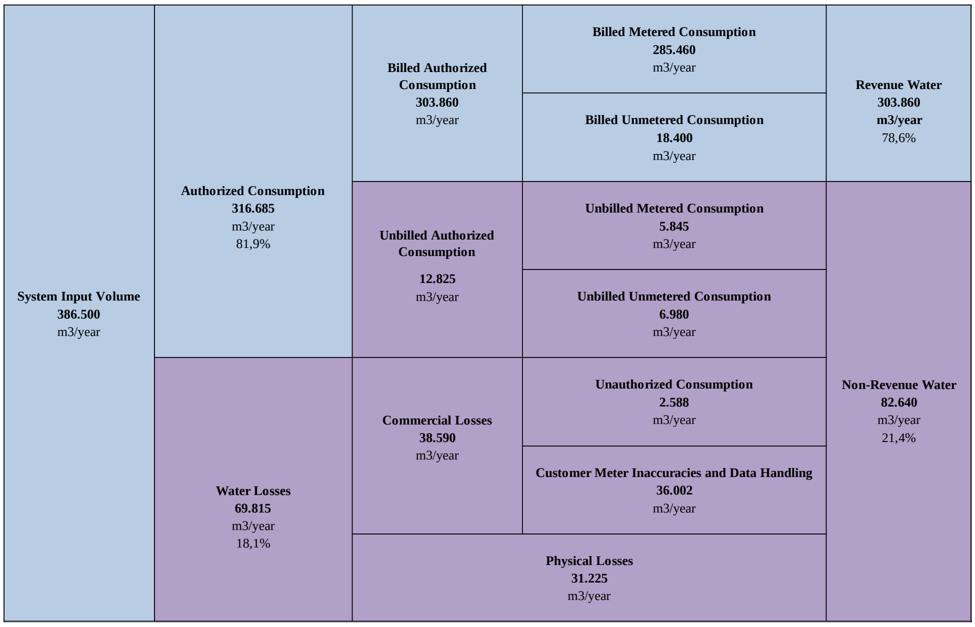


Table 2 presents the volume of NRW and other relevant volumes for the DMA Halmat over the three-year period 2020-2022.

TABLE 2 – NON-REVENUE WATER AND RELEVANT VOLUMES DMA HALMAT (EGYPT) THREE-YEAR PERIOD 2020-2022.

Relevant indicator	2020	2021	2022
Non-Revenue Water (m^3/year)	102.880	94.290	82.640
Unbilled Authorised Consumption (m^3/year)	15.600	13.960	12.825
Water Losses (m^3/year)	87.280	80.330	69.815
Apparent (or: commercial) Losses (m^3/year)	46.030	43.445	38.590
Real (or: physical) Losses (m^3/year)	41.250	36.885	31.225

Two initial observations:

All specified volumes are decreasing year by year. E.g., NRW in 2021 is lower than in 2020, and NRW in 2022 is lower than in 2021. We learn from Table 1 that the water distribution system in this DMA Halmat is increasing, indicated by an increase of length of mains and number of service connections. *The NRW reduction performance of the water utility staff operating this DMA is excellent*.

The apparent losses volume is higher than the real losses volume in each of the three years. The apparent losses volume is predominantly Customer Metering Inaccuracies (CMI) and Systematic Data Handling Errors (SDHE), and only to a lesser extent Unauthorised Consumption. If this continues to be the case in 2023, the *recommendation is to develop a strategy for reducing both CMI and SDHE in the coming years*.

5 APPENDIX 1

5.1 KEY DEFINITIONS

Authorized consumption

= billed wholesale supply + billed metered consumption + billed unmetered consumption + unbilled metered consumption + unbilled unmetered consumption.

The volume of metered and/or unmetered drinking water delivered to registered, connected customers, including the utility's own water usage (e.g., flushing) and water consumption by third parties for which the water utility has provided implicit or explicit permission (e.g., firefighting). This includes drinking water for residential, small business, and industrial use.

Average length of customer service pipe

Often referred to as the house connection, from the distribution pipeline to the water meter. The total length of underground service pipes is one of the variables in the formula for calculating UARL.

Average operating pressure

The average pressure in the distribution system for which the Water Balance is being prepared.

Customer Metering Inaccuracy

All water meters wear out over time due to the volume of drinking water passing through them. Typically, the wear and tear of water meters result in the under-registration of the volume of drinking water passing through them.

In addition to under-registration due to worn-out water meters, there is also under-registration due to improperly sized water meters or the installation of the wrong type of water meter for the specific consumption pattern. If a commercial connection is made with an excessive delivery capacity, there is a risk that a low flow rate of drinking water will not be measured or will only be partially measured. Large-volume water meters, as they are known, also wear out over time.

Customer retail unit cost

The drinking water rate charged to customers. This is a weighted average drinking water rate per m^3 that includes both the water price, fixed charges (capacity fee), taxes, and any billing costs. Any collection costs and the costs associated with making or modifying (new) connections should not be included in the drinking water rate. The drinking water rate varies by customer segment (residential, small business, and large business consumption) and delivery capacity.

Customer variable production cost

The variable costs for the production and distribution of drinking water, in €/m^3, for each additional m^3 of drinking water that can be produced without requiring an extra new investment. These are the drinking water operational costs per delivered m^3. These costs include taxes, depreciation, and operational costs (electricity and chemical usage, auxiliary and waste materials, checks, research, and analysis costs). Any wholesale purchases also fall under the drinking water operational costs per m^3.

Infrastructure Leakage Index (ILI)

The ratio of the current Annual Real Losses (CARL) to the Unavoidable Annual Real Losses (UARL). ILI is the sole performance indicator for comparing the technical performance of water utilities in the operational management of real leakage losses.

Length of mains

The total length of all transmission and distribution pipelines in the distribution system, starting from the production meter(s) at the production location(s).

Number of service connections

The total count of active and inactive connections includes connections to the distribution pipeline through which drinking water can be supplied to customers. It encompasses all connections, including those for firefighting supply. The total number of active and inactive connections is most times greater than the number of customers.

Service Connection Density

= total number of connections / total length of all transmission and distribution pipelines in the distribution system.

Service connection density is a critical parameter in selecting the appropriate performance indicator.

Total annual cost of operating water system

Total annual costs for the operation, management, maintenance, and preservation of the entire production and distribution system of the water utility. Replacement investments and depreciation costs are part of the total annual operational costs. Other examples include personnel costs, materials, equipment, insurance, fees, administrative costs. These encompass all daily expenses and the costs for the sustainable maintenance of the entire drinking water system for the long term.

Unavoidable Annual Real Losses

The volume of Unavoidable Annual Real Losses represents the best estimate of the technically achievable lowest actual leakage from a pressurized distribution system. It serves as a reference value for the "lowest possible actual leakage" of a distribution system, with relevant system-specific parameters being determining factors. The reference value assumes a well-maintained and well-operated distribution system, in good technical condition at the current average pressure.

Water Abstracted

The volume of water obtained for input to raw water mains leading to water treatment plants.

Water Produced or Supplied

The volume of water treated for input to water transmission mains or directly to the distribution system.

Water Losses

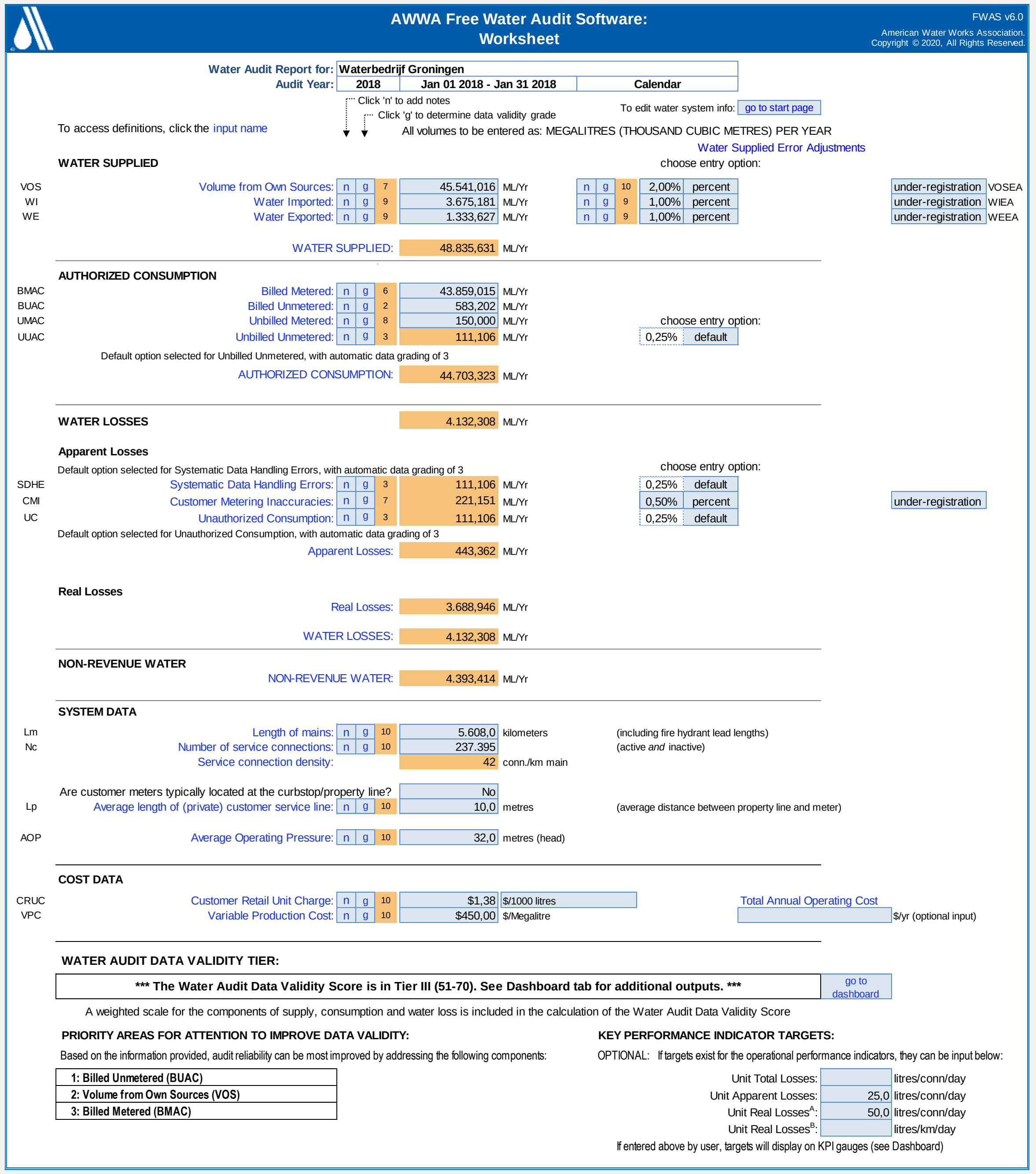
Water losses, refers to the volume which remains after all the components of consumption (metered and unmetered) have been deducted from the volume entering the water distribution system (the System Input Volume). Water losses include both apparent losses and real losses.

6 APPENDIX 2

6.1 AVAILABLE SOFTWARE

AWWA Free Water Audit (FWAS)

Available on the American Water Works Association's website under "Resources & Tools" or by searching for the key term "Water Loss Control". The FWAS is documented in the AWWA Manual of Water Supply Practices M36 *Water Audits and Loss Control Programs* (© AWWA, 2016).



AWWA Free Water Audit Software: Worksheet

FWAS v6.0
American Water Works Association.
Copyright © 2020, All Rights Reserved.

Water Audit Report for: Waterbedrijf Groningen
Audit Year: 2018 | Jan 01 2018 - Jan 31 2018 | Calendar

Click 'n' to add notes
Click 'g' to determine data validity grade
To edit water system info: go to start page
To access definitions, click the input name
All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED

Water Supplied Error Adjustments
choose entry option:

VOS	Volume from Own Sources:	n	g	7	45.541,016	ML/Yr	n	g	10	2,00%	percent	under-registration	VOSEA
WI	Water Imported:	n	g	9	3.675,181	ML/Yr	n	g	9	1,00%	percent	under-registration	WIEA
WE	Water Exported:	n	g	9	1.333,627	ML/Yr	n	g	9	1,00%	percent	under-registration	WEEA

WATER SUPPLIED: 48.835,631 ML/Yr

AUTHORIZED CONSUMPTION

BMAC	Billed Metered:	n	g	6	43.859,015	ML/Yr		
BUAC	Billed Unmetered:	n	g	2	583,202	ML/Yr		
UMAC	Unbilled Metered:	n	g	8	150,000	ML/Yr	choose entry option:	
UUAC	Unbilled Unmetered:	n	g	3	111,106	ML/Yr	0,25%	default

Default option selected for Unbilled Unmetered, with automatic data grading of 3

AUTHORIZED CONSUMPTION: 44.703,323 ML/Yr

WATER LOSSES 4.132,308 ML/Yr

Apparent Losses

choose entry option:

Default option selected for Systematic Data Handling Errors, with automatic data grading of 3

SDHE	Systematic Data Handling Errors:	n	g	3	111,106	ML/Yr	0,25%	default	
CMI	Customer Metering Inaccuracies:	n	g	7	221,151	ML/Yr	0,50%	percent	under-registration
UC	Unauthorized Consumption:	n	g	3	111,106	ML/Yr	0,25%	default	

Default option selected for Unauthorized Consumption, with automatic data grading of 3

Apparent Losses: 443,362 ML/Yr

Real Losses

Real Losses: 3.688,946 ML/Yr

WATER LOSSES: 4.132,308 ML/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 4.393,414 ML/Yr

SYSTEM DATA

Lm	Length of mains:	n	g	10	5.608,0	kilometers	(including fire hydrant lead lengths)
Nc	Number of service connections:	n	g	10	237.395		(active *and* inactive)
	Service connection density:				42	conn./km main	
	Are customer meters typically located at the curbstop/property line?				No		
Lp	Average length of (private) customer service line:	n	g	10	10,0	metres	(average distance between property line and meter)
AOP	Average Operating Pressure:	n	g	10	32,0	metres (head)	

COST DATA

CRUC	Customer Retail Unit Charge:	n	g	10	$1,38	$/1000 litres	Total Annual Operating Cost
VPC	Variable Production Cost:	n	g	10	$450,00	$/Megalitre	$/yr (optional input)

WATER AUDIT DATA VALIDITY TIER:

***** The Water Audit Data Validity Score is in Tier III (51-70). See Dashboard tab for additional outputs. ***** go to dashboard

A weighted scale for the components of supply, consumption and water loss is included in the calculation of the Water Audit Data Validity Score

PRIORITY AREAS FOR ATTENTION TO IMPROVE DATA VALIDITY:

Based on the information provided, audit reliability can be most improved by addressing the following components:

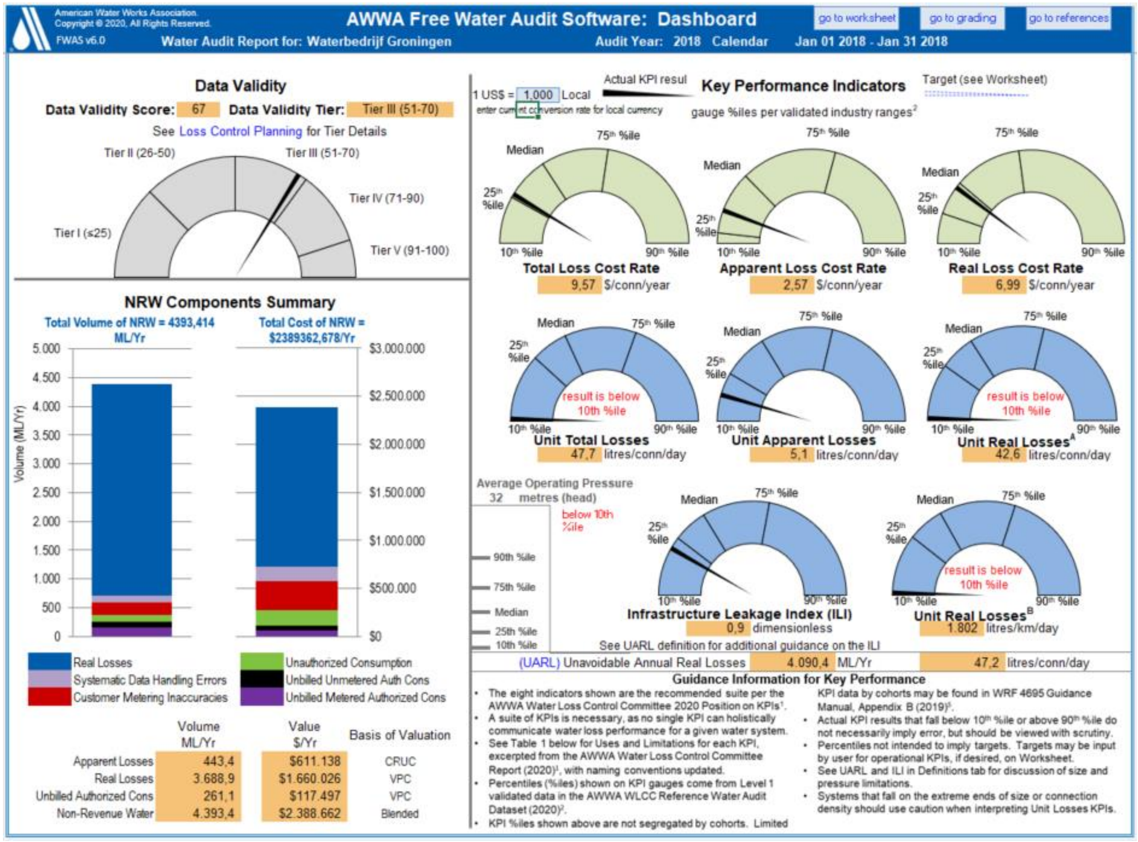
1: Billed Unmetered (BUAC)
2: Volume from Own Sources (VOS)
3: Billed Metered (BMAC)

KEY PERFORMANCE INDICATOR TARGETS:

OPTIONAL: If targets exist for the operational performance indicators, they can be input below:

Unit Total Losses:		litres/conn/day
Unit Apparent Losses:	25,0	litres/conn/day
Unit Real Losses^A:	50,0	litres/conn/day
Unit Real Losses^B:		litres/km/day

If entered above by user, targets will display on KPI gauges (see Dashboard)



AWWA Free Water Audit Software: Dashboard

Water Audit Report for: Waterbedrijf Groningen

Audit Year: 2018 Calendar Jan 01 2018 - Jan 31 2018

Data Validity Score: 67 Data Validity Tier: Tier III (51-70)

Total Volume of NRW = 4393,414 ML/Yr

Total Cost of NRW = $2389362,678/Yr

1 US$ = 1,000 Local

	Volume ML/Yr	Value $/Yr	Basis of Valuation
Apparent Losses	443,4	$611.138	CRUC
Real Losses	3.688,9	$1.660.026	VPC
Unbilled Authorized Cons	261,1	$117.497	VPC
Non-Revenue Water	4.393,4	$2.388.662	Blended

Total Loss Cost Rate	9,57	$/conn/year
Apparent Loss Cost Rate	2,57	$/conn/year
Real Loss Cost Rate	6,99	$/conn/year
Unit Total Losses	47,7	litres/conn/day
Unit Apparent Losses	5,1	litres/conn/day
Unit Real Losses^A	42,6	litres/conn/day
Infrastructure Leakage Index (ILI)	0,9	dimensionless
Unit Real Losses^B	1.802	litres/km/day
(UARL) Unavoidable Annual Real Losses	4.090,4	ML/Yr
	47,2	litres/conn/day

Average Operating Pressure 32 metres (head)

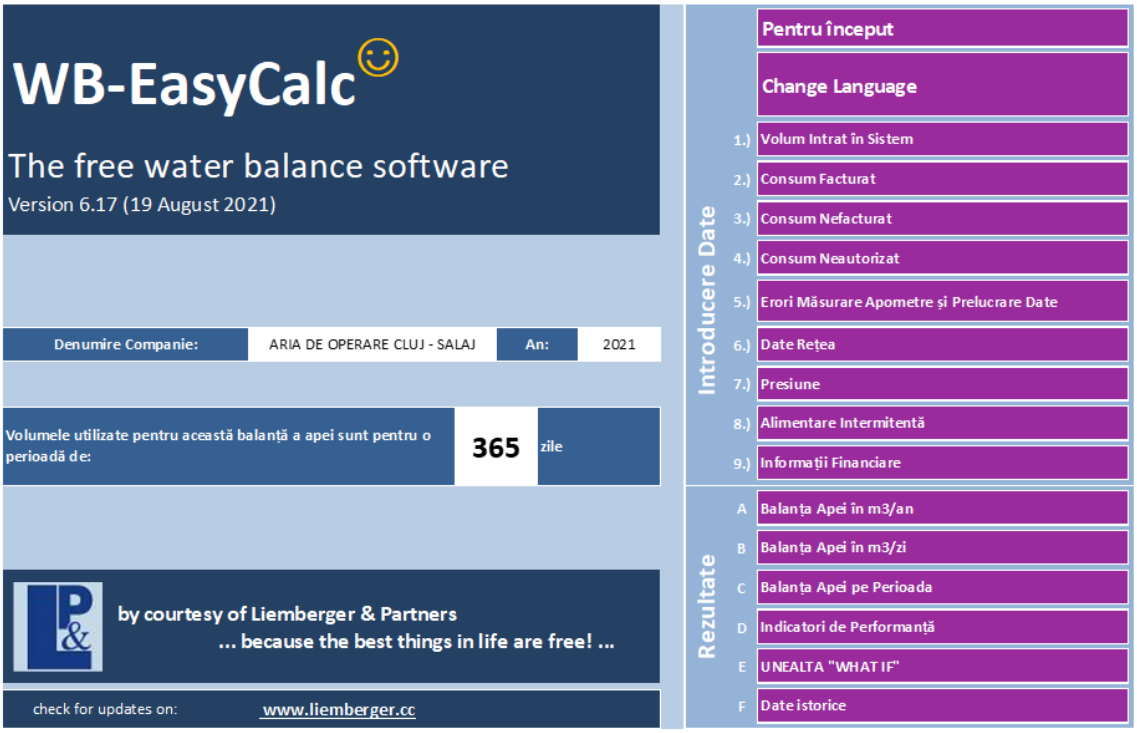
See UARL definition for additional guidance on the ILI

Guidance Information for Key Performance

- The eight indicators shown are the recommended suite per the AWWA Water Loss Control Committee 2020 Position on KPIs¹.
- A suite of KPIs is necessary, as no single KPI can holistically communicate water loss performance for a given water system.
- See Table 1 below for Uses and Limitations for each KPI, excerpted from the AWWA Water Loss Control Committee Report (2020)¹, with naming conventions updated.
- Percentiles (%iles) shown on KPI gauges come from Level 1 validated data in the AWWA WLCC Reference Water Audit Dataset (2020)².
- KPI %iles shown above are not segregated by cohorts. Limited KPI data by cohorts may be found in WRF 4695 Guidance Manual, Appendix B (2019)³.
- Actual KPI results that fall below 10th %ile or above 90th %ile do not necessarily imply error, but should be viewed with scrutiny.
- Percentiles not intended to imply targets. Targets may be input by user for operational KPIs, if desired, on Worksheet.
- See UARL and ILI in Definitions tab for discussion of size and pressure limitations.
- Systems that fall on the extreme ends of size or connection density should use caution when interpreting Unit Losses KPIs.

[Free Water Balance Software (WB-EasyCalc®)](https://wb.easycalc.cc/)

WB-EasyCalc® is available for offline use on any device, both on mobile phone (application) and computer (browser-based). It is currently available at: https://wb.easycalc.cc/. The structure of the calculations is anchored in the IWA Water Loss Specialist Group Methodology



WB-EasyCalc

The free water balance software

Version 6.17 (19 August 2021)

Denumire Companie: ARIA DE OPERARE CLUJ - SALAJ An: 2021

Volumele utilizate pentru această balanță a apei sunt pentru o perioadă de: 365 zile

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