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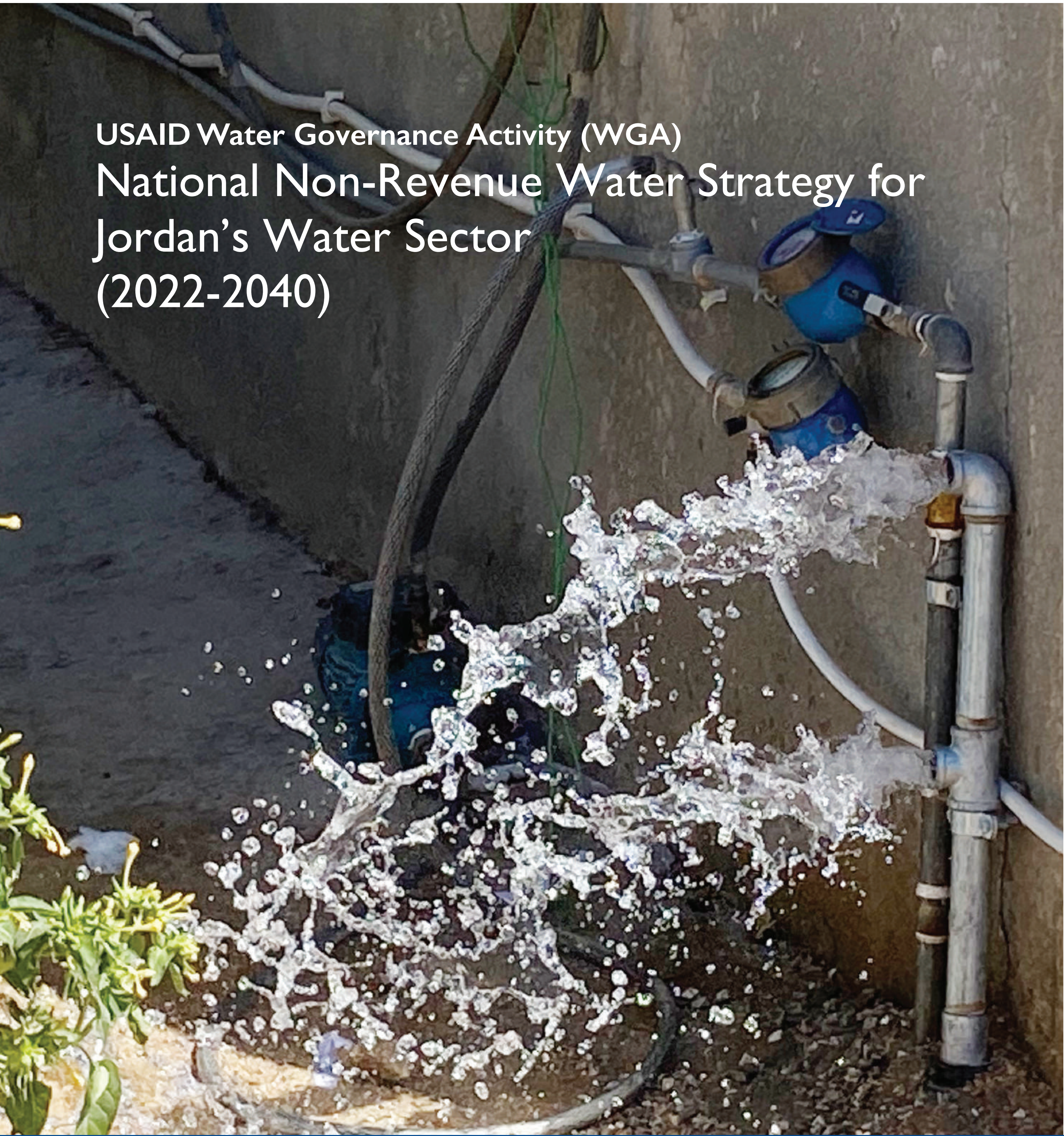

USAID Water Governance Activity (WGA)

National Non-Revenue Water Strategy for Jordan's Water Sector (2022-2040)

May 2022

This publication is made possible by the support of the American People through the United States Agency for International Development (USAID). The contents of this strategy are the sole responsibility of Chemonics International Inc. and do not necessarily reflect the views of USAID or the United States Government.

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Acronyms and Abbreviations

AAWDCP	Amman-Aqaba Water Desalination and Conveyance Project
AW	Aqaba Water
BOT	Build Operate Transfer
CBA	Cost Benefit Analysis
CIS	Customer Information System
COP	Chief of Party
COR	Contract Officer Representative
CP	Condition Precedent
CRM	Customer Relation Management
FARA	Fixed Amount Reimbursable Agreement
FY	Fiscal Year
IWA	International Water Association
IWS	Intermittent Water Supply
GIS	Geographic Information System
GOJ	Government of Jordan
KPI	Key Performance Indicator
MESC II	Management Engineering Services Contract II
MNF	Minimum-Night-Flow
MWI	Ministry of Water and Irrigation
NA	Not Applicable
NRW	Non-Revenue Water
NWS	National Water Strategy
O&M	Operations and Maintenance
RBAP	Result-Based Action Plan
SCADA	Supervisory Control and Data Acquisition System
SIV	System Input Volume
SG	Secretary General
SOW	Scope of Work
USAID	United States Agency for International Development
UPMU	Utilities Program Management Unit
WAJ	Water Authority of Jordan
WGA	Water Governance Activity
WMI	Water Management Initiative project
YWC	Yarmouk Water Company

EXECUTIVE SUMMARY

Non-Revenue Water (NRW) represents the main water supply constraint and fiscal drag on Jordan's water sector, which is crimping Jordan's economy and leading to massive debts. While fully accurate measurements aren't available, direct financial losses are reliably estimated in the hundreds of millions of dinars per year. The high level of NRW contributes greatly to the ongoing unsustainable depletion of Jordan's water and financial resources.

Jordan's water sector has a top priority goal to reduce NRW from its current level of around 50% nationally to 25% of water supplied to urban systems by 2040. The investment needed to reach this objective is at least JD 1.3 billion over the next 10 years, and around JD 60 million per year is needed to sustain the NRW results. It is essential that NRW be greatly reduced to address both existing supply and financial needs, and to prepare for the significant water supply expansion needed. Without these NRW reductions, as history has demonstrated, pumping more water into Jordan's defective systems results in much of that water also being "lost" as non-revenue. Simultaneously, Jordan's water utilities need to greatly improve their own NRW control activities to optimize and sustain the anticipated gains from ongoing and future investment. Done well, the additional cost will be repaid many times over.

Major challenges to reducing NRW include a number of factors: poor infrastructure condition, lack of preventative asset maintenance, insufficient utility resource allocation to NRW control, the prevalence of intermittent supply (damaging water system assets and reducing the effectiveness of some NRW reduction techniques), too high/variable water pressure, redundant pipes not disconnected, lack of systematic leak detection, the poor quality of water metering and inadequate attention to illegal water use.

This document presents a National NRW Reduction Strategy which is a comprehensive summary of the interconnected efforts and investments required to achieve national NRW reduction goals. It presents an overview of the ongoing activities and approved strategies, based particularly on the MWI-approved Strategic Master Plan for NRW Reduction and the Water Infrastructure Master Plan, required to achieve kingdom-wide NRW reduction targets. This strategy covers management, infrastructure, and operational investments and actions. The strategy's objective is to reduce NRW in Jordan to an appropriate level considering the arid climate, decline in surface and groundwater supplies and financial burden associated with Jordan's current NRW level.

This Strategy, which will be part of the National Water Strategy 2022-2040, includes four key pillars:

1. ***Institutional Capacity***. A capable and well-equipped water utility is needed to reduce NRW and sustain the lower NRW level.
2. ***Measurement, monitoring and controlling***. NRW reduction is not possible without accurate measurement of water supply, transmission and distribution. Effective monitoring and controlling enables utilities to prioritize NRW reduction actions and take corrective actions.
3. ***Commercial losses***. Improving metering and billing accuracy and reducing illegal use is fundamental to NRW reduction. These actions are potentially faster and require less investment than reducing physical water losses. Remedies should be strongly influenced by cost/benefit analyses since this loss is mainly financial, not of the water supply.
4. ***Physical losses.*** Minimizing leakage is fundamental to NRW reduction. These actions need a longer timeframe and larger investment than reducing commercial losses but are even more important as this is loss of both water and money—and there is no substitute for water.

The strategy section below provides estimated costs for capital, maintenance and operation which are extracted from the Strategic Master Plan for NRW Reduction and are considered preliminary. These cost estimates should be reviewed based on the actual results of NRW reduction actions and investments on current projects. The timing and details of these costs and related actions will be confirmed with each utility as part of developing their respective NRW implementation plans.

1 INTRODUCTION

1.1 Background

Non-Revenue Water (NRW), which is the difference between the water supplied and the water that is paid for, is one of the most critical challenges facing water utilities in Jordan. Particularly for a country faced with extreme water scarcity, the NRW level is far too high at around 50%. There have been some improvements in specific areas but also challenges that have kept the reduction in NRW too small. Jordan's National Water Strategy 2016-2025 set a goal to reduce NRW to 30% by 2025 (MWI, 2016). The Ministry of Water and Irrigation (MWI) is currently updating the National Water Strategy to cover the period 2022-2040 with the target to reduce NRW to 25% or below by 2040 and to sustain it.

Jordan's high NRW level is one of the major issues affecting municipal water supply. Intermittent Water Supply (IWS) increases the difficulty of reducing NRW and sustaining reduced NRW levels after upgrade projects are carried out. In addition, there are many interrelated factors that contribute to the current high NRW levels. Therefore, there is a need to address NRW with a comprehensive approach to tackle not only the root causes of high NRW but also the sufficiency and continuity of water supply. Interventions and investments must include upgrades to defective assets, improved operational practices (such as water network management), improved customer relationship management, and enhanced staff capacity to tackle all of these issues.

Several programs, plans, and initiatives over the past several years have been developed or carried out to address NRW in Jordan. These include the Strategic Master Plan for NRW Reduction (USAID WMI, 2021), the National Water Infrastructure Master Plan (USAID WMI, 2021), Result-Based Action Plan (RBAP)– Reduce NRW in Municipal Water Systems Objective (USAID WMI, 2019), and multiple implementation projects. Summaries of the key elements of the existing plans are provided below.

Strategic Master Plan for NRW Reduction (2021)

The goal of the Strategic Master Plan for NRW Reduction is to establish a unified framework and roadmap for improving the reliability and sustainability of Jordan's water supply systems in an accountable and holistic approach. Implementation requires improved utility management practices, targeted technical assistance, and institutional capacity-building related to NRW reduction. This plan sets a roadmap towards effective NRW management in Jordanian utilities in a phased approach. This will facilitate the transition from current conditions through reliable and accountable solutions that will be established and sustained in high-priority water supply systems, and progressively in entire utilities.

The transition begins with the establishment of sector-wide policies and standards, then with the establishment of utility institutional capacity by focusing business processes and information systems on NRW control. This central capacity will focus on transitioning one supply system at a time to meet the established policies and standards and will provide the operational support to sustain transitioned supply systems. The investment in further supply systems will be linked to sustained effort that will be continuously audited by a reference authority like the current Utility Performance Monitoring Unit or a future regulatory entity.

National Water Infrastructure Master Plan (2020)

The National Water Infrastructure Master Plan analyzed each Jordanian governorate's water supply situation and population projections to then develop supply and demand estimates for each. This includes development of scenarios for the required quantities and projected deficits for each governorate. The master plan determined the infrastructure investment needs from 2020 to 2040 to address the supply-demand situation and estimated phased costs. Investment requirements were categorized based on: new water resources, transmission systems, network rehabilitation, network expansion and NRW reduction. The plan further integrated and consolidated the efforts required of the different utilities into this unified National Water Infrastructure Master Plan.

Result-Based Action Plan (RBAP) (2019)

The Result-Based Action Plan (RBAP) is a disciplined framework that outlines the sector's fundamental goals and objectives and illustrates what outcomes need to be achieved in order to meet the strategic goals (USAID WMI, 2019). The RBAP included the key outcomes that, if realized, would lead to achieving the objective: "Reduce NRW in municipal water systems". These outcomes were grouped under three interventions as follows:

- Improve measurement, monitoring and control
- Reduce municipal water commercial losses
- Reduce municipal water physical losses

NRW Reduction Implementation Projects (various timing, some ongoing)

Numerous NRW reduction projects have been completed, are currently being implemented and are planned to be implemented by various donors. These projects are not covered here. As part of the National NRW Strategy, however, it is important that these projects are better coordinated and executed in line with the overall agreed strategy between donors and MWI to maximize their impact. Several past projects have failed to show any improvement in NRW, such as pipe replacement without effectively disconnecting old mains, and/or didn't measure their impact on NRW against a baseline.

1.2 Key Challenges

Water supply in Jordan is intermittent (except in Aqaba City and some small areas in Amman). As a result, managing NRW in most locations is more difficult and faces additional challenges than if all systems were under continuous supply, as detailed below. With pressure on the water utilities to deliver water equitably to customers in only one to two days a week, and with limited financial resources, it becomes harder to reduce the NRW. The major challenges are summarized as follows:

1) Institutional Capacity

1.1. ***Human resources.*** There has been a focus on utility staff training in recent years, however the number of people dedicated to NRW control is insufficient;

1.2. ***Systems.*** NRW management systems are improving, especially in Amman and Aqaba, but this needs further improvement and to be extended to the other systems;

1.3. ***Equipment.*** NRW equipment and specialized vehicles have been obtained in recent years, however, once each utility's NRW action plan is complete, more may be required;

1.4. ***Financial Capacity.*** Utility budgets are too low to properly maintain existing assets, let alone new ones. Major asset depreciation is not accounted-for properly which makes utility financial performance seem better than it is.

2) **Monitoring and measurement**

2.1. ***Flow Measurement***. Metering for source, production, inter-system bulk transfer, distribution zone (DZ) and district flows is deficient. There are efforts under way to remedy some of these problems, but lack of maintenance, harsh operating conditions and *ad-hoc* cross connections within networks undermine flow measurement;

2.2. ***Pressure Measurement***. Intermittent supply and the lack of network instrumentation and communications in many locations makes pressure measurement very difficult. Upgrades have been made and are under way in some systems but not all;

2.3. ***Maintenance of Measurement Devices.*** Network instrument upgrades will not lead to sustainable improvement unless specialized maintenance of such devices is employed.

3) Commercial losses (loss of revenue but not of water)

3.1. ***Metering inaccuracies***. High rates of meter deterioration, large numbers of aged mechanical meters with low accuracy or which have failed, limited meter data management systems and limited actions to correct improperly-installed meters;

3.2. ***Control of Unauthorized Consumption.*** Hard to locate illegal connections, weak legal support, lack of strong procedures to follow up locations with suspected illegal uses, reluctance of utilities to tackle the issue, and high customer dissatisfaction rates exacerbate illegal use;

3.3. ***Billing efficiency.*** High number of unread meters resulting in estimated billing, weak follow up of abnormalities in meter reading, weak quality control of meter reading, weak follow up of meter reader observations, and possible errors in the billing process;

3.4. ***Customer mapping.*** For many areas, there is no updated mapping of customer locations and information (this has been corrected in Amman and Aqaba and is in progress in some other governorates but not all).

4) Physical losses (leakage)

4.1. ***Pressure Management.*** It is difficult to stabilize pressure within acceptable ranges and operate the water system as designed;

4.2. ***Leak Detection and Control***. Very difficult under IWS condition because leak detection methods and equipment depend on pipes being full of water, customer storage tanks being full, and that there is no air in the network. Quantification of leakage via minimum-night-flow (MNF) monitoring is also impossible under short IWS periods (which most areas in Jordan face) because much of the water flow at night is merely tank filling not leakage. Also, some leaks that would be visible under continuous supply are invisible under IWS because the surrounding ground doesn't have enough time to become saturated before the water is turned off;

4.3. ***Speed of Repairs***. It is hard to locate leaks due to deficient GIS maps of networks and low capacity of crews in terms of numbers and tools, although this is improving due to the vehicles and equipment provided recently by USAID;

4.4. ***Infrastructure Condition.*** IWS damages water pipes and other assets such as meters more rapidly than under continuous supply due to pressure surges and entrained air. Unknown and usually undocumented cross-connections between districts that are meant to be isolated from each other make it impossible to operate the network according to design (such as within pressure limits) or even to measure NRW at the district level. Redundant pipes still connected (and mostly not shown in the GIS) increase leakage and provide opportunities for water theft. Many water system assets are in poor condition which would be a problem even under continuous supply;

4.5. ***Asset Management***. The sector suffers from insufficient asset management. This includes weak maintenance planning, little preventive or predictive maintenance, inaccurate asset records, and low capacity of maintenance functions within the utilities;

4.6. ***Hydraulic Modeling***. Many networks are not well designed, or have not been adapted to rapid development and population growth, and there is not a validated and up-to-date hydraulic model of all water networks.

1.3 Lessons Learnt from NRW Reduction Efforts to Date in Jordan

Donors have supported NRW reduction in Jordan over many years, with USAID being the most prominent. Until recently, NRW reduction efforts have focused on asset replacement (mains, house connections, meters, etc) and conversion from pumped to gravity supply, which are valuable steps, but without a comprehensive program the impact on NRW was not measurable. For example, replacing mains without disconnecting the old mains may actually *increase* NRW, as the old mains will still leak and offer a new easy way to steal water. And conversion to gravity supply has often been defeated by reconnecting to the primary system to overcome local hydraulic issues, with the effect of increasing leakage and damaging infrastructure – a vicious cycle.

As a result of learning from the NRW Pilot Project in 2010/11, USAID's main tangible support for NRW reduction in Jordan started in 2015 as the Non-Revenue Water Project/Management Engineering Services Contract (MESC). This project was initially limited to Amman with a budget of $30 million, under the fixed amount reimbursable agreement (FARA) model, whereby Miyahuna is reimbursed for pre-agreed and certified NRW reduction activities. By several stages the scope of this project has grown to include the whole of the Kingdom, and with a current budget of over $350 million. Despite good results when and where these upgrades are completed, sustaining NRW reduction is problematic. Various steps are being taken to improve sustainability, including pilot "public-private partnerships" and a condition precedent (CP) that is intended to establish or enhance NRW Units at each utility.

Major lessons learnt from the Non-Revenue Water Project, and the earlier NRW Pilot Project, include that:

- NRW reduction requires a comprehensive approach, including better utility management, not just asset replacement or technology;
- NRW can be reduced under intermittent supply to a much lower level than previously thought, as low as 11% in one DZ in Amman (DZ 27) using comprehensive network upgrades but still with the existing mechanical meters, and to 25-30% by implementing only basic improvements to the network, a great improvement on Amman's recent 46-49% NRW level;
- Under short intermittent supply (<48 hrs/week) working mechanical customer meters within their lifetime are not a major source of NRW or revenue loss;
- NRW can be reduced to no more than 25% under continuous supply (based on results in Aqaba) as long as the customer meters are upgraded to ultrasonic (US);
- All DZs and DMAs within distribution systems must be isolated from each other in order to limit the amount of network under pressure at a time (intermittent supply) and to control network pressure especially in hilly areas (intermittent or continuous supply);
- Old network must be disconnected when new pipes are installed, otherwise the old pipes still leak and offer illegal use opportunities;
- Pressure control in each DZ and DMA is very important to minimize leakage. This is achieved party by network design (limited elevation differences in each district), partly by using gravity supply (not pumped), and where needed by using pressure reduction valves (PRVs);
- Illegal use needs stronger action by Jordan's water utilities;
- Measuring the impact of NRW upgrades requires accurate customer information system (CIS) databases and bulk meters;
- Network troubleshooting and upgrades are impeded greatly by an inaccurate GIS;
- Private sector involvement in NRW reduction cannot be on a purely performance basis for several reasons, including GIS and CIS deficiencies, the artificially low tariff and the inability of a contractor to control all relevant factors such as water availability;
- Utility operations can undo the benefits of NRW reduction efforts, such as by failing to disconnect redundant pipes, and by connecting the primary system to the distribution network (which defeats pressure control systems).

The link between NRW reduction measures and actual NRW reduction (and revenue increase) has been studied by the MESC contractor intensively:

- Of the four NRW causes (leakage, illegal use, customer meter error and administrative errors), customer meter under-registration in Amman with existing (often poor condition) mechanical meters, and with supply hours about 36-48/week, is about 5-8 percentage points (the NRW Pilot estimated 4-6 points). However, the installation of 192,000 US meters out of 730,000 total residential meters did not lead to NRW reduction at the system-wide level, nor revenue increase from the affected customers (revenue increase is more important than NRW reduction re meter choice, because NRW from meter error isn't loss of water, only money);

- In contrast to the above, in Aqaba City, which has continuous supply, NRW was reduced from about 55% to about 25% by replacing all mechanical customer meters with ultrasonic meters, and in Amman districts 04B and 05C NRW was similarly reduced from 85 to 48% and 62 to 32% under continuous supply (although these NRW levels may have increased subsequently for reasons that are being studied);
- Measurements from numerous sample districts indicate an average reduction of NRW from 44% to 26% in Amman following only basic hydraulic upgrades ("foundational activities" – see Figure 3 below). A similar result was obtained in Madaba City, with NRW reduced from 42% to 28% from basic hydraulic upgrades, reducing the main pumping station pressure, and by replacing defective customer meters (still mechanical);
- Estimates of leakage are generally not available because night flow measurements are not being done. However, results in several sample districts show that fixing just a few major leaks can sometimes dramatically reduce NRW (eg from 17% to 5% in district 27-A2 in Amman). In district 27-A3 NRW was reduced from 22% to 7% using network restructuring and leak detection, and in 27 D from 45% to 18% using the same approach. In another case, fixing just one leak in district 24 E5 reduced NRW from 55% to 28%. With final NRW results of 11% in DZ 27 and 10% in district 01 B4, background leakage (eg from house connections), seems not to be the major cause of leakage in Amman – rather it is a limited number of big leaks on mains. This is good news as it is much easier to locate and fix a small number of large leaks than a multitude of small ones, and large-scale network replacement seems not to be needed;
- Illegal use is not possible to independently quantify – it can only be calculated as the "residual" after the other causes have been subtracted from total NRW. However, it is known that illegal use is rife in some locations, such as the peri-urban area south of Amman and in Marfraq, Maán and Jordan Valley areas. It is not necessary to have an exact figure in order to tackle illegal use, and it isn't an expensive problem to address.

Regarding cost/benefit analysis of various NRW remedial actions, basic physical upgrades (mostly foundational actions as well as some pressure control) costing $1-3 million/DZ resulted in an average NRW reduction from about 44% to 26% in Amman. In Aqaba, the increased revenue from the ultrasonic meters gave an estimated payback on the investment of about 4 years. In Madaba, network upgrades and pressure reduction via the main pumping station upgrade costing $2.9 million created annual benefits of about $2.0 million, including $0.3 million worth of electricity usage reduction. More such data will be collected through this project as it becomes available.

The above results show that for most of Jordan basic physical upgrades to the network (foundational actions – see Figure 3) are the initial priority, followed by pressure control and major leak detection and repair. In some locations illegal use is also a major problem. In continuous supply areas, it is also important to replace the mechanical meters with static meters. All such actions will give an attractive cost/benefit ratio even at the artificially low tariff.

It should be noted that NRW for Amman and Madaba at the system-wide level remains stubbornly higher than the results measured while working in specific DZs there. It is suspected that operating practices like cross-connecting districts, not disconnecting all redundant mains, inoperative pressure control equipment, lack of regular leak detection, lack of systematic illegal use surveys and connections from the primary system to the distribution network are cancelling out the benefits of NRW upgrades. Therefore, it is critical for Jordan's water utilities to sustain the gains from all investment in NRW reduction. Recently, USAID issued a condition precedent (CP) requesting utilities to do that.

1.4 Purpose

The aim of this document, which will be part of the National Water Strategy 2022-2040 is to:

- Compile and summarize a National NRW Reduction Strategy for Jordan's water sector based on the sector targets and existing plans, particularly the MWI-approved Strategic Master Plan for NRW Reduction and the Water Infrastructure Master Plan;
- Develop a simplified and comprehensive overall strategy for managing NRW that can be utilized as the basis for allocating investment and project resources and developing the detailed NRW implementation plan for each water utility and each donor;
- Standardize the understanding of the NRW reduction approach, measurements, and key outcomes for Jordan's water sector;
- Set targets for NRW key indicators and outcomes;
- Summarize the estimated investment and operation and maintenance (O&M) costs needed to achieve the NRW targets.

2 NRW INDICATORS AND TARGETS

2.1 Water Balance and NRW Indicator

A simplified International Water Association (IWA) water balance is illustrated in Figure 1, which is used to calculate the NRW indicator. It is important to stress that IWA at its Performance Indicators Conference in May 2017 in Vienna stated that "Everyone knows percentages of System Input Volume (SIV) must not be used for target-setting and/or making technical comparisons" (Lambert, 2019). Therefore, NRW should be calculated based on the water supplied to a distribution system (not SIV) to indicate the right operational performance of that water distribution system. This is because SIV can include bulk water transfers to other systems, not just the water supplied to the subject distribution system.

The % of NRW is calculated using the following equations:

Water supplied = Water produced[1] + Water imported[2] – Water exported[3]

NRW = Water supplied – Billed quantity

NRW % = NRW / Water supplied * 100%

Where the water produced, and the water imported formulate the SIV.

<table>
<tr><td rowspan="5">System Input Volume (SIV)</td><td colspan="3">Water Exported</td><td></td></tr>
<tr><td colspan="3">Billed authorized consumption (metered and unmetered) within the distribution system (Billed quantity)</td><td rowspan="4">Water supplied</td></tr>
<tr><td rowspan="3">Non-Revenue Water</td><td colspan="2">Unbilled authorized consumption</td></tr>
<tr><td rowspan="2">Water losses</td><td>Commercial losses</td></tr>
<tr><td>Real Losses</td></tr>
</table>

Figure 1: Simplified IWA Standard Water Balance (Lambert, 2019)

Table 1 summarizes the recently available NRW ratios of water supplied to the water distribution systems per governorate/utility. It is to be noted that water supply during 2020, which was affected by the Covid situation, was increased from 2019, because water was supplied at the maximum capacity of the water resources leading to an increase in the supply duration in some areas as well as water quantities, which thereby increased water losses (NRW generally increases with supply hours). Additionally, due to the long lock down periods and re-connecting all disconnected water customers for hygiene needs, illegal use increased, and that also increased NRW in 2020.

[1] Water produced is the water quantity comes from the utility's own resources.
[2] Water imported is the water quantity received from other utilities and/or private operator like private wells and Disi BOT.
[3] Water exported is the water quantity conveyed to other utilities as bulk quantities.

Table 1: Key NRW indicators – most recent data available (2020), actual measurement or estimates[4]

Utility	Governorate	Water produced (MCM)	Water imported from utility (MCM)	Water imported from private operator (MCM)[5]	Water exported (MCM)	Water supplied to system (MCM)	Billed quantity (MCM)[6]	NRW quantity (MCM)	NRW % of water supplied to system
YWC	**Irbid**	48,427,676	11,662,732	1,318,352	3,064,357	58,344,403	34,499,030	23,845,373	40.9%
	Mafraq	34,551,174	2,046,090	8,798,433	14,482,485	30,913,212	10,598,919	20,314,293	65.7%
	Mafraq Qasaba					22,478,022	8,404,680	14,073,342	62.6%
	Northern Badiya					8,148,351	2,194,239	5,954,112	73.1%
	Jarash	7,436,208	2,334,931		-	9,771,139	5,078,072	4,693,067	48.0%
	Ajloun	5,082,126	1,503,089		-	6,585,215	3,819,155	2,766,060	42.0%
	Subtotal	**95,497,184**		**10,116,785**		**105,613,969**	**53,995,176**	**51,618,793**	**48.9%**
Miyahuna	**Amman**	151,141,216	1,779,336	100,003,060	43,748,796	209,174,816	106,589,859	102,584,957	49.0%
	Zarqa	41,882,362	22,163,167	3,064,446	3,918,561	63,191,414	25,625,354	37,566,060	59.4%
	Madaba	10,841,249	894,113		1,445,424	10,289,938	5,381,566	4,908,372	47.7%
	Balqa	15,705,666	24,327,921	5,973,606	51,756	45,955,437	13,689,612	32,265,825	70.2%
	Subtotal	**219,570,493**		**109,041,112**		**328,611,605**	**151,286,391**	**177,325,214**	**54.0%**
AW	**Karak**	21,200,892				21,200,892	7,720,864	13,480,028	63.6%
	Tafileh	8,032,205				8,032,205	2,763,505	5,268,700	65.6%
	Ma'an	13,239,663				13,239,663	4,684,048	8,555,615	64.6%
	Aqaba	20,822,233		7,875,760		28,697,993	18,092,715	10,605,278	37.0%
	Subtotal	**63,294,993**		**7,875,760**		**71,170,753**	**33,261,132**	**37,909,621**	**53.3%**
Jordan			**378,362,670** **-**	**127,033,657**	**-**	**505,396,327**	**238,542,699**	**266,853,628**	**52.8%**

Source: WAJ and UPMU

[4] Many NRW figures for Jordanian water systems are estimates due to the lack of accurate bulk flow metering. Various projects are under way to remedy this situation, but it will be some time before actual figures are available. In the meantime, some figures can only be estimated.

[5] This includes water imported from Disi water and private wells

[6] Billed water is the annual billed quantity to the water customers served by a distribution network, as obtained from the billing system

2.2 NRW Strategic Objectives and Targets

The overarching goal and objective for the water sector is to reduce NRW in Jordan as much as possible in recognition of the supply constraints from the arid climate, decline in surface and groundwater supplies and the financial burden of Jordan's current NRW level. The water sector has made recent commitments to NRW reduction targets ranging from 25-36% kingdom-wide by 2040. It is important to note that these need to be considered as intermediate targets and that further reductions are required, and earlier than 2040. These targets correspond with additional sector objectives and goals related to NRW which include the following:

- Ensure that all supply expansion, which is highly costly, is essential to meet needs and is utilized to the fullest extent possible given the already high financial deficit for the sector;
- Help to stabilize the gap between water consumption and the sustainable supply;
- While there are many possible NRW indicators, the limitations on reliable base data and the level of sophistication of NRW management at the utilities means that overly-elaborate indicators will not be useful at this stage – although it is anticipated that this will change as the utilities develop their NRW capabilities over time.

Figure 2 presents the NRW national targets and their timelines to 2040, where a few percentage points increase in NRW level is expected in the first year of operating the Amman-Aqaba Water Desalination and Conveyance Project (AAWDCP) as water supply duration will be longer or even continuous, which then should be followed up with more aggressive reduction of NRW. Under continuous water supply with the additional water quantities of AAWDCP, NRW reduction techniques and activities should become more effective and should lead to further reduction in NRW levels. Since current NRW figures are not highly reliable, and the losses in 2020 increased as explained in the previous section, it is assumed that the baseline NRW level for 2021 will be around 50%.

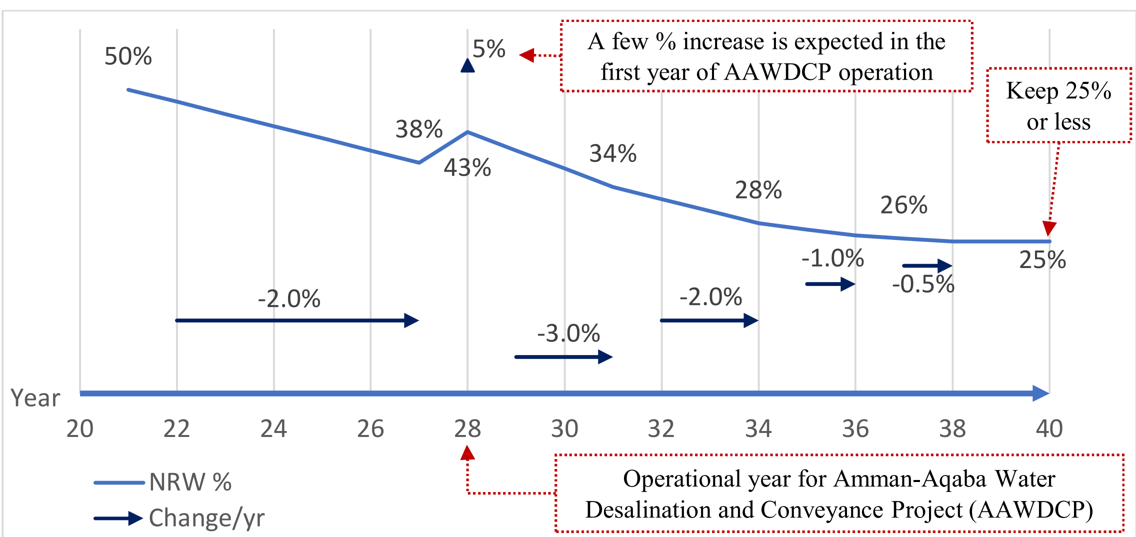


Figure 2: NRW national targets and timeline by 2040 (Illustrative)

3 Comprehensive NRW Approach

3.1 Overall Approach

An overall strategy to reducing NRW is described in the Strategic Master Plan for NRW Reduction. Specific NRW reduction actions are also being implemented through donor programs. Figure 3 below illustrates a comprehensive step approach for reducing NRW in Jordan. The approach includes four key pillars as follows:

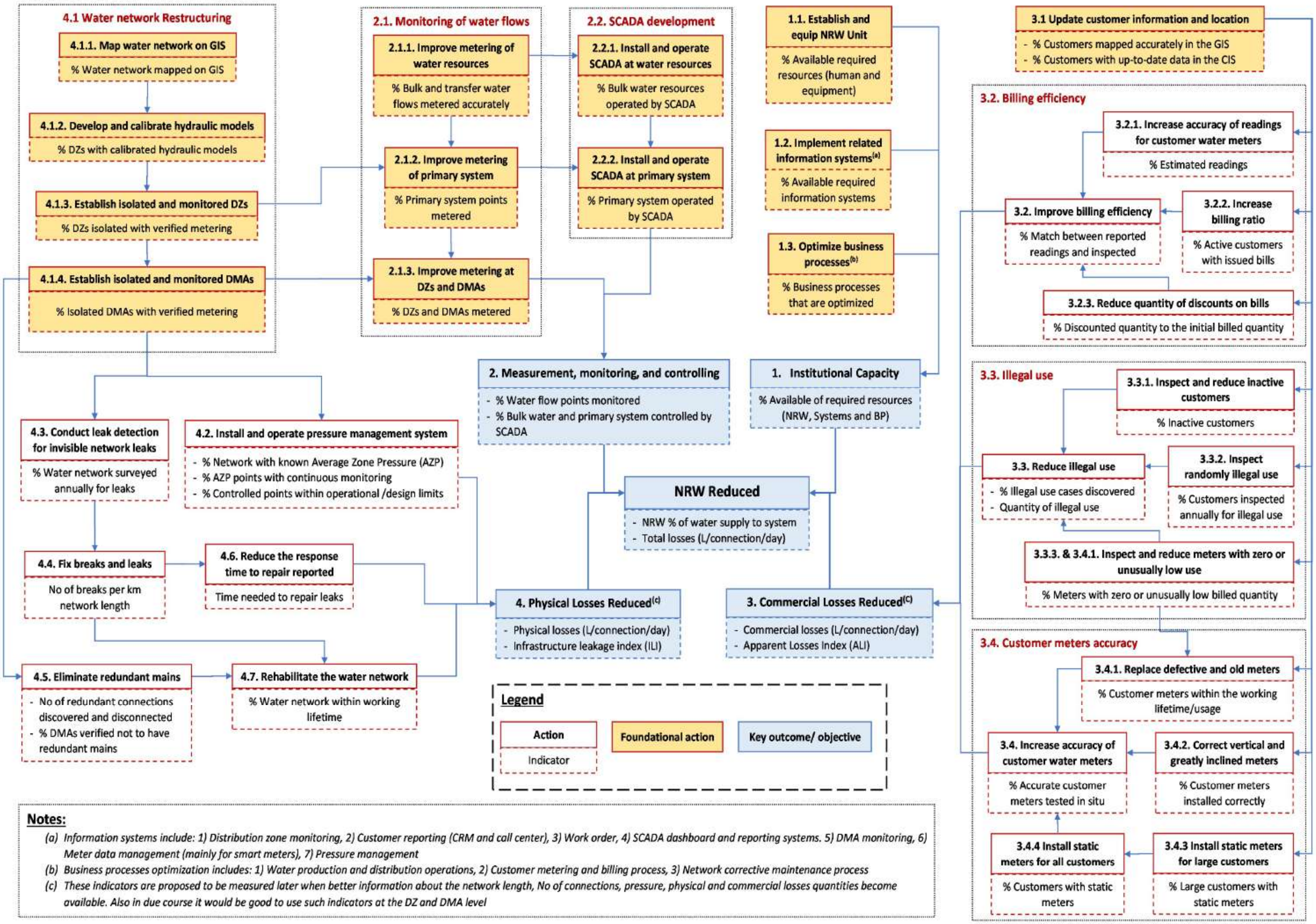
1. ***Institutional Capacity***: A capable and well-equipped water utility is needed to reduce NRW and sustain a lower NRW level;
2. ***Measurement, monitoring and control***: To prioritize NRW reduction actions and take corrective actions within a "closed-loop" management system;
3. ***Commercial losses:*** Potentially faster and requiring less investment compared to reducing physical water losses. The approach to reducing commercial losses should be heavily (but not totally) influenced by cost/benefit analysis, since this loss is mainly financial not of water;
4. ***Physical losses:*** This needs a longer timeframe and larger investment to reduce, but it is even more important to reduce because it is a loss of both water and revenue, and there is no substitute for water.

The approach shown in Figure 3 below includes "foundational actions", which do not lead directly to reducing NRW but are needed to optimize other actions, and incorporates the learning to date from the Non-Revenue Water Project/MESC. Nonetheless, some remedial actions can be tackled early depending on the water system condition and operational context. For example:

- ***All water systems***: Each utility should analyze its water system and determine if it is possible to reduce water pressure in some areas without affecting the service level, reduce repair response time, conduct some form of leak detection and control illegal use. Leakage and theft are prime causes of inadequate/intermittent water supply[7];
- ***Lack of accurate customer data:*** Even where up-to-date customer information and location is not available, the utility may still be able to improve metering/billing efficiency and meter accuracy, and better control illegal use;
- ***Lack of measurement***: Specific measurements of different parts of the water system may still be possible to assist in identifying NRW issues and prioritize actions;
- ***Continuous water supply***: Where there is continuous water supply, reducing pressure levels as much as possible while keeping acceptable service levels, and conducting active leak detection should be possible.

All actions in Figure 3 will be customized within each utility's implementation plan, and early actions ("quick wins") can help pay for further improvements.

[7] For example, water supplied to Amman is already at the Government of Jordan (GoJ) target of 120 litres/person/day, enough for continuous supply in theory, but NRW reduces this so much that supply has to be "rationed" via intermittent supply. This in turn damages the network and increases NRW.



Notes:

(a) *Information systems include: 1) Distribution zone monitoring, 2) Customer reporting (CRM and call center), 3) Work order, 4) SCADA dashboard and reporting systems. 5) DMA monitoring, 6) Meter data management (mainly for smart meters), 7) Pressure management*

(b) *Business processes optimization includes: 1) Water production and distribution operations, 2) Customer metering and billing process, 3) Network corrective maintenance process*

(c) *These indicators are proposed to be measured later when better information about the network length, No of connections, pressure, physical and commercial losses quantities become available. Also in due course it would be good to use such indicators at the DZ and DMA level*

Figure 3: NRW reduction comprehensive step approach

3.2 NRW Key Outcomes

To achieve targeted NRW reductions, the comprehensive approach includes key outcomes that, if achieved, should result in reduced NRW levels. Many of these outcomes are extracted from the NRW objective in the RBAP and other key outcomes will be added as they are deemed to be important. Each utility must measure these outcomes, which will help in determining weak areas to be tackled through targeted actions and projects, as illustrated in Figure 4 below.

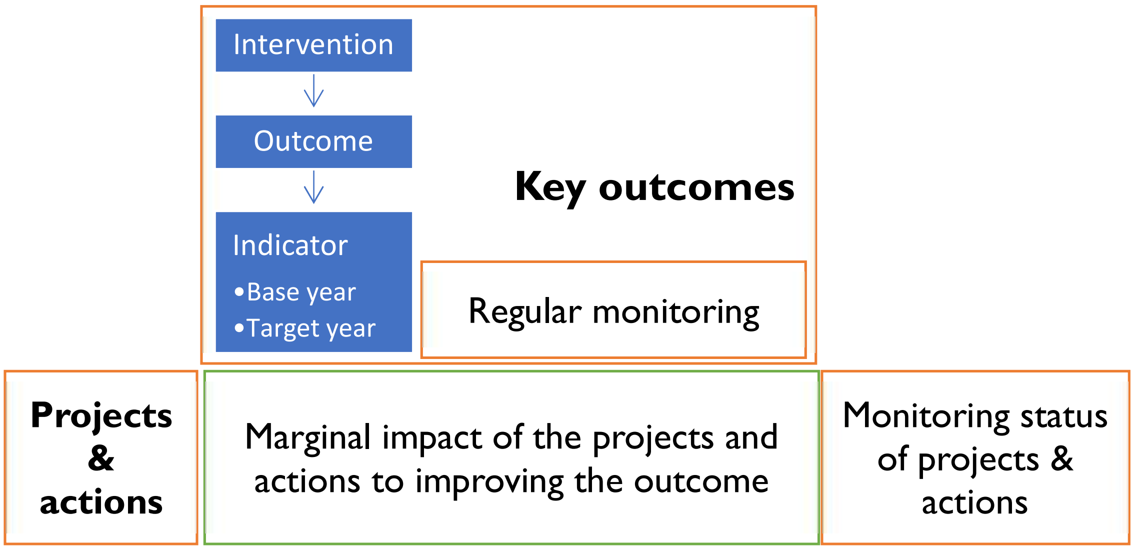


Figure 4: Implementation plan approach for each outcome

Table 2 below summarizes the key outcomes and proposed indicators for NRW reduction based on the comprehensive approach shown in Figure 3. Outcomes and targets need to be set re: cost/benefit, timing and practicality, as well as physical priorities (e.g. minimum supply quantities to customers) and in the context of alternatives and avoided costs (like excessive supply expansion).

Table 2: Key Outcomes for NRW Reduction

Intervention	Outcome/Action	Indicator	Definition	Optimal target	Notes
1. Improve institutional capacity	1.1. Establish and equip NRW Units at each utility	% Available required resources (human and equipment)	Number of available human resources and equipment to total required human resources and equipment for a fully functional NRW unit in a certain utility	100%	• Likely a combination of specialist staff and contractors • Required resources based on utility size • Miyahuna could provide centralized expertise for some specialist functions
	1.2. Implement related information systems	% Available required information systems	Utilization of related information systems to the required ones	100%	Data accuracy also to be considered, e.g. CIS, GIS data
	1.3. Optimize business processes	% Business processes that are optimized	Optimized business processes to total business processes	100%	Related to NRW as noted in Figure 3
2. Improve measurement, monitoring and controlling	2.1. Improve monitoring of water flows	% Water flow points monitored	No. water flow points (bulk, inter-system transfer, primary system, DZs and DMAs) metered to total no. of water flow points	100%	Some work under way or planned
	2.1.1. Improve metering of water resources	% Bulk and transfer water flows metered accurately	No. of accurate bulk and transfer meters to total number of bulk and inter-system transfers	100%	Some work under way or planned
	2.1.2. Improve metering of primary system	% Primary system points metered	No. of functional and verified primary system meters to total number of primary system points	100%	
	2.1.3. Improve metering at DZs and DMAs	% DZs and DMAs metered	No. of functional and verified DZ and DMA meters to total number of DZs and DMAs	100%	Example of a task for NRW Units, need for specialist skills and regular auditing
	2.2. Improve SCADA	% Bulk water and primary system controlled by SCADA	Sites and points of bulk water resource and primary system operated by SCADA to total sites of bulk resources and points of primary system	Cost-benefit based	
	2.2.1. Install and operate SCADA at water resources	% Bulk water resources operated by SCADA	Sites of bulk water resources operated by SCADA to total sites of bulk water resources	~100%	
	2.2.2. Install and operate SCADA at primary system	% Primary system operated by SCADA	Points of primary system operated by SCADA to total points of primary system	Cost-benefit based	Monitoring of all primary system should be first priority, then controlling at a later stage

Intervention	Outcome/Action	Indicator	Definition	Optimal target	Notes
3. Reduce municipal water commercial losses	3.1. Update customer information and location	% Customers mapped accurately in the GIS	No. of customers accurately mapped on GIS to total no. of active and inactive customers	100%	Will need comprehensive customer surveys – Amman and Aqaba done, Zarqa planned
		% Customers with up-to-date data in the CIS	No. of customers with updated information to total no. of active and inactive customers	100%	In progress in Amman
	3.2. Increase billing efficiency	% Match between reported and inspected readings	No. of matches between readings in field and randomly inspected readings to total no. of inspected readings	100%	A round inspection to be carried out to check the accuracy of reported vs actual readings
	3.2.1. Increase billing ratio	% Active customers with issued bills	No. of active customers with bills issued to total no. of active customers	100%	
	3.2.2. Increase accuracy of readings for customer water meters	% Estimated readings	No. of estimated meter readings to total no. of meter readings	~0%	Needs meter relocation in some cases
	3.2.3. Reduce quantity of discounts on bills	% Discounted quantity to the initial billed quantity	Quantity and value of discounts to the initial billed quantity and value	~0%	Additional billing and discounts to be closely monitored by utilities
	3.3. Reduce illegal use of water	% Illegal use cases discovered	No. of discovered illegal cases to total no. of active customers	NA	Recovery of funds is tracked by utilities, but this should be periodically audited
		Quantity of illegal use	Annual quantity of illegal use billed	NA	
	3.3.1. Inspect and reduce inactive customers	% Inactive customers	No. of inactive customers to total no. of active and inactive customers	0%	
	3.3.2. Inspect randomly illegal use	% Customers inspected annually for illegal use	No. of customers inspected for illegal use to total no. of active customers	Risk-based	Need regular schedule and focus on suspect cases
	3.3.3. Inspect and reduce meters with zero or unusually low use	% Meters with zero or unusually low billed quantity[8]	No. of meters with zero/low reading to total no. of meters	~0%	• Indicates potential illegal use or meter defect • Specialist detective work required
	3.4. Increase accuracy of customer water meters	% Accurate customer meters tested *in situ*	No. of accurate customer meters tested in situ to total no. of tested customer meters	~100%	*In situ*, not on test benches, which have been shown to not relate to actual conditions in Jordan.

[8] A meter with four consecutive quarters with the same reading is considered a meter with zero or unusually low use. However, this should be disaggregated between those customers who live in their property and vacant properties. Customers with unexpectedly low billed consumption should also be investigated.

Intervention	Outcome/Action	Indicator	Definition	Optimal target	Notes
	3.4.1. Replace defective and old meters	% Customer meters within the working lifetime/usage	No. of customer meters within the working lifetime/usage[9] to total no. of meters	~100%	
	3.4.2. Correct vertical and greatly inclined[10]	% Customer meters installed correctly	No. of customer meters installed correctly to total no.	~100%	This is mainly for mechanical meters in case they are vertically installed or greatly inclined
	3.4.3. Install static meters for large customers	% Large customers with static meters	No. of large customers with static meters to total no. of large customers	100%	
	3.4.4. Install static meters for all customers	% Customers with static meters	No. of customers with static meters to total no. of customers	Cost benefit-based	• Static meters needed under continuous supply • Under intermittent supply, benefit from static meters varies and CBA must be conducted
4. Reduce municipal water physical losses	4.1. Restructure water network as needed	Same as 4.1.4			
	4.1.1. Map water network on GIS	% Water network mapped on GIS	Length of water network mapped on GIS to total water network length	100%	• Redundant mains are an issue • May need specialized technology to locate unregistered pipes • Another specialist function for NRW Units
	4.1.2. Develop and calibrate hydraulic models	% DZs with calibrated hydraulic models	No. of DZs with calibrated and updated hydraulic models to total no. of DZs	100%	
	4.1.3. Establish isolated and monitored DZs	% Isolated DZs with verified meters	No. of isolated DZs with verified meters to total no. of DZs	100%	
	4.1.4. Establish isolated and monitored DMAs	% Isolated DMAs with verified metering	Length of water network that is located in isolated and established DMA to total network length	100%	

[9] As general guidance, the working lifetime for moving meters (mainly mechanical) in Jordan is 5 years or 3,000 m^3 of cumulative recorded volume. For static meters (mainly ultrasonic), the working lifetime is anticipated to be about 15 years, but these are new to Jordan so there is no lifetime history.

[10] Correcting inclined meters could be expensive and impractical. Thus, targeted correction should be made for large consumers and greatly inclined meters. This issue can be reduced by installing new house connections and meters correctly.

Intervention	Outcome/Action	Indicator	Definition	Optimal target	Notes
	4.2. Ensure pressure is managed in the pressure zones	% Network with known Average Zone Pressure (AZP)	Length of network with known AZP to total length of network length	100%	
		% Average Zone Pressure (AZP) points with continuous monitoring	No. of AZP points monitored to total no. of AZP Points	100%	
		% Controlled points within operational/ design limits	No. of controlled points within the operational/design limit to total no. of controlled points	100%	
	4.3. Conduct leak detection for invisible network leaks	% Water network surveyed annually for leaks	Length of surveyed water network for leak detection to total length of water network	100% every 2 years	Need regular schedule, i.e. all mains surveyed every 2 years. Requires additional staff in NRW Unit.
	4.4. Fix breaks and leaks	No. of breaks per km network length	No. of breaks per year to km network length	NA	This is indicative of network condition
	4.5. Eliminate redundant mains	No. of redundant connections discovered and disconnected	No. of annually verified redundant connections discovered and disconnected on water mains	NA	This is indicative of progress in addressing this issue
		% DMAs verified not to have redundant mains	No of DMAs verified not have redundant mains to total No of DMAs	100%	
	4.6. Reduce the response time to repair reported leaks	Time needed to repair leaks	Average time in hours needed to repair reported leaks	Less is better	
	4.7. Rehabilitate the water network	% water network within working lifetime	Length of network within working lifetime to total length of network	100%	

3.3 Context and NRW Indicators

NRW results should be reported in the context of operational conditions and water system characteristics. Feasible approaches to NRW control depend on local factors and operational conditions, which should also be considered when reporting NRW indicators, including the following factors amongst others (Al-Assa'd and Charalambous (2022):

- ***Duration of water supply***. As the supply period is increased, higher NRW is expected in the immediate term, all else being equal, as additional supplies to a faulty system result in additional losses. This issue is a major barrier to the introduction of continuous supply in Jordan and a major argument for the critical need for the current and planned NRW reduction interventions to strengthen the current system. The experience of NRW reduction in Aqaba and certain areas in Amman will inform strategies to increase supply hours in other locations;
- ***Consumption per connection***. A water system with higher consumption per connection is expected to have a lower NRW level, all else being equal, since leakage will not vary with consumption and meters will be more accurate at higher average flow;
- ***Connection density***: A water system with more connection density is expected to have less NRW per connection as this system has a lower length of water network per connection;
- ***Operational pressure***: The higher the average water pressure, the higher the NRW level that is expected.

Context indicators of each utility should be tracked over time to aid in the interpretation of NRW figures and measure other relevant trends. Some context indicators, such as system pressure, are also at least partly controllable, so they should not be used to adjust NRW figures. The focus should be on NRW reduction in light of factors such as cost/benefit analysis, lowest cost/quickest/most practical alternatives, etc. A summary of the context indicators for each utility based on the best available data (considering that some data are not accurate like network length and number of connections) is summarized in Table 3.

Table 3: Context indicators per utility for year 2019

Governorate / Context Indicator	Unit	Jordan	YWC	Amman	Zarqa	Madaba	Balqa	Karak	Tafileh	Maán	AW
Duration of water supply	Hours/ week	TBD	9	36	72	TBD	TBD	TBD	TBD	TBD	168
Consumption per connection	m^3/ week	TBD	4.77	12.01	4.55	3.79	TBD	TBD	TBD	TBD	15.74
Connection density	Connection /km	TBD	21.1	17.6	28.8	20.7	TBD	TBD	TBD	TBD	23.1
Operational pressure	Bar	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

4 Cost of NRW Reduction Pillars

The cost summary and details such as timing will be confirmed with each utility as part of developing their NRW implementation plans. In the meantime, high-level estimates for Jordan from the Strategic Master Plan for NRW Reduction have been used. These cost estimates should also be reviewed based on actual experience of NRW reduction through past and current projects. Table 4 summarizes the estimated capital, maintenance and operational costs required to implement the key actions of the comprehensive approach as illustrated in Figure 3 and based on the assessment carried out in 2018 as part of the development of the Strategic Master Plan for NRW Reduction.

The estimated capital investment at JD 1.3 billion is that which is required to move the utilities to Category C (as classified by the Strategic Master Plan for NRW Reduction), which is the second highest level of NRW performance.

Table 4: Capital and sustainability cost of NRW reduction actions – Jordan

No	Action	Cost in JD 1000		
		Capital	Maint.	Oper.
1	**Institutional capacity**			
1.1	**Establish and equip NRW Unit**	637	64	510
1.2	**Implement related information systems**	3,328	666	0
1.3	**Optimize business processes**	2,124	531	0
	Subtotal	**6,089**	**1,260**	**510**
2	**Measurement, monitoring, and controlling**			
2.1	**Monitoring of water flows**			
2.1.1	Improve metering of water resources	0	0	248
2.1.2	Improve metering of primary system	3,350	670	319
2.1.3	Improve metering at DZs and DMAs	Included in 4.2		
2.2	**SCADA development**			
2.2.1	Install and operate SCADA at water resources	0	0	0
2.2.2	Install and operate SCADA at primary system	26,564	2,656	1,536
	Subtotal	**29,914**	**3,326**	**2,103**
3	**Commercial Losses Reduced**			
3.1	**Update customer information and location (Comprehensive Customer Survey)**	2,471	494	
3.2	**Billing efficiency**			5,069
3.3	**Illegal use**			1,168
3.4	**Customer meters accuracy**			1,168
3.4.1	Replace defected and old meters	7,385	739	
3.4.2	Correct vertical and inclined meters	11,509	1,151	
3.4.3	Install static meters for big customers	7,912	949	
3.4.4	Install static meters for all customers	127,457	12,746	
	Subtotal	**156,734**	**16,079**	**7,406**
4	**Physical Losses Reduced**			
4.1	**Water network Restructuring**			
4.1.1	Map water network on GIS	3,490	349	1,912
4.1.2	Develop and calibrate hydraulic models	6,372		637
4.1.3	Establish isolated and monitored DZs	173,782	5,793	0
4.1.4	Establish isolated and monitored DMAs	91,141	3,038	0
4.2	**Install and operate pressure management system (including DMA meters)**	27,990	5,598	1,345
4.3	**Execute leak detection for invisible network leaks**	86,916	8,692	1,437

No	Action	Cost in JD 1000		
		Capital	Maint.	Oper.
4.4	Fix breaks and leaks			
4.5	Eliminate redundant mains			
4.6	Reduce the response time to repair reported leaks			
4.7	Rehabilitate the water network	689,780		
	Subtotal	**1,079,471**	**23,469**	**5,331**
	Total	**1,272,209**	**44,135**	**15,349**

Data source: Strategic Master Plan for NRW Reduction (2021)

The cost breakdown per water utility/governorate is developed. Table 5 summarizes the capital cost required per utility/governorate per pillar and Table 6 summarizes the annual O&M cost that should be carried out to sustain the NRW reduction level. It is important to stress the need for cost/benefit analyses for NRW remedial actions as illustrated in Figure 5, where for example water network rehabilitation comprises more than 50% of total estimated costs, and should therefore be carried after conducting other less expensive and quicker actions to reduce physical losses. Additionally, installing static meters for water customers is the most expensive option to reduce commercial losses, so should be carried out only if needed after completing other actions to reduce commercial losses or where the water supply is continuous.

Note that the capital cost of the foundational actions, which are needed to allow for better execution of the other actions particularly for the physical losses, comprises about a quarter of the total cost, and will be disbursed at the beginning of remediation of each subject area. However foundational tasks alone have been shown to have a significant impact on the NRW reduction. Nonetheless, utilities can do a lot to reduce NRW even before completing the foundational actions as explained in section 3.1: Overall Approach.

Table 5: Summary of capital investment per utility per pillar in JD1000

Pillar / Utility	Institutional capacity	Measurement, monitoring and control	Commercial losses	Physical losses	Total
YWC	737	9,423	43,903	353,035	407,098
Amman	947	3,140	59,561	245,263	308,910
Zarqa	693	2,903	23,219	103,733	130,547
Madaba	613	1,138	4,218	67,056	73,024
Balqa	650	2,940	10,170	116,627	130,387
Karak	650	4,158	6,777	80,731	92,317
Tafileh	617	1,305	2,259	43,204	47,384
Ma'an	622	3,637	3,171	59,324	66,754
AW	561	1,271	3,456	10,499	15,787
Jordan	**6,089**	**29,914**	**156,734**	**1,079,471**	**1,272,209**

Table 6: Summary of O&M cost per utility per pillar in JD1000/year

Utility \ Pillar	Institutional capacity	Measurement, monitoring and control	Commercial losses	Physical losses	Total
YWC	212	1,614	6,176	4,755	12,756
Amman	265	622	9,418	9,693	19,998
Zarqa	201	552	3,323	3,676	7,752
Madaba	181	235	624	1,629	2,669
Balqa	190	545	1,485	3,430	5,649
Karak	189	687	1,038	2,778	4,692
Tafileh	181	261	375	886	1,701
Ma'an	182	642	497	1,148	2,469
AW	170	272	550	806	1,798
Jordan	**1,770**	**5,429**	**23,484**	**28,801**	**59,484**

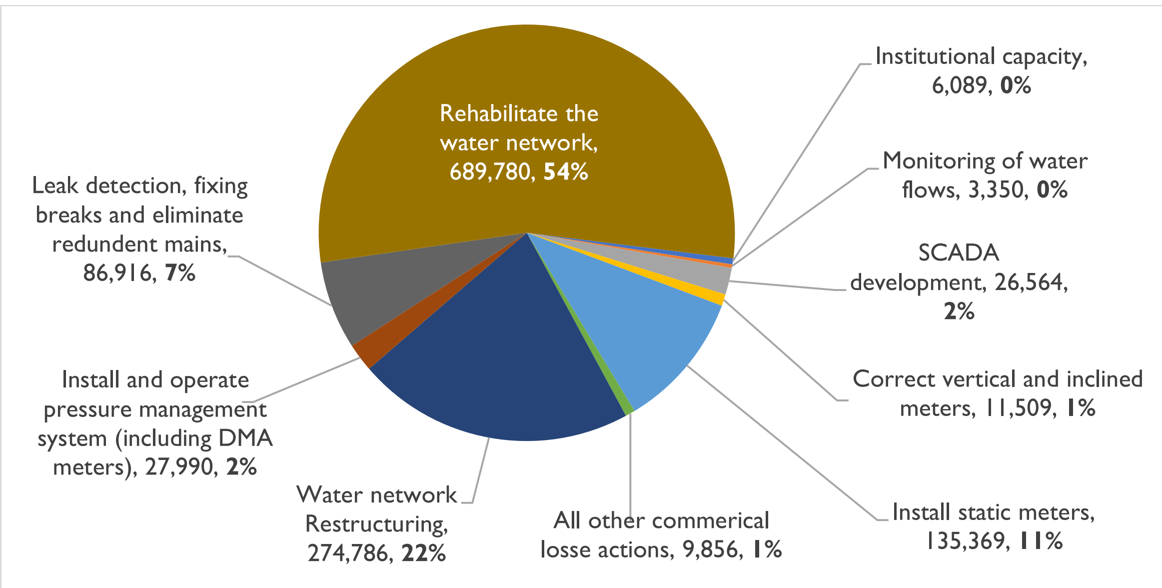


Figure 5: Capital cost distribution of key actions/outcomes in JD1000

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6 ANNEXES

6.1 Annex I: Data Used for Indicators Estimation – 2019

Context Indicator	Unit	Jordan	YWC	Amman	Zarqa	Madaba	Balqa	Karak	Tafileh	Maán	AW
No of water customers	No		350,974	731,858	183,739	35,488					43,651
No of connections	No		220,127	179,407	99,012	27,495					21,143
Network length	km		10,449	10,172	3,436	1,330					913
Billed quantity	MCM		54.6	112.1	23.4	5.4					17.3