TECHNICAL ASSISTANCE ON SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR IN CROATIA - PHASE 2 (P505592)

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OUTPUT 1

Report on preparation of a proposed utility water loss reduction action plan template

December 2024

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ACTIVITY 1:

STRENGTHENING THE CAPACITY OF RELEVANT PUBLIC AUTHORITIES AND PUBLIC WATER SERVICE PROVIDERS IN WATER LOSS REDUCTION AND SUPPORTING THE PREPARATION OF INDIVIDUAL UTILITY LOSS REDUCTION ACTION PLANS (ULRAPS)

SUBACTIVITY 1.1:

REPORT ON PREPARATION OF A PROPOSED UTILITY LOSS REDUCTION ACTION PLAN TEMPLATE

The template will be used by Public Water Service Providers in Croatia for the preparation of individual Utility Loss Reduction Action Plans (ULRAP). The template will serve as a basis for standardized utility level assessments and identification of actions for the reduction of water losses. The template will include an organizational and technical section, as well as a section addressing the required calculations for investment need estimates, financing gap, and identification of potential sources of financing needed for the reduction of water losses.

24HR01 CROATIA: SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR - PHASE 2

OBJECTIVE

Support the efficiency of operations of Croatia's water utility sector by helping the Public Water Service Providers (PWSP) to reduce excessive losses from water supply systems., through preparation and implementation of utility level activities and supporting regulator, monitoring and technical capacity strengthening.

ULRAP – DRAFT TEMPLATE

December 2024

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PREAMBLE

The Project 24HR01 **Croatia: Support to reduce water loss within the reform of the water sector - Phase 2** is implemented through a number of activities over a period of 18 months (July 2024 - December 2025).

Measures within this Project directly contribute to the implementation of the reform of the water utility sector and investments under the National Recovery and Resilience Plan 2021-2026 as well as the Operational Program Competitiveness and Cohesion 2021-2027. The Project is financed by the European Union through the Technical Support Instrument and is implemented by the World Bank in cooperation with the Directorate-General for Structural Reform Support (DG REFORM).

A mandatory activity preceding the preparation of a Utility Loss Reduction Action Plan (ULRAP) is implementation/revision of the basic measures or sub-measures that are required to adequately define baseline water losses, better foresee suitable measures and make their prioritization, and properly calculate baseline water loss indicators. These initial measures include: Group (i) measures - System data improvement measures - Sub-measure: GIS - General module (with input/update of system data) in order to know one's own system (mains, structures, connections, materials, age, profiles, etc.), and Group (ii) measures - Water supply system optimization measures - Submeasure: Development/Update of calibrated mathematical models in order to update the proposed DMAs and calculate the basic components of water loss indicators (Annex 1).

When preparing Utility Loss Reduction Action Plans and the sub-measures mentioned above, data from the new water meters installed by Croatian Waters needs to be used.

1 INTRODUCTION

Describe the baseline (directives, regulations, general water loss issue, where Croatia stands in terms of water losses, documents and plans prepared) and then define objectives both in the sector of water services and from the National Loss Reduction Action Plan (NLRAP).

2 BASELINE ASSESSMENT

Prepare a questionary for the Client which should encompass all the areas that affect the analysis and state of water losses. The proposed content of the questionary is presented in Annex 2 to this template. The questionary needs to cover an integral future service area but needs to be filled in by water supply systems in the service area.

The questionary should consider all the issues related to data about water supply systems and public providers, with a focus on the water loss issue.

In addition to general data about system characteristics (lengths by categories, materials, age, water storage tanks, water treatment plants, pumping stations, intake structures, etc.), prominent issues also concern hydrulic optimization of systems in stationary state (pressures in the system, valves, in particular hydraulic valves to regulate downstream pressures) and non-stationary state (protection from water hammer, air release and air release/intake valves, frequency converters on pumps) in order to identify unfavorable hydraulic states and consequently an increased number of bursts, incl. increased water leakage.

Key data also includes data about consumers and connections by categories for existing and planned state, and data related to estimating the sufficiency of basic resources at present and in the future period (capacities of main supply routes, storage tanks, sources, etc.), as well as data that facilitates analysis of the status of (or the level of knowing) apparent and real water losses and the capacities of PWSPs according to IWA matrixes, and relate to data about the PWSP's technical capacities (GIS, SCADA system, loss metering and control equipment), employee structure (staff, engineers, teams), water loss management efficiency (plans, establishment of DMAs, measurements, analyses, locating leakage, rate of repair, system maintenance, reconstruction plans, preparation of balances, economic value of water losses, reporting, etc.).

It is also necessary to analyze and process data related to the consumption and production of energy.

2.1 Basic data about PWSP/service area

Collect and process basic data about each PWSP which in the current state functions on its own but is planned to be included into an integrated service area. The data needs to include the name, the type of service provided, ownership relations, the area covered, the number of population, the number of connections, and the service connection and coverage rates. Present basic data about water consumption; analyze and present the existing structure and price of water.

Systematize the presentation of basic data about the service area according to the following categories/chapters:

- *Information about the service area (area, ownership structure, types and quantities of water services provided)*
- *Coverage with public water supply services*
- *Basic data about the financial performance of the water service sector*
- *Water fees (water usage fee, development fee)*
- *Water price today*
- *Water price affordability today*
- *Financing of operating and capital costs (financing of water services, financing of system investment, depreciation calculation model)*
- *Performance efficiency* (available *benchmarks and indicators of PWSP performance)*

2.2 Public water supply systems

From responses to the questionary and other available data collect and analyze basic information about each PWSP, i.e. water supply system included into an integrated service area. Data has to encompass the area covered, the number of population, the number of connections, service connection and coverage rates. Provide more detailed data about water consumption, network lengths, water intakes, structures, plants, energy consumption:

- *Area and PWSPs*
- *Number of population, number of connections, connection and coverage rates*
- *Water consumption*
- *Analysis of sources/water intakes with capacities and water treatment plants (if applicable)*
- *Data about structures (storage tanks, pumping stations, regulation structures) based on the activity of GIS development/update*
- *Data about the water supply network based on the activity of GIS development/update (length, profile, age, materials, etc.)*
- *Application of protection from water hammers*
- *Data about SCADA system*
- *Data about DMAs and PMAs*
- *Main problems in the systems*
- *Projects in preparation and implementation*

Attach a map showing basic system elements in a scale of 1:100 000 or 1:50 000.

Systematize the presentation of information about all public water supply systems in the service area according to the following categories/chapters:

- *General technical data about water supply systems*
- *Hydraulic characteristics of water supply systems*
- Planned development of water supply systems

It is also necessary to present all local water supply systems in the service area which are in operation in the current state, in accordance with available information at the Client's disposal. Systematize the presentation of information about all local water supply systems according to the following categories/chapters:

- *General technical data about local water supply systems*
- *Method of operation and hydraulic characteristics of local water supply systems*
- Planned method of inclusion of local water supply systems into an integrated public water supply system

2.3 Existing GIS and register of the condition of water supply infrastructure

Describe for each PWSP in the service area the existing GIS functionalities, starting with the register of condition of water supply infrastructure. Use as existing state the data obtained from the activities implemented for the purpose of preparing utility loss reduction action plan (activities in Annex 1). Pay special attention to functionalities such as linking the business IT system with the GIS, registering and method of registering failures with a link to the GIS, link to the SCADA system, link to the hydraulic model or link to the GIS module for water loss management. Describe the method of registering field data and its potential link to the GIS.

Since construction is under way of water and wastewater infrastructure (agglomerations) within which the GIS implementation is often planned, it is necessary to analyze the implemented procedures or plans for the procurement of the GIS module and identify the missing elements.

2.4 Organizational structure and technical capacities of leakage detection team

The technical capacities of the PWSP are a key prerequisite for successful water loss management. These capacities can be divided into technical equipment and human resources, with both components requiring continuous financial investment. It is therefore necessary to describe and present for each PWSP in the service area the method of operation of the existing water loss management system, starting with the description of the organizational structure, including the presentation of an organization chart.

The presentation of technical capacities needs to start with data about the GIS modules used, with reference to the link to other databases (consumers, failures, SCADA system, hydraulic model, loss control, field data). Analyze and present the existing teams for leak detection and repair and management, teams for the GIS, SCADA and hydraulic model, and the composition, educational qualifications and number of teams.

Analyze available equipment (portable flow and pressure meters, correlators, geophones, pipe and metal detectors, noise loggers, etc.) also depending on the network length and human resources, as well as the relation between mains length and available human resources per employee categories.

Systematize the presentation of the organizational structure, method of operation and technical capacities for loss management in the service area (including their presentation for characteristic zones of supply/systems) according to the following categories/chapters:

- *Organizational structure of loss management*
- *Technical equipment*
- *Human resources*

2.5 Current state and practice of Non-Revenue Water (NRW) management

Prepare an extended water balance based on the data from the developed/updated GIS, data from the developed/updated hydraulic model, and new data about measurements at water intakes. It is mandatory to use the guideline standardizing the calculation of average pressure (Annex 3). The extended water balance must be prepared using "Good Practice Manual: DMA ESTABLISHMENT AND MANAGEMENT", taking account of intermediary export, losses during drinking water treatment, flushing of the water supply network, etc.

Table 1. Presentation of the extended water balance

<table>
<tr><td rowspan="3">Water Imported</td><td rowspan="10">System Input Volume (corrected for known errors)</td><td>Water Exported</td><td></td><td></td><td></td><td>Billed Water Exported</td></tr>
<tr><td rowspan="9">Water Supplied</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized Consumption</td><td rowspan="2">Revenue Water</td><td>Billed Metered Consumption</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="7">Volume from Own Sources</td><td rowspan="2">Unbilled Authorized Consumption</td><td rowspan="7">Non-Revenue Water</td><td>Unbilled Metered Consumption</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies (and data handling errors)</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Mains</td></tr>
<tr><td>Leakage and Overflows at Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to point of customer metering</td></tr>
</table>

Estimate real losses according to the "top-down" method (using the above table for the preparation of the extended water balance) and analyzing 95% confidence limit for the calculation of water balance components. Real losses have to be estimated according to the "bottom-up" method where measurements are available.

After defining real losses, calculate the current state of 6 basic indicators of water losses:

- *Non-revenue water expressed in m^3/year and in % of system input volume;*
- *Infrastructure leakage index (ILI);*
- *Real losses per service connection, annual volume in m^3 and in liters per day (l/service connection/d)*
- *Real losses per network length, volume in m^3 per hour (m^3/km/h)*
- *Real losses per connection in relation to network pressure, in liters per day (l/service connection/d/m of pressure)*
- *Combined Real Loss Indicator (CRLI)*

The water balance and basic indicators of water losses have to be calculated at the level of the PWSP/service area, at the level of individual water supply systems, and at the level of DMAs! In doing so, at the level of DMAs the water balance calculation has to be made exclusively according to the "bottom-up" method (where measurements exist). Present the indicators on a map as in Figure 5 - Calculated unit value of Real Losses in liter/service connection/day.

Express the Non-Revenue Water obtained from the extended water balance in m^3/year, and additionally in % of System Input Volume.

Calculate the ILI using the following expressions:

$$ILI = \frac{Current\ annual\ real\ losses}{Unavoidable\ annual\ real\ losses} = \frac{CARL}{UARL}$$

$$UARL = (6.57 \cdot L_m + 0.256 \cdot N_c + 9.13 \cdot L_t) \cdot P_{av} \quad (m^3/year)$$

Where:

- *CARL - Current annual real losses in m^3*
- *UARL – Unavoidable annual real losses in m^3*
- *Lm - Mains length, transmission and distribution mains in km*
- *Nc - Number of service connections*
- *L_t - Total length of service pipes – from connection to the street main to the water meter*
- *Pav - Average operating pressure in m*

Calculate real losses per service connection (URL_{lcd}) as a volume in litres per service connection per day using the following expression:

URL_{lcd} = l / service connection / day

URL_{lcd} *= Real annual losses in l / number of service connections / 365*

Calculate real losses per network length (URL_{lmd}) as a volume in m^3 per hour per network length in kilometres using the following expression:

URL_{lmd} *= m^3 / km mains / h*

URL_{lmd} = Real annual losses in m^3 / network length in km / 365 / 24

Calculate real losses per service connection in relation to network pressure (URL_{lcdp}) using the following expression:

URL_{lcdp} *= l / service connection / day / m of pressure*

URL_{lcdp} *= Real annual losses in liters / number of service connections / 365 / m of pressure*

Calculate the CRLI according to the following expression:

$$CRLI = l / d$$

$$CRLI = \sqrt{URL_{lcd} \cdot URL_{lmd}}$$

With regard to water loss management practices, it is necessary to create a database from responses to the questionary and analyze the current water loss management practices, methods of adopting plans, monitoring of implementation and reporting on implemented activities and state of water losses.

Systematize the presentation of the current NRW state and management practice in the service area (including their presentation for characteristic supply zones/systems) according to the following categories/chapters:

- *Current level of water losses, potential and risks of future water losses*
    - *Description of existing problems related to water losses*
    - *Data verification*
    - *Extended water balance*
    - *Water reduction potential and risks of future water losses*
- *Calculation of water loss performance indicators (for 6 basic indicators)*
- *Overview of findings from existing plans and design documents (optimization of water supply systems, reduction of water losses)*
- *Conclusions about the current state of water loss reduction (They must be made in relation to a number of different relevant parameters. It is certainly necessary to draw conclusions in relation to the assessment matrices of real losses and non-revenue water, according to the table below).*

Table 2. Assessment matrix of real losses (left) and non-revenue water (right)

Technical performance category		ILI	Litres/service connection/day (when the system is pressured) at average pressure of					Technical performance category		Litres/service connection/day (when the system is pressured) at average pressure of				
			10 m	20 m	30 m	40 m	50 m			10 m	20 m	30 m	40 m	50 m
Standard	A1	< 1,5		< 25	< 30	< 40	< 60	Standard	A1		< 50	< 65	< 75	< 85
	A2	1,5 - 2		25-50	40-75	50-100	60-125		A2		50-100	65-125	75-150	85-175
	B	2 - 4		50-100	75-150	100-200	125-250		B		100-200	125-250	150-300	175-350
	C	4 - 8		100-200	150-300	200-400	250-500		C		200-350	250-450	300-550	350-650
	D	> 8		> 200	> 300	> 400	> 500		D		> 350	> 450	> 550	> 650

2.6 Energy and greenhouse gas emissions

The baseline assessment needs to take into account how the preservation of water resources provides protection from increasing climate change risks, which can therefore be a cost-effective adaptation measure. When physical losses are reduced, abstraction (sources and distribution) could be reduced. That would save energy and reduce greenhouse gas emissions if the production of energy includes carbon-based fuels.

It is therefore necessary to analyse energy consumption (total kWh per year, specific by water supply systems in kWh/m3 and weighted average with water volume delivered in the area of water supply systems), and based on such values estimate savings in energy consumption due to reduced water losses. Energy savings will in the selection of loss reduction measures be considered in a financial context of cost reduction, but also through requirements for more efficient energy use, creating preconditions for the eligibility of loss reduction measures for financing from the European Union's financial instruments.

Systematize the status assessment in terms of energy and greenhouse gas emissions in the service area (including their presentation for characteristic supply zones/systems) according to the following categories/chapters:

- *Total energy consumption*
- *Specific energy consumption*

- *Carbon balance (use tools for a standardised assessment which link the assessment of a water balance with the assessment of a carbon balance, e.g. WCB-EasyCalc - v1.08, https://globalnrw.com/free-downloads/free-software/)*

2.7 Risks associated with limitations in available water volumes and climate change

Climate change has to be taken into account when selecting water loss reduction measures by particularly evaluating areas with an estimated bigger climate change impact and with lower availability of sources, limitations in water volume or increased water demand in the planning period, when water loss reduction measures will enable adjustment to climate change and increase reliability of water supply systems.

Analyze available water volumes in the context of the following parameters and their combinations (cumulative impacts), existing limitations at water intakes, possibility to extend the capacities of existing intakes or open new identified intakes, and increased water demand by new users (planned extension of the system and/or users).

Estimating the severity of climate change as an element of assessment of risks in the service area is a rather complex task due to the fact that multiple impacts intertwine. Therefore, in order to unify the approach at the level of Croatia and for the purpose of preparing this Action Plan, the NLRAP estimate results can be used, presenting the classification of climate change severity based on the "average" scenario (temperature impact taken into account).

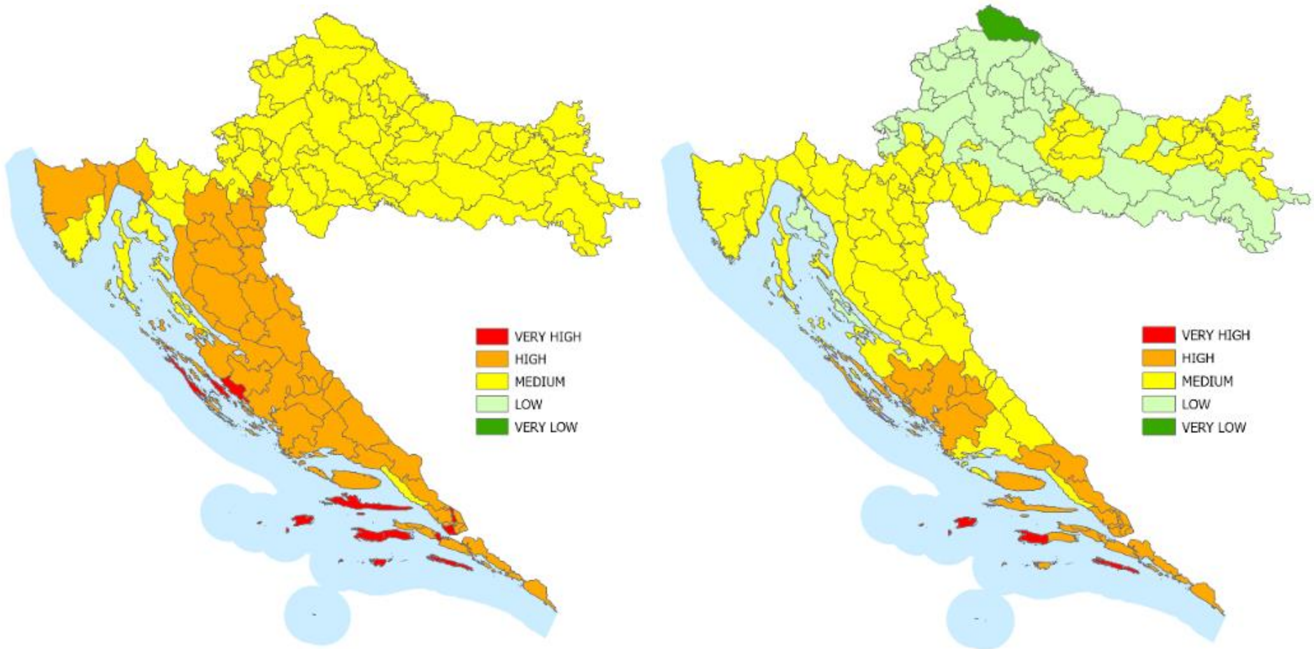

Figure 1. Climate change severity classes based on RCP 4.5 (left) and RCP 8.5 (right) scenarios (temperature impact taken into account), SOURCE NLRAP

Figure 2. Classification of climate change severity based on the "average" scenario (temperature impact taken into account), SOURCE NLRAP

For each water supply system it is necessary to assess the risk using the indicators of limitations in available water volumes in combination with (if applicable) increasing demand, and indicators of climate change severity, as well as other indicators for which the author thinks will enable a proper, permanent and adaptable assessment of risks which will later be used for the selection of measures/responses to an increased strain on water supply systems.

Systematize the presentation of risks associated with limitations in available water volumes and climate change (and other factors relevant for risk assessment) according to the following categories/chapters:

- *Limitations in available water volumes*
- *Climate change*
- *Other risks*
- Risk matrix associated with limitations in available water volumes and climate change

2.8 Obligations from the DWD Recast and towards EU bodies

DWD Recast (December 2020) puts focus on water leakages with a clear timeline to identify the (targeted) water leakage levels, prepare action plans (with defined leakage reduction measures) and present them to the European Commission.

It is noted that the major part of obligations from the DWD Recast refers to the obligations of Member States to perform an assessment[1] of water leakage levels within their territory and report the results to the European Commission by 12 January

[1] Clause 4.3: "3. In accordance with Directive 2000/60/EC, Member States shall ensure that an assessment of water leakage levels within their territory and of the potential for improvements in water leakage reduction is performed using the infrastructural leakage index (ILI) rating method or another appropriate method. That assessment shall take into account relevant public health, environmental, technical and economic aspects and cover at least water suppliers supplying at least 10 000 m3 per day or serving at least 50 000 people. The results of the assessment shall be communicated to the Commission by 12 January 2026. By 12 January 2028, the Commission shall adopt a delegated act in accordance with Article 21 in order to supplement this Directive, by setting out a

2026. After that and based on the results of the Member States' assessments, the European Commission shall set out a threshold (target levels) by January 2028.

Croatia has performed the baseline assessment of leakage levels and potential for their reduction through the NLRAP (2023). It is noted that one of the key measures resulting from the NLRAP is precisely the preparation of action plans on the level of future (41) service areas (utility action plans). Such plans will analyse in more detail the possibilities to reduce water losses and, equally important, more reliably estimate (revise) the specific objectives (effects of measures for the analysed area), all based on the NLRAP framework and methodology. For that reason, the results of utility loss reduction action plans will be used for the preparation of future national loss reduction action plans and evaluation of objectives, which will be communicated with the European Commission (2026, 2030, DWD Recast).

Utility Action Plans shall describe/foresee time schedules for the evaluation of objectives in the service area / national level associated with the provisions of DWD Recast and with thresholds (target values) to be set by the European Commission.

3 WATER LOSS MANAGEMENT PLAN

3.1 Methodology applied

Describe suitable water loss reduction methodology harmonized with the National Loss Reduction Action Plan (NLRAP). The methodology has to be based on increasing knowledge about own water supply systems, users, operating states, and water loss issues starting with the management boards of water service providers all the way to technical teams that will operate on the field.

The methodology needs to foresee digitization of data about water supply systems, identify hydraulic characteristics in water supply systems, approach to active leakage control and optimum rehabilitation of the water supply network, and identify PWSP capacities for water loss assessment and reduction.

3.2 Measures and prioritization of measures

Take over the plan of measures with all sub-measures from the NLRAP. For each of the sub-measures, analyze the state and foresee required financial investment, taking into account the different states of existing PWSPs in the service area.

I. System data improvement measures

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
GIS - General module (with input/update of system data)	*Based on the implemented activity in the GIS sub-measure which will analyze the quality of data, define the required future activities/measures to form the general module and input accurate data. These activities can include additional geodetic surveys, digging, etc. and potential procurement of a GIS software module and GIS input/correction. Base the planned financial investment on the categories of inputs ("GIS_correct", "design documents", "overview map" or "Client's information") and then foresee the required investment by each category based on the total mains length.*
GIS - Link to the business IT system (with development of the customer database)	*Based on the implemented activity in the GIS sub-measure, analyze the quality of development of the database about customers and their position in space, and foresee a measure to analyze all customers and potentially procure a GIS software*

threshold, based on ILI or another appropriate method, above which Member States shall present an action plan. That delegated act shall be drafted using the Member States' assessments and the Union average leakage rate determined on the basis of those assessments. Within two years of the adoption of the delegated act referred to in the third subparagraph, Member States having a leakage rate exceeding the threshold set out in the delegated act shall present an action plan to the Commission laying down a set of measures to be taken in order to reduce their leakage rate."

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
	module to link it with the business IT system. Base the planned financial investment on the total number of connections.
GIS - Register of failures (with input of data for the last 5 years)	*Based on the implemented activity in the GIS sub-measure, analyze quality of development of the database of failures and their location with suitable descriptions, and foresee a potential measure of potential update and potential procurement of a GIS software module for the input of failures. Base the planned financial investment on the total length of mains.*
GIS - Link between the technical and SCADA IT systems	*Check and analyze the possibility to link the technical and SCADA systems and foresee a measure of the linking need. Base the planned investment in the procurement of the linking module on the total length of mains.*
GIS - Control of losses	*Check whether the PWSP has at its disposal a module for the control of losses. The planned measure foresees implementation of the module on the joint platform, with the module automatically analyzing flows, night flows and pressures in individual PMAs, and alarming in case of deviations from expected values. Base the planned investment in the loss control module on the total number of connections.*
SCADA (with enabled links to all the structures and data storage)	*Check and analyze the current state of the SCADA system and foresee a measure of planned investment in terms of upgrading the existing system and enabling multi-year analytics and alarming. Base the planned investment on the total number of structures within the system.*
Recording and digitizing field data (procurement of software and equipment, education)	*Check whether the PWSP has at its disposal a technology for direct storage of field data from mobile devices directly into the GIS. Base the planned investment in the measure to procure the linking module (software, equipment and education) on the total length of mains.*

II. Water supply system optimization measures

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Development/revision of the conceptual solution with the calibrated mathematical model	*Analyze the state, quality (reviewed) and up-to-datedness of developed conceptual solutions. Foresee revising the solutions or developing conceptual solutions for the system for which they haven't been developed. Base the planned investment on the cost of the preparation of conceptual solution reduced based on the state and quality of the already developed solutions.*
Extension of storage tanks, pumping stations, mains, and other structures to achieve pressure and energy optimization of water supply systems	*Analyze the existing water supply structure (status of pressures and system operation) and check the possibility of potential significant structure modification (interpolating storage tanks and pumping stations and forming new pressure relations within the network) in order to reduce initial pressures and energy consumption, and consequently water losses. Base the planned investment in the measure to extend/modify the structure on the specific analyzed solution.*

III. Measures to divide the system into DMAs

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Design documentation and construction of DMA shafts (incl. SCADA system extension)	*Analyze the degree of construction and planning of DMAs and foresee the financial investment to design and construct the remaining shafts.*

IV. System pressure control and management measures

SUB-MEASURE	*ACTIONS AND FINANCIAL INVESTMENT REQUIRED*
Hydraulic analysis and development of concept to protect the system from water hammers (hydraulic shocks)	*Analyze the state and functionality of the existing water hammer protection system. Also check second logs from measurements made. Foresee the need for hydraulic check/analysis of exceeded pressures - water hammers, and preparation of a concept for optimum protection from water hammers. Base the financial investment on the conclusions about the state of the system, depending on system complexity and total network length.*
Installation of structures and equipment to protect from water hammers (incl. designing)	*Based on the analysis of state, foresee the preparation of designs and installation of structures and equipment to protect from water hammers. Base the planned investment on the total number of structures in the system and total network length.*
Formation of PMAs - Installation of new hydraulic valves for pressure regulation (with replacement of spring valves)	*Analyze the current state of system operation, how much regulation valves are installed and planned, how many of these are spring valves, and foresee the construction of new (with a design) or replacement of spring valves with hydraulic valves. Base the financial investment depending on system complexity and total network length.*
Control and management of air in the pipes (application and control of air release and air release/intake valves)	*Check the condition/servicing of air release and air release/intake valves and foresee their potential application where so foreseen by the hydraulic analysis of water hammer protection with the aim of releasing the air and enabling intake of bigger quantity of air when negative pressure forms. Base the financial investment depending on total network length.*

V. Active leakage control measures

SUB-MEASURE	*ACTIONS AND FINANCIAL INVESTMENT REQUIRED*
Conducting a campaign to investigate illegal practices in the network and connections	*Foresee funds to analyze the network and connections (consumption) and visits to those with identified deviations from standard consumption in order to look for illegal practices (bypass, illegal connections, tampering with water meters, illegal hydrant use, etc.)*
Procurement of equipment for active leakage control (pressure and flow meters, geophones, correlators, noise loggers, etc.)	*Analyze the availability of required equipment. Foresee supplementing the existing equipment and procuring new equipment for ALC where no equipment exists. Base the financial investment depending on the required number of teams, i.e. total network length.*
Conducting additional pressure and flow measurements (with identification of priority zones)	*Foresee the implementation of additional metering campaign to identify the zones with the highest leakage in which micro-locating the leakage will be done as a priority. Base the financial investment depending on the total network length.*
Identification of leakage micro-locations	*Foresee touring approximately 50% of the route to identify leakage micro-locations. Base the financial investment depending on the total network length.*
Repairing detected failures (leaks, pipe bursts, damage to water supply fittings)	*Foresee the repair of detected failures assuming the detection of an expected number of failures per network kilometer.*

VI. Measures to address apparent losses

SUB-MEASURE	*ACTIONS AND FINANCIAL INVESTMENT REQUIRED*
Water meter accuracy analysis and preparation of a replacement plan	*Collect and analyze available data about the condition of water meters. Prepare a replacement plan for water meters in the worst condition. Base the financial investment depending on the total number of connections.*
Replacement of water meters	*Foresee the replacement of approximately 10% of the water meters in the worst condition. Base the financial investment depending on the total number of connections.*

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Hydraulic analysis of possibilities for remote reduction of pressure at valves and possibilities to shut off zones in case of unauthorized water consumption	*Foresee the preparation of a hydraulic analysis to foresee the possibility for valve closure or pressure reduction at automatic alarm about unusually increased consumption. Base the financial investment depending on the total network length.*
Informing the public about the problem and cost of unauthorized water consumption (printing leaflets, daily press, billboards, newspaper articles, radio and tv broadcasts)	*Foresee the measure to inform the public about the water loss issue, raise the public awareness, particularly about the issue of unauthorized consumption and about all the measures taken to reduce water losses. Base the financial investment depending on the total number of connections.*

VII. Planning and mains replacement measures

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Preparation of mains replacement plans - optimum rehabilitation (based on the GIS, register of failures, additional measurements and micro-locating)	*Foresee the preparation of plans for optimum rehabilitation - replacement of mains based on updated data about Group I. measures, according to expected needs (prioritization of measures) and possibilities. Base the financial investment depending on the total network length.*
Preparation of design documents	*Foresee the preparation of design documents and obtaining permits as needed. Base the financial investment depending on the total network length.*
Replacement of mains	*Plan the replacement of mains in the length of 5-15%, depending on a number of priority parameters. Base the financial investment depending on the total network length.*

VIII. Institutional strengthening measures

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Preparation of an organization scheme, processes, tasks, human resources, control, communication	*Foresee the preparation of suitable documents to strengthen PWSP capacities for water loss management. Base the financial investment depending on the total number of connections and total network length.*
Preparation of PWSP Loss Reduction Action Plans, preparation of PWSP business plans	*Action plans are in preparation; through this measure, analyze the need to prepare PWSP business plans. Base the financial investment depending on the total number of connections and total network length.*
Staff training	*Foresee investment in staff training - management, engineering and field staff. Base the financial investment depending on the total number of connections and total network length.*

IX. Analysis and reporting measures

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Preparation of analyses of losses, updating the hydraulic model, GIS	*Foresee continuous updating of databases and models, preparation of analyses of losses during multi-annual implementation of the plan. Base the financial investment depending on the total number of connections and total network length.*
Project economic and financial analysis	*Foresee continuous financial and economic analysis of the project to monitor justification of investment. Base the financial investment depending on the total number of connections and total network length.*

SUB-MEASURE	***ACTIONS AND FINANCIAL INVESTMENT REQUIRED***
Preparation of monthly and annual reports incl. preparations for entry into the future central database	*Foresee continuous reporting towards the competent bodies of the Ministry and Croatian Waters. Base the financial investment depending on the total number of connections and total network length.*

After the definition of measures and required financial investment, it is necessary to define the prioritization of measures. Namely, the NLRAP objectives foresee the reduction of NRW by around 120 million m^3/year in the planned 15-year period. The current annual NRW volume on the national level amounts to around 240 million m^3/year, accounting for around 50% of the total abstracted volume. The targeted reduction of annual NRW volumes on the national level will in the end result in an NRW percentage share of around 30 %. In line with that, utility action plans have to follow the national objectives, noting that utilities with better state of water losses will adjust the methodology and prioritization to achieve appropriate objectives which will be verified by the national body, but also ensure conditions for further sustainability of the water loss management system.

The prioritization of measures has to be done on the basis of the system, with a focus on the zones with the most significant losses, and with the analysis based on at least the following criteria which have to be analyzed and evaluated:

- ***Unit real losses***
- ***Age of mains in combination with the frequency of bursts*** *(priorities for rehabilitation based on the analysis of asset value, system age, written-off value, failure dynamics, etc.)*
- ***Economic analysis of water losses*** *(energy savings, reduction of mains repair costs, new regulation on the water usage fee)*
- ***Risks*** *(**quantity** limitations, **climate** change, other risks)*
- ***Additional technical criteria*** *as needed (type of material, bearing capacity, etc.)*

When establishing/analyzing the criterion "Risks (quantity limitations, climate change)", it is necessary to at least analyze the elements applied in the NLRAP which refer to estimated available volumes, demand and limitations in available volumes, and estimated climate change severity based on an analysis of climate change indexes (precipitation, temperature) for two 30-year periods (near future, 2011-2040, and distant future, 2041-2070).

*Based on the analysis of selected criteria and their weights, identify the overall **relevance of water losses** by water supply areas, which will primarily be used for an initial proposal of the share of rehabilitation of existing mains in a PWSP area, which is considered a very important loss reduction measure. Also use the relevance of losses to develop a time plan to implement all the defined water loss reduction measures.*

3.3 Effects of measures

Based on experience and calculations, foresee the effects of all measures in terms of the reduction of water losses, i.e. the reduction of NRW volume. The foreseen effects have to be planned by each group of measures and integrated at the PWSP/service area level, with the following set of information.

Table 3. Presentation of the estimated value of measures and effects of improving water loss management

NO.	***GROUP***	***Financial share of the measure in total measures (%)***	***Share of the NRW reduction measure in total reduction (%)***	***MEASURE***	***AMOUNT (EUR)***	***AMOUNT (m3)***
I.	*System data improvement measures*			*GIS - General module (with input/update of system data)*		
				GIS - Link to the business IT system (with development of the customer database)		
				GIS - Register of failures (with entry of data for the last 5 years)		
				GIS - Link between the technical and SCADA IT systems		
				GIS - Control of losses		

NO.	GROUP	Financial share of the measure in total measures (%)	Share of the NRW reduction measure in total reduction (%)	MEASURE	AMOUNT (EUR)	AMOUNT (m3)
				SCADA (with enabled links to all the structures and data storage)		
				Recording and digitizing field data (procurement of software and equipment, education)		
				Total price of system data improvement measures		
				Effect of system data improvement measures on the % of water loss reduction (m^3/year)		
..	….					
IX.	Analysis and reporting measures			Preparation of analyses of losses, updating the hydraulic model, GIS		
				Project economic and financial analysis		
				Preparation of monthly and annual reports incl. preparations for entry into the future central database		
				Total price of analysis and reporting measures		
				Effect of analysis and reporting measures on the % of water loss reduction (m^3/year)		
TOTAL MEASURES I.-IX.		100.0%	100.0%	MEASURES TOTAL		
X.				TECHNICAL (EXTERNAL) ASSISTANCE TO IMPLEMENT MEASURES		

3.4 Water balance calculation

For the targeted planned state of water losses, prepare the planned water balance. The water balance calculation has to be made on the level of an integrated PWSP/service area, and on the level of individual water supply systems, as well as on the level of DMAs (if they have been established either under existing practice or within the preparation of this Action Plan through the implementation of additional measurements), comparing it with the existing water balances.

Use the "Good Practice Manual: DMA ESTABLISHMENT AND MANAGEMENT" for the calculation of the water balance and presentation of results.

3.5 Calculation of water loss indicators

For the targeted planned state of water losses, prepare the planned state of real losses. The calculation of basic indicators of water losses has to be made on the level of the PWSP/service area, on the level of individual water supply systems, as well as on the level of DMAs, comparing it with the results of current state indicators for the 5 basic water loss indicators:

- *Non-revenue water expressed in m^3/year and in % of system input volume*
- *Infrastructure leakage index (ILI)*
- *Real losses on an annual level in m^3 (m^3/year)*
- *Real losses per service connection in liters per day (l/service connection/d)*
- *Real losses per network length, volume in m^3 per hour (m^3/km/h)*
- *Real losses per connection in relation to network pressure, in liters per day (l/service connection/d/m of pressure)*
- *CRLI (l/d)*

Show the results of indicators in ranges and in charts.

In this chapter, for a service area (summary/weighted for the entire service area and by water supply systems and/or PWSPs) pay special attention to the visualization of effects through a prism of 6 basic indicators of water losses, following the examples presented in the NLRAP.

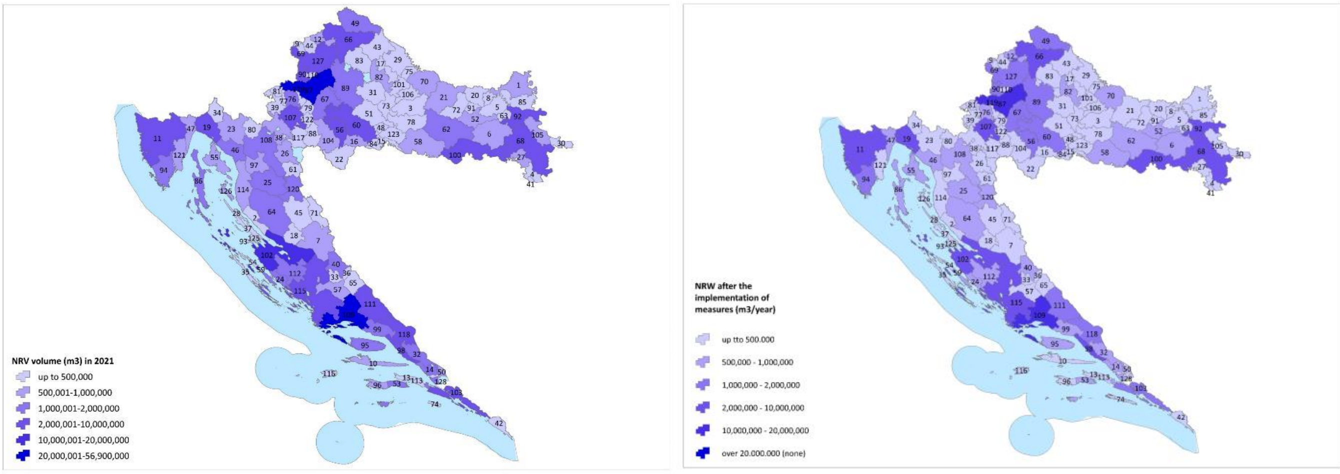

Figure 3. EXAMPLE - Spatial distribution of NRW today (left) and after the implementation of measures in 2038 (right)

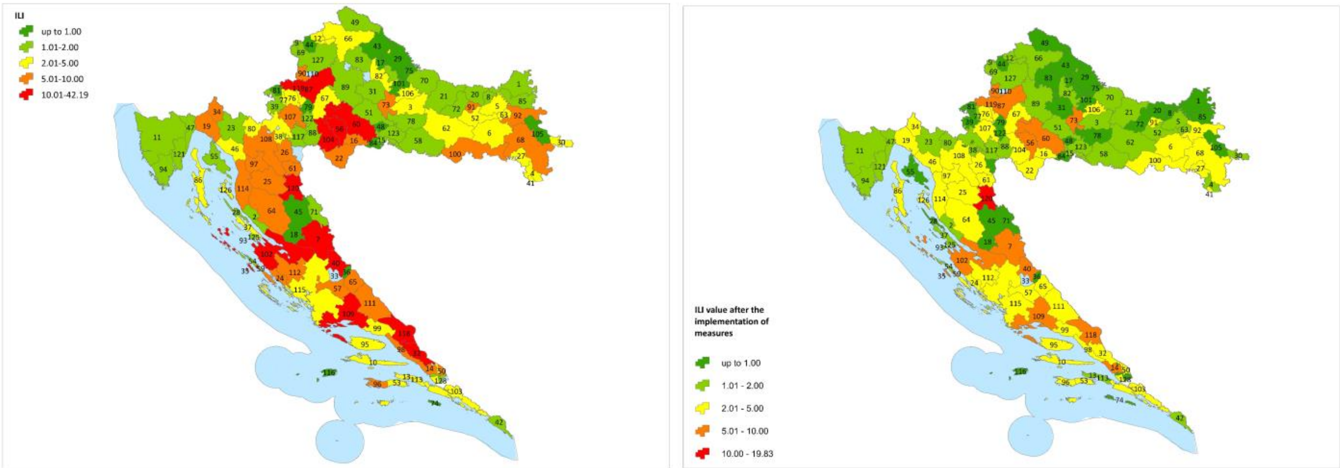

Figure 4. EXAMPLE - ILI today (left) and after the implementation of measures in 2038 (right)

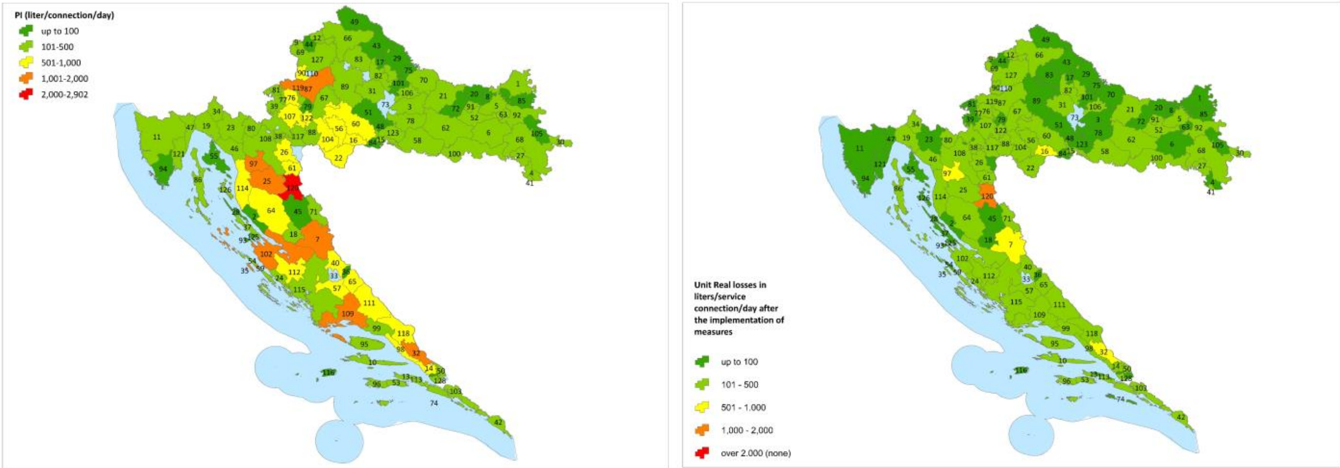

Figure 5. EXAMPLE - Unit value of Real Losses today (left) and after the implementation of measures in 2038 in l/service connection/d (right)

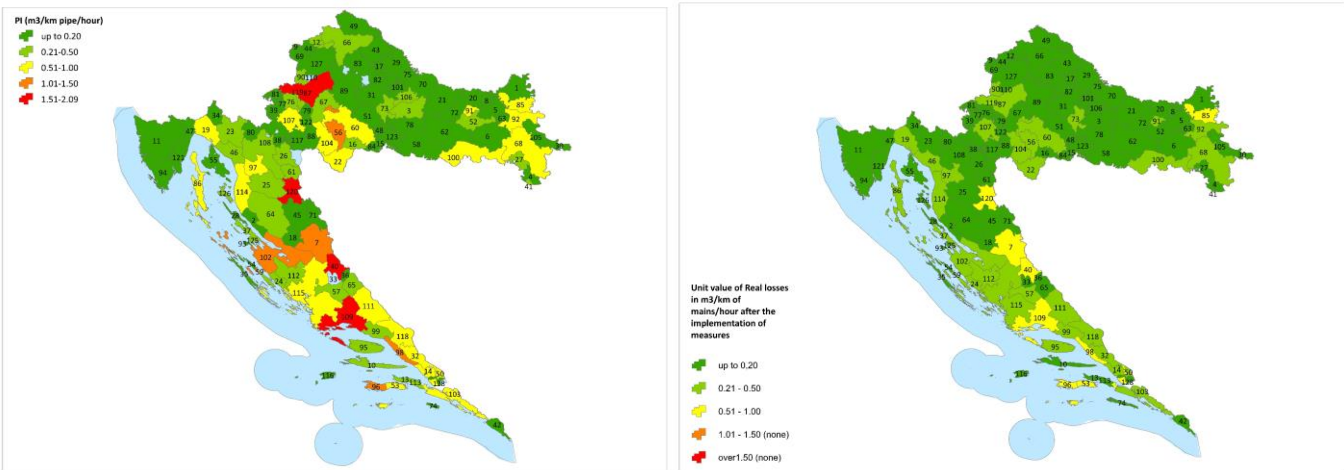

Figure 6. EXAMPLE - Unit value of Real Losses today (left) and after the implementation of measures in 2038 in m³/km of mains/h (right)

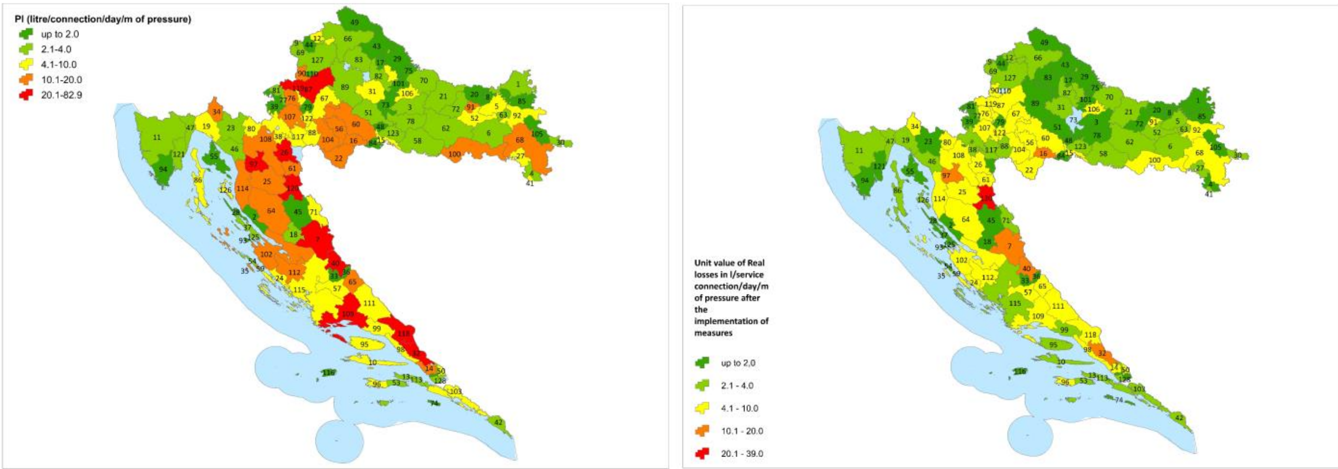

Figure 7. EXAMPLE - Unit value of Real Losses today (left) and after the implementation of measures in 2038 in l/service connection/d/m of pressure (right)

4 SOURCES OF FINANCING AND TIME PLAN

4.1 Sources of financing

When analyzing the sources of financing, focus on the identification of available international and national grants and definition of a financing gap, i.e. make a preliminary calculation of the missing funds to close the financial structure of proposed measures and activities.

Make a detailed analysis of financing sources by analyzing:

- *Basic model (Model 1): Identify the potential of financing exclusively through PWSP's price of water (with or without taking out a loan), particularly in the part of savings from water loss reduction (incremental impact of reduced operating costs which has a positive impact on the reduction of PWSP's total operation costs, and reduction of the development fee when applying the model of calculation based on abstracted water volumes)*
- *Alternative model (Model 2) of financing presented in the NLRAP (co-financing measures from current and future EU funds and from national funds in the total amount of 40%, and the remaining 60% from loan financing by charging the future water price or increasing the development fee)*
- *A potentially new model of financing*

Present the simulations of projections of using a particular financing source according to the dynamics of implementation of individual measures. Projections have to present the time dynamics of the financing gap (regardless of the analyzed model).

For all analyzed models, present pressures on the price of water (development fee increases) which refer to an increase calculated in relation to the missing investment funds for all the analyzed models.

Also present the impacts of implementation of measures which positively impact operating costs (cost reduction in EUR/m^3) which is reflected on the incremental part of the overall price of water.

4.2 Effect on the price of water and affordability

Since the investment dynamics is directly related to the dynamics of achieving effects of defined measures and activities, the financial plan has to be considered through the prism of the water usage fee and the price of water supply. Based on the investment dynamics, define the years/period in which significant effects on the water service price are expected.

The planned investment in water loss reduction has an effect on the price of water service through calculated depreciation and through customers co-financing the investment. It is therefore necessary to make projections of incremental operating costs and maintenance costs respecting the effects of measures on total abstracted volumes. In addition to the effect on the price of water supply service, the reduction of losses will also have an effect on the adjustment of the level of the water usage fee.

Effects on the price of water have to be presented in total amount and broken down into the basic price of water (fixed and variable parts) and water fees (development fee and water usage fee), taking account of the methodological guidelines defined by the provisions of the Regulation on the methodology to define the prices of water services adopted in June 2023 (OG 70/23) and the Guidelines of the Water Service Council on the methodology to define the prices of water services. If different tariff areas are used in a service area, prepare effects on the price of water for each tariff area.

For the analyzed financing models, analyze the affordability of the price of water services for the population, taking into account:

(i) Water loss reduction measures

(ii) Measures of projects in preparation and/or implementation which refer to meeting the national objectives of water supply and wastewater collection in a service area

Analyze the affordability of the price of water services for the population (ratio of the annual cost paid by the household for water to the average net available household income) in relation to the total price of water for all tariff areas (if different tariff areas are applied in a service area).

4.3 Time plan

Elaborate a time plan for the implementation of all foreseen measures, in the scope/amounts adapted to the priority reduction of water losses, i.e. to the needs of the service area. Make sure that already in initial steps of implementation those activities are implemented at least partly which will lead to a faster initial effect of loss reduction. Adapt the dynamics of implementation of individual groups of measures to the specifics of each water supply system and real needs, while certain groups of measures can be implemented simultaneously. For example, some of active leakage control measures such as micro-locating (correlators, geophones, noise loggers, smart balls, etc.) can be implemented even before regulating pressure in the system or its parts, since leak detection using acoustic methods is more efficient at higher pressures in the network.

Analyses that the time plan needs to contain:

- *Levels of water losses (real and apparent) in the service area;*
- *PWSP capacities to implement measures and improvement possibilities;*
- *Time required to prepare plans and designs, obtain building permits, and form teams by PWSPs (including if needed hiring external technical assistance);*
- *Time required for public procurement procedures (for the activities that include public procurement of services/works/equipment);*
- *Capacities of available consulting and construction sectors;*
- *Financial weight of investment into measures to improve water loss management;*
- *Requirements of the Directive (EU) 2020/2184 on the quality of water intended for human consumption - recast (DWD recast) that refer to time schedule related to water loss reduction action plans and in a later phase expected setting of thresholds and/or target values of water loss reduction indicators.*

Define time priorities of investment in relation to the relevance of water losses of each PWSP:

- *Level of losses*
- *Specific indicators of water losses*
- *Loss reduction significance in relation to the sensitivity/risks of water supply systems (system condition and impact from the environment)*

Plan the targeted water loss reduction values in the period until 2038.

NOTE:

The NLRAP period for the implementation of measures to improve water loss management is 2024-2038. During that period, it is estimated that the national-level NRW will be reduced from the current 235 million m^3/year to 113 million m^3/year. That 15-year period (particularly its initial years) also includes activities implemented by PWSPs according to available resources and measures identified earlier, then activities on the preparation of utility action plans (deadline December 2025), but also significant strengthening of PWSPs to address water losses. The implementation of measures continues after 2038 as well, when further progress in water loss reduction is expected (continued implementation of active leakage control measures and continued rehabilitation/replacement of mains with proposed investment in replacement of at least 2% per year).

All the measures have to be identified in utility loss reduction action plans and elaborated in detail in terms of implementation for the period until 2038, including a financial plan and effects of implementing measures for the period until 2038. In that way, utility loss reduction action plans will in planning terms be harmonized with the NLRAP, thus making it possible on the national level to monitor progress and achieve the targeted values from the NLRAP until 2038.

4.4 Assessment of plan implementation risks

Assess the risks in implementing the utility loss reduction action plan.

The following methodological steps in risk assessment are defined:

- *Step 1: Risk identification (in relation to the defined measures, identify the main groups of external and internal risks that may have a significant impact on implementation)*
- *Step 2: Risk level assessment (identify the risk levels for the identified risks using Guide to Cost-Benefit Analysis of Investment Projects (European Commission, December 2014) where the risk level is defined as the combination of risk severity and risk probability)*
- *Step 3: Sensitivity analysis (analyze the sensitivity of the impact of change of certain factors on the main outputs of the plan, in particular impact on the water usage fee and on the price of water services)*
- *Step 4: Conclusion (draw conclusions, in particular the consequences of delays in the implementation of measures)*

Present the results of risk assessment with risk reduction measures in the form of tables and charts.

Pay special attention to the visualization of effects of potential delays in the implementation of water loss reduction measures, using as an example the presentations in the NLRAP.

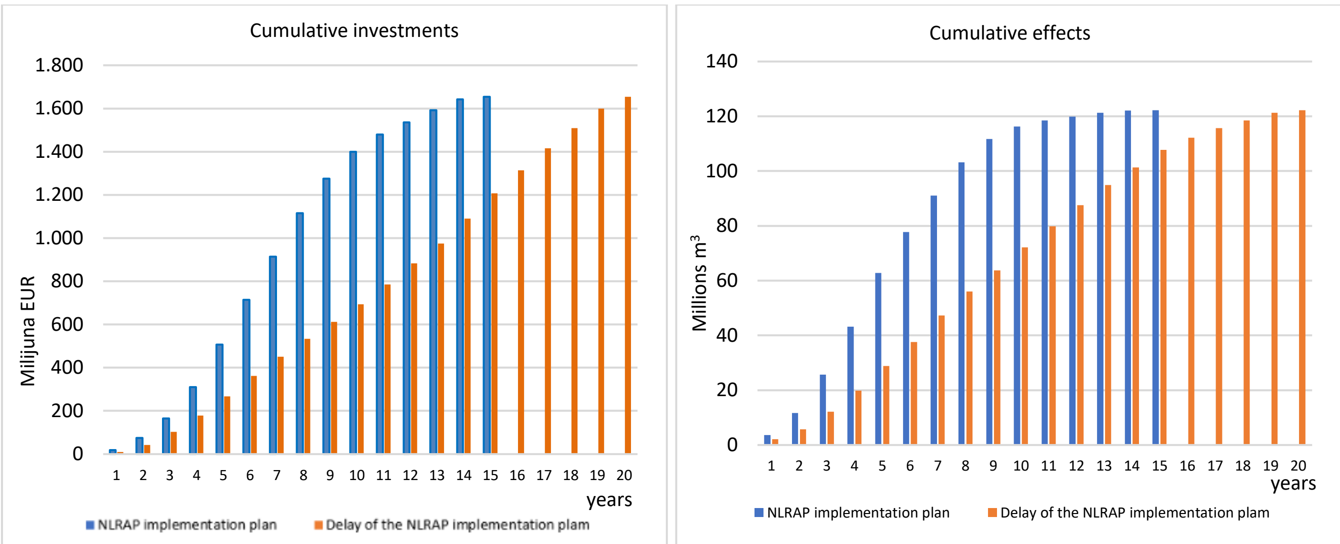

Figure 8. EXAMPLE - Effects of potential delay in the implementation plan

The utility loss reduction action plan needs to foresee safety mechanisms for the implementation of the plan, thus mitigating adverse results of the failure to achieve water loss reduction objectives.

5 IMPLEMENTING THE PLAN

5.1 Establishment of organizational structure

Prepare a proposal for the establishment of PWSP's organizational structure for water loss management.

When preparing the proposal, follow the following guidelines:

- *Recognize the importance of water loss management in PWSP's structure and organizational chart;*

- *Form a water loss management department as a precondition for successfully coping with losses (contributing to PWSP performance efficiency, i.e. water loss management through changing the PWSP-level approach, adopting suitable plans and investment programs, and taking timely action on water loss reduction);*
- *The organizational chart shall make sure (if it is not its part) that the water loss management department is actively connected with the planning and development department, the water supply system maintenance department, the customer department (accounting or business department), and IT department with an integrated database (including GIS);*
- *The water loss management department must be headed by an engineer (technical sciences with broad operational experience, in particular in NRW management);*
- *The number of people in the department will depend on the network size, system complexity, significance of water losses, level of knowledge, and the number/size of control areas.*
- *In terms of capacities, specify which services will be in-house and which services shall be outsourced to specialised companies*

5.2 Establishment of a water loss management team

Based on European and global guidelines, i.e. the guidelines given in the National Loss Reduction Action Plan and supporting tools, foresee suitable establishment of water loss management teams. These teams have to consist of experts with adequate qualifications, and it is necessary to define areas which individual engineers can integrate and cover. The teams have to be equipped with appropriate leak detection software and equipment.

5.3 Establishment of a GIS team (integrated into an "integral" system of the GIS team)

Propose the establishment of a GIS team to know, monitor and manage water losses. Plan the establishment of a joint GIS platform or a similar platform which will collect and analyze system data, and which in addition to basic indicators also needs to contain a link to the customer database, register of failures, SCADA system data, data from field visits, and water loss analysis module (zoning, monitoring, alarming, etc.).

5.4 Plan to establish/update DMAs

Prepare an economic analysis of DMA establishment. DMAs enable less time required to become aware of, locate and repair leaks once located, thus reducing the overall leakage volume. However, due to costs and a significant change in flow directions and operating conditions, forming a bigger number of DMAs can be problematic in its initial phase. Likewise, establishing DMAs in dense city areas could also be problematic due to inability to shut off certain sections or install new valve meter shafts. In certain circumstances of difficult establishment of DMAs, the establishment of virtual DMAs may be deemed as a more acceptable solution.

Prepare a plan to establish/update DMAs in the reference period of app. 15 years, since smaller zones can be established after the establishment of DMAs. If needed, additionally prepare a plan to establish/update the virtual DMAs in the reference period of app. 15 years.

5.5 Plan to update hydraulic model

Prepare a plan to update the hydraulic model, with updates concerning the character of change in the system and periodic updates since it is expected that the implementation of the action plan will last some 15 years. Namely, with the formation of new DMAs and PMAs, operating parameters and consumption will change, and thus also the parameters for the calculation of certain components (e.g. average pressure).

5.6 Plan of activities to implement measures

Develop in detail an implementation plan for the foreseen measures, containing at least:

- *Definition of all the activities and sub-activities (including organizational aspects) on the implementation of water loss reduction measures;*
- *Elaboration of measures (and in which period) which will be implemented by PWSP alone (without external services/works);*
- *Elaboration of measures (and in which period) which will be implemented by PWSP through external works/services contracts;*
- *Identification of needs for technical assistance to PWSP in the implementation of water loss reduction measures;*
- *Definition of project packages for targeted financing (on their own or within other water and wastewater projects).*

Prepare an outline of the plan to implement measures which will continue to be implemented (or introduction of new measures) even after the completion of the 15-year period.

6 INDICATORS TO MONITOR PLAN IMPLEMENTATION

Establish a utility-level monitoring and reporting system for the implementation of the Utility Loss Reduction Action Plan in order to:

- *Monitor the establishment of the water loss management system, including the effects of implementing measures on the reduction of water losses, i.e. achievement of the water loss reduction objectives in the service area defined by the Plan;*
- *Report to the national bodies that monitor NLRAP implementation on the results in the service area and on the achievement of national objectives in water loss management.*

The utility-level monitoring and reporting system needs to contain at least the following:

- *Water loss reduction indicators (NRW reduction, m^3/year, ILI, unit real loss in l/service connection/d and in l/service connection/d/m, and in l/km of mains/h, CRLI);*
- *Information about the employees (office and field) working on water loss reduction measured through number/km of mains or number/service connection;*
- *Data about specific energy consumption, expressed in kWh/m^3 and in kWh/m^3/m pumping height of water supplied;*
- *Data on the implementation of measures (by groups of measures) expressed in EUR/year;*
- *Data on the implementation of measures (by groups of measures) expressed through % of investment in relation to the total identified value of the measure/s;*
- *Data about reduced pressures to water bodies (reduction of abstracted water volumes) expressed in m^3/year.*

It is also necessary to ensure that the proposed monitoring system established in the service area is harmonized with the national system which monitors the implementation of loss reduction action plans of all PWSPs and with the reporting system according to the Regulation on evaluation of PWSPs' operational efficiency which lays down the benchmarks and indicators of operational efficiency, the method of collecting and submitting data to calculate the indicators, the method of measuring, evaluating, and reporting on operational efficiency, and the method of data record keeping.

7 LIST OF ABBREVIATIONS AND SCOPE OF TABLE AND CHART PRESENTATIONS

7.1 Abbreviations used in the document

DG	Directorate-General for Structural Reform Support
DMA	District metered area
DWD	Directive 98/83/EC on the quality of water intended for human consumption
DWD Recast	Directive (EU) 2020/2184 on the quality of water intended for human consumption (Recast)
EBRD	European Bank for Reconstruction and Development
EIB	European Investment Bank
ESIF	European Structural and Investment Funds
EU	European Union
EurEau	European Federation of National Associations of Water Services
HGVIK	Croatian Association of Water and Wastewater Companies
HV	Croatian Waters
IBRD	International Bank for Reconstruction and Development
ID	Identification number
ILI	Infrastructural leakage index
IWA	International Water Association
KPI	Key performance indicator
LSGU	Local self-government unit
MEPGT	Ministry of Environmental Protection and Green Transition
MIS	Management Information System
MS	Member State
NLRAP	National Loss Reduction Action Plan
NLRP	National Loss Reduction Program
NRW	Non-revenue water
OG	Official Gazette
OPCC	Operational Program Competitiveness and Cohesion
PE	Population equivalent
PI	Performance indicator
PMA	Pressure management area
PWSP	Public water service provider
RBMP	River Basin Management Plan
SIV	System input volume
ULRAP	Utility Loss Reduction Action Plan
UWWTD	Directive 91/27/EEC and 98/15/EC concerning urban wastewater treatment
VAT	Value added tax
WAREG	European Water Regulators
WFD	Directive 2000/60/EC establishing a framework for Community action in the field of water policy (Water Framework Directive)
WLSG	Water Loss Strategic Group
WSC	Water Service Council
WWTP	Wastewater treatment plant

7.2 Scope of table and chart presentations

List of figures and/or charts - recommended to use the presentations like those in the NLRAP.

Chapter 2

In Chapter 2 (Baseline Assessment), prepare the following table and chart presentations (not necessarily ranked chronologically) based on data from the questionaries and Consultant's analyses.

List of tables:

- Water supply systems in the service area according to system input volumes
- Components of total price of water paid by customers (population or industry)
- Analysis of introducing the new calculation model for the water usage fee (old/new/difference)
- Basic water balances by water supply systems (NRW m^3/year and %)
- Extended water balance according to the IWA methodology, on the level of water supply systems, DMAs, and total
- Description of the main terms in the extended and simplified water balance
- Analyses of 95% confidence of the calculation of Water Balance components on the level of water supply systems, DMAs, and total
- Overview of water supply systems by unit value of real losses in l/service connection/d, m^3/km of mains/h, l/service connection/d/m of pressure
- Overview of activities implemented within the NLRP

List of figures and/or charts:

- Spatial distribution of water volumes (billed authorized consumption) delivered to customers by water supply systems
- Chart with water volumes (billed authorized consumption) delivered to customers by water supply systems
- Rate of connection to public water supply systems
- PWSP financial performance (water services and other permitted activities) over the last 5 years (revenue/expense/ profit before tax)
- Share of revenue from individual water services (water supply, wastewater collection, wastewater treatment) in total revenue from water services
- Operating revenue from water services of water supply, split into households and industry categories
- Spatial distribution of average price of water for the population category, water supply system/PWSP level
- Share of the average water price paid by the population in disposable household income, water supply system/PWSP level
- Water price structure by water supply systems
- Amounts of calculated water usage fee (in EUR/year) in the last 5 years
- Chart with amounts of the calculated water usage fee before and after the introduction of the new model by water supply systems (going up or down)
- Revenue from mandatory water usage fee according to the new model
- Difference in revenue from the water usage fee according to the old and new models
- Investment in the water supply sector over the last 5 years (in EUR/year) by water supply system/PWSP
- Spatial distribution of water input into the water supply system, water supply system level
- Spatial distribution of annual water volumes delivered to customers (billed authorized consumption), water supply system level
- Spatial distribution of NRW (estimate), water supply system level
- Coverage with water storage capacity in current state, water supply system level and total
- Coverage with water storage capacity for planned state, water supply system level and total
- Water meter accuracy (classes) on the national level, water supply system level and total
- Register of pipe material statistics, water supply system level and total
- Pipe statistics by materials, water supply system level and total
- Register of pipe profile statistics, water supply system level and total
- Register of pipe age statistics, water supply system level and total

- Distribution of average age of mains network, water supply system level and total
- Percentage of usage of hydraulic valves for pressure regulation, water supply system level and total
- Average pressure in water supply systems and total
- Lengths of mains within particular pressure ranges, water supply system level and total
- Method of implementing water hammer protection, water supply system level and total
- Share of frequency regulated pumps, water supply system level and total
- Method of implementing pressure control, water supply system level and total
- Water consumption forecast (drop, stagnation, growth), water supply system level and total
- Water supply risk in dry years, water supply system level and total
- Limited capacities of main supply routes in relation to current demand, water supply system level and total
- Limited capacities of main supply routes in relation to planned increased demand, water supply system level and total
- Limitations in available water supply volumes in relation to demand (today) and identified capacities, water supply system level and total
- Limitations in available water supply volumes in relation to increased demand and identified capacities, water supply system level and total
- Types of limitations in available water supply volumes, water supply system level and total
- Possibility to increase available water volumes, water supply system level and total
- Status of GIS development, water supply system level and total
- Register of leaks in a five-year period, water supply system level and total
- How leak record is kept, water supply system level and total
- Status of SCADA system implementation, water supply system level and total
- Number of portable flow meters, water supply system level and total
- Number of portable flow meters per team, water supply system level and total
- Number of portable pressure meters, water supply system level and total
- Number of portable pressure meters per team, water supply system level and total
- Other active leakage control equipment, water supply system level and total
- How staff training is implemented, water supply system level and total
- Total number of employees, employees in development and maintenance, and employees on water losses, water supply system level and total
- Mains length by employee categories, water supply system level and total
- Technical teams for water losses established, water supply system level and total
- Mains length per team, water supply system level and total
- Average number of employees per team, broken down into the number of engineers and low-skilled workers, water supply system level and total
- Repair frequency of pressure regulation valves, water supply system level and total
- Repair frequency of air release-intake valves, water supply system level and total
- How water supply network is released of air, water supply system level and total
- Method of implementation of active leakage control, water supply system level and total
- Method of DMA establishment, water supply system level and total
- Duration of leak repair on transmission mains, water supply system level and total
- Duration of leak repair on distribution mains, water supply system level and total
- Duration of leak repair on house connections, water supply system level and total
- How potential for system pressure management is analyzed, water supply system level and total
- How system pressure is regulated, water supply system level and total
- How work in a company is organized, water supply system level and total
- How different departments in a company are coordinated, water supply system level and total
- How water loss control programs are planned and implemented, water supply system level and total
- Planning and implementing annual water mains reconstruction programs, water supply system level and total
- Average annual quantity of rehabilitated mains, water supply system level and total
- Average annual rate of rehabilitation of house connections (a pipe from connection to the main to the water meter), water supply system level and total
- Defining short- and long-term improvement measures, water supply system level and total

- Do PWSPs themselves prepare a simplified water balance on the annual level, water supply system level and total
- Assessment of water theft intensity, water supply system level and total
- How customer consumption is measured, water supply system level and total
- Water meter reading frequency, water supply system level and total
- How water meter readings are controlled, water supply system level and total
- Practice related to water meter replacement and water meter age, water supply system level and total
- How illegal connections are controlled, water supply system level and total
- Customer database management method, water supply system level and total
- Result of analysis of 95% confidence of the calculation of individual Water Balance components, level of water supply systems, DMAs, and total
- Change in non-revenue water volumes over the last 5 years, water supply system level and total
- How performance indicators are used, water supply system level and total
- Calculated ILI, water supply system level and total
- Spatial distribution of the ILI value, water supply system level
- Calculated unit value of Real Losses in l/service connection/d, water supply system level and total
- Spatial distribution of unit values of Real Losses in l/service connection/d, water supply system level
- Calculated unit value of Real Losses in m^3/km of mains/h, water supply system level and total
- Spatial distribution of unit values of Real Losses in m^3/km of mains/h, water supply system level
- Calculated unit value of Real Losses in l/service connection/d/m of pressure, water supply system level and total
- Spatial distribution of unit values of Real Losses in l/service connection/d/m of pressure, water supply system level
- Number of flow (a) and pressure (b) measurements per km of the mains network in PWSPs, water supply system level and total
- Establishment of DMAs, water supply system level and total
- Size of DMAs, water supply system level and total (km/DMA)
- Change in non-revenue water over the last 5 years, water supply system level and total
- Relation between system input volume and total energy consumption, water supply system level
- Limitations in available water volumes
- Climate change indexes (precipitation decrease in mm, precipitation decrease in %)
- Climate change severity classes based on RCP 4.5 and RCP 8.5 scenarios (temperature impact taken into account)
- Classification of climate change severity based on the “average” scenario (temperature impact taken into account)
- Adopted risk assessment matrix related to limitations in available water volumes and climate change

Chapters 3 and 4

In Chapter 3 (Water Loss Management Plan) and Chapter 4 (Sources of Financing and Time Plan), prepare the following table and chart presentations (not necessarily ranked chronologically) based on data from the baseline assessment and Consultant’s analyses.

List of tables:

- Groups of water loss reduction measures
- Description of water loss reduction measures
- Recapitulation of water loss reduction measures
- Estimated value of basic measures to improve water loss management and effects on NRW reduction
- Water supply systems grouped according to the ILI value after the implementation of measures
- Relevance of water losses and investment priorities
- Classification of severity of plan implementation risks
- Probability of plan implementation risks
- Level of plan implementation risks
- Identification of plan implementation risks and prevention measures
- Results of analysis of plan implementation risks

- Extended water balance according to the IWA methodology for the planned state, on the level of water supply systems, DMAs, and total
- Analyses of 95% confidence of the calculation of Water Balance components for the planned state on the level of water supply systems, DMAs, and total
- Additional sensitivity analysis for the identified risks
- Projection of available and missing funds to implement the identified measures
- Target NRW reduction values until 2038

List of figures and/or charts:

- Result of analysis of 95% confidence of the calculation of individual Water Balance components, level of water supply systems, DMAs, and total
- Spatial distribution of unit values of Real Losses (with indicator values specified) and Criterion 1
- Spatial distribution of the volume of Real Losses (with the values in m^3 specified) and Criterion 2
- Spatial distribution of the scope of the required rehabilitation of mains in Priority Groups I and II (specifying the % of replacement) and Criterion 3
- Spatial distribution of risks (Criterion 4) according to the risk matrix, limitations in available water volumes and climate change severity
- Spatial distribution of additional technical criteria (Criterion "n") as needed (type of material, bearing capacity, etc.)
- Spatial distribution of the relevance of water losses
- Overall relevance of losses to assess the required replacement of mains and the estimated amount of investment in the replacement of mains
- Spatial distribution of the NRW after the implementation of measures, water supply system level
- Comparison of NRW volumes before and after the implementation of measures by water supply systems
- NRW and Real Losses after the implementation of measures in the service area
- ILI after the implementation of measures, water supply system/PWSP level
- Comparison of the ILI before and after the implementation of measures, water supply system/PWSP level
- Unit value of Real Losses in liters/service connection/day after the implementation of measures, water supply system/PWSP level
- Comparison of unit values of Real Losses in liters/service connection/day, PWSP level before and after the implementation of measures, water supply system/PWSP level
- Unit value of Real Losses in m^3/km of mains/h after the implementation of measures, water supply system/PWSP level
- Comparison of unit values of Real Losses in m^3/km of mains/h, PWSP level before and after the implementation of measures, water supply system/PWSP level
- Unit value of Real Losses in l/service connection/d/m of pressure after the implementation of measures, water supply system/PWSP level
- Comparison of unit values of Real Losses in l/service connection/day/m of pressure, PWSP level before and after the implementation of measures, water supply system/PWSP level
- Investment by years
- Effects of investment by years (NRW reduction, m^3/year)
- Cumulative investment by years
- Cumulative effects by years (NRW reduction, m^3)
- Costs of loss reduction measures by years (EUR/year)
- Effects of loss reduction measures by years (m^3/year)
- Effects of potential delay in the implementation plan
- Investment structure and intensity by investment years
- Projection of potential sources of financing
- Projections of potential sources of financing by years
- Projections of potential sources of financing by years in %
- Implementation of measures by years, %
- Implementation of measures by years and groups of measures
- Cumulative effects of measures by years, %

- Effects of measures by years and groups of measures
- Impact of measures on the price of water services (EUR/m^3), for the analyzed models
- Impact of measures on affordability for the analyzed models

ANNEX 1. ACTIVITIES IMPLEMENTED FOR THE PURPOSE OF PREPARING THE ACTION PLAN

(i) Part of Group of measures - System data improvement measures, GIS sub-measures (with input/update of system data)

Request, collect and systematize data and background documents in an integrated service area (for each water supply system, without field investigations in terms of geodetic surveys, excavations, etc.). Data can be taken over from different GIS software tools or other background documents. It is necessary to encompass the entire network of the present state using all available background documents (shapes, CADs, maps) or, if data is missing, draw the system in cooperation with the Client.

After collecting data in chronological order of data quality, develop a joint database where for each element the level of information quality will be specified: "GIS_correct", "design documents", "overview map" or "Client's information". If data for the year in which mains were built is not known, it is together with the Client necessary to make an assumption and attribute whether it is mains "more than 40 years old" or "less than 40 years old".

The said data, particularly the length of the water supply network, will be the basis for the development/update of hydraulic models and calculation of the basic components of water loss indicators and the basis for the prioritization of measures.

The database that is formed/upgraded needs to be prepared in a digital, open, vector format. After completion, it will be handed over to the competent PWSP. The database (including the shape format) needs to contain information about:

- *Mains (material, nominal profile, nominal pressure, year of construction and length)*
- *Service connections (material, nominal profile, nominal pressure, route, year of construction, name of user with the defined consumer category and annual delivered volume in m^3)*
- *Failures (for the period from 2019 onward, with position and description)*
- *Structures*
  - Pumping stations (number of pumps, operating algorithm, pump model, year of construction, installed capacity, Q/H characteristics, metering instruments, is there frequency regulation or not, is there water hammer protection and if yes, what are its technical characteristics)
  - Water storage tanks (volume, number of water chambers, volume of each water chamber, is there a separate valve chamber or not, bottom level, overflow level, and level of inflow pipeline in the water chamber, method of filling the water chamber, device to regulate the filling of the water chamber, year of construction, metering instruments)
  - Regulation shafts (regulator type, regulation value, year of installation)
  - Abstraction sites/water intakes (capacity, water intake positions, other structures with description of their function, metering instruments)
  - Metering points (type of equipment, metering type, communication method)

Completely fill the database will all available data and stick with the specified attribute names so that analyses can be made on the national level as well.

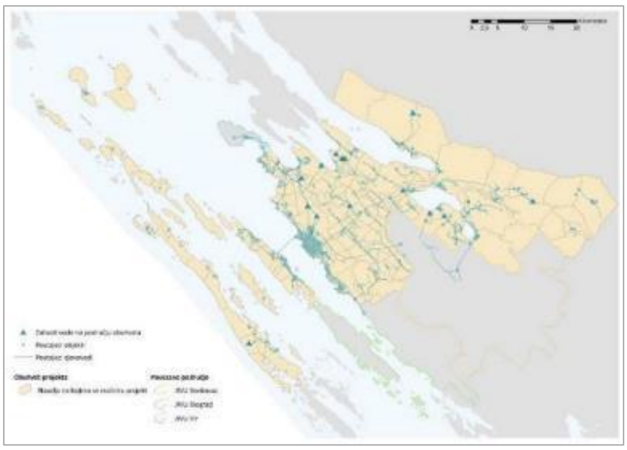

Figure 9. Example of a map from a GIS database

Table 4. Example of a database - mains (shape file)

ID_MAIN	*SOURCE_DATA*	*YEAR_CONST*	*YEAR_REHAB*	*MATERIAL*	*……*
1	*Text*	*Number*	*Number*	*Text*	
2	*Text*	*Number*	*Number*	*Text*	
3	*Text*	*Number*	*Number*	*Text*	
4	*Text*	*Number*	*Number*	*Text*	

Table 5. Mandatory attributes - mains (shape file)

Attribute	*Entry*	*Note*
ID_MAIN	*Number*	
SOURCE_DATA	*Text*	*Selection (specify possible selection: GIS_CORRECT, DESIGN_DOC, OVERVIEW_MAP, INF_CLIENT)*
TYPE	*Text*	*Selection (specify possible selection: MAIN_LINE, SERVICE_CONN)*
SERVICE_CONN_YEAR_VOL	*Number*	*Selection (specify possible selection: IND, TEMPORARY_POP, PERMANENT_POP)*
YEAR_CONST	*Number*	*Entry or Selection (specify possible selection: LESS_40YEARS, MORE_40YEARS)*
MATERIAL	*Text*	*Selection (specify possible selection: DUCTILE, PVC, PEHD, AC, STEEL, GALV_OTHER)*
LENGTH	*Text*	
DN	*Text*	*Nominal*
FAILURES_5YEAR	*Number*	*Entry in the last 5 years with the time (date) of each failure*
NOMINAL PRESSURE	*Number*	

Table 6. Example of a database - structures (shape file)

ID_STRUCTURE	*SOURCE_DATA*	*YEAR_CONST*	*YEAR_REHAB*	*VOLUME*	*……*
1	*Text*	*Number*	*Number*		
2	*Text*	*Number*	*Number*		
3	*Text*	*Number*	*Number*		
4	*Text*	*Number*	*Number*		

Table 7. Mandatory attributes - structures (shape file)

Attribute	*Entry*	*Note*
ID_STRUCTURE	*Number*	
TYPE_STRUCTURE	*Text*	*Selection (specify possible selection: STORAGE TANK, PUMP_STATION, INTAKE, MET_REG_SHAFT)*
YEAR_CONST	*Number*	*Entry or Selection (specify possible selection: LESS_40YEARS, MORE_40YEARS)*
INST_CAPAC	*Number*	
Q/H	*Number*	*Selection (specify possible selection: FREQ_REGULATED, NO_FREQ_REG)*
VOLUME	*Text*	
LEVEL_BOTTOM_ST	*Text*	
LEVEL_WATER_ST	*Text*	
TYPE_REGULATOR	*Number*	*Selection (specify possible selection: DOWNSTR, UPSTR, CONSTANT, DEPEND_ON_DEMAND)*
MEASUREMENT	*Number*	*Selection (specify possible selection: PRESSURE, FLOW)*
PROTECTION_HAMMER	*Text*	*Selection (specify possible selection: YES, NO)*
SCADA	*Text*	*Selection (specify possible selection: YES, NO)*

(iii) Part of Group of measures - Water supply system optimization measures - Sub-measure: Development/Update of calibrated mathematical models

Identify together with the Client whether hydraulic models have been prepared for each water supply system in the last 10 years (particularly after 2017). Define the quality category for each system: "calibrated and reviewed", "revision required" or "development required". Each hydraulic model will have to be updated at least with data about water volume abstracted at water abstraction sites/water intakes established at the level of Croatia, with current consumption, extending it to encompass the entire water supply network.

Development/Update of preliminary mathematical model of the current state

It is necessary to analyze in detail the current state and to develop/update a preliminary mathematical model of the current state of the water supply system within the integrated service area. The preliminary mathematical model has to be developed/updated based on data from the group of measures implemented earlier - GIS.

Development/Update of the preliminary mathematical model of the current state with all system elements implies defining the following:

- Spatial distribution and interrelations of all system elements (mains, water intakes/water abstraction sites, storage tanks, pumping stations, valve shafts, fittings, etc.) based on existing data
- Elevation of node points and structures of the water supply system, based on existing data
- Characteristics of all system elements - pipe material, internal pipe diameter, operating pipe roughness, dimensions of storage tanks and pressure regulation chambers (effective volume, elevation of the bottom levels of storage tanks and pressure regulation chambers, elevation difference between the bottom level and overflow level), characteristics of pumping stations (Q-H curves, capacity, efficiency, etc.), regulation equipment (set-up of pressure regulation valves, etc.), fittings (e.g. set-up of valves), etc. based on existing data
- Operating algorithms of individual structures/elements of the system (dynamics of filling and emptying of water storage tanks, operation of pumping stations, etc.) and their mutual dependence
- On the developed/updated preliminary mathematical model it is necessary to analyze basic hydraulic and operating conditions (in the period of average daily, minimum night and maximum daily consumption). Furthermore, it is necessary to analyze a database about real water consumption (identify the spatial distribution of consumption and volume of water, identify the existence of big and special consumers and other approximate assumptions of distribution of consumption per area), estimate water losses by zones or identify water losses based on existing available measurements (if the system or its individual parts are already divided into metered zones), and enter data into software for hydraulic modelling of water supply systems. The results of analyses made have to be described textually and in the form of graphs. The results of analyses made have to be used for preliminary division of the system into DMAs

Develop the finally defined hydraulic model of the current state in one of the regionally recognized and accepted programs for hydraulic mathematical modelling of water supply systems, and export and convert it in such a way that will enable its further use with all the data in the EPANET application (see: http://www.epa.gov/ORD/NRMRL/wswrd/epanet.html).

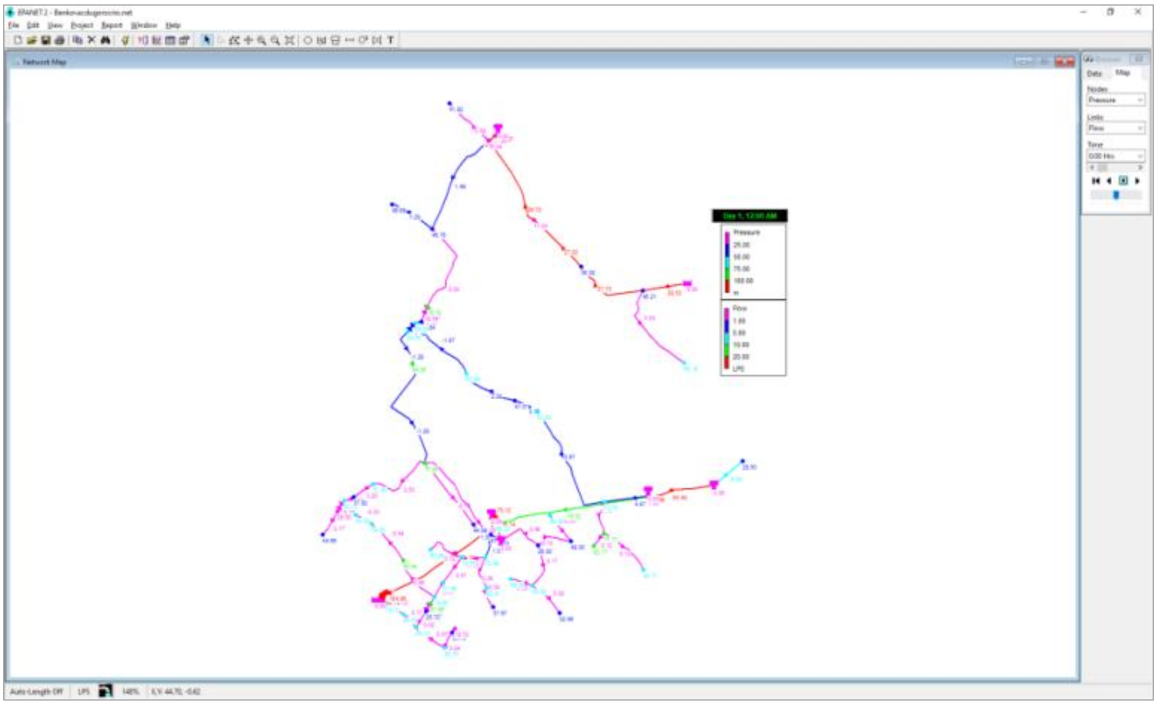

Figure 10. Example of an EPANET hydraulic model

Preliminary division of the system into DMAs and preparation of plan and program for flow and discharge measurements

Collect and analyze the developed conceptual solutions within which the system was divided into DMAs/PMAs and identify the correctness of the proposed zones. Update the preliminary division of the system into DMAs/PMAs, i.e. prepare it for those water service providers/systems for which division into DMAs/PMAs is not foreseen. Present the division of the system into DMAs/PMAs in the form of maps (.dwg) and in GIS.

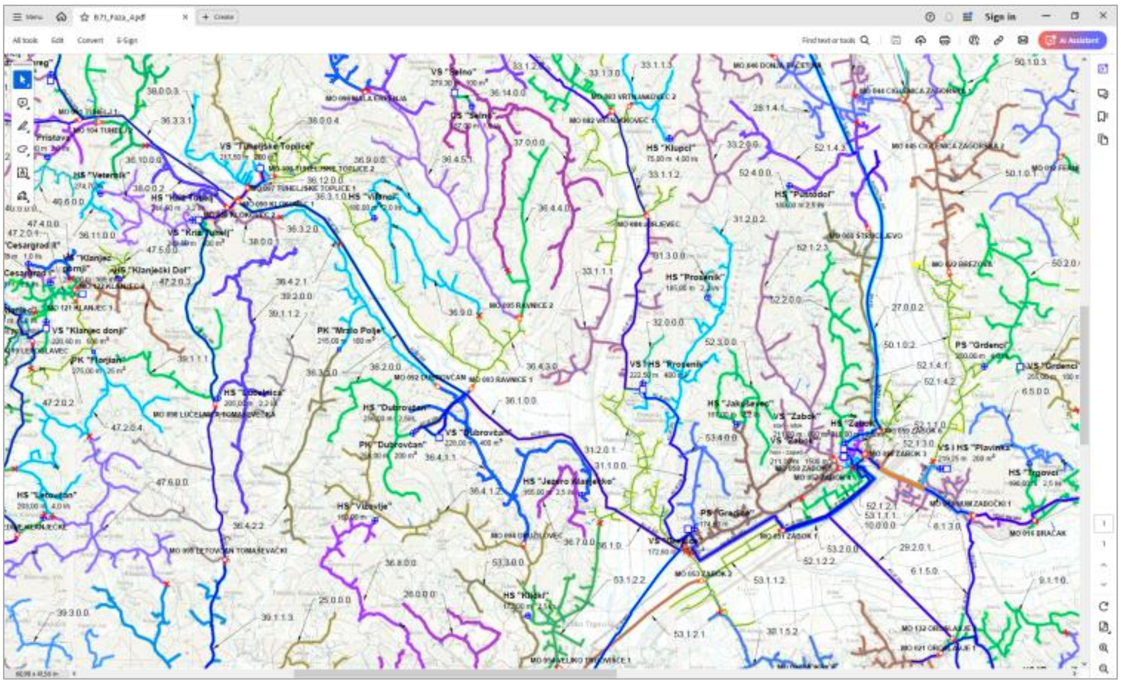

Figure 11. Example of division of the system into DMAs/PMAs with presentation of metering points

If needed, prepare the Plan and Program of potentially required additional measurements of flows and pressures within the integrated water supply system (which will be implemented under this contract). To be prepared on a suitable map in coordination with the Client.

It is necessary to measure flows and pressures on those systems where adequate data is not available. Measurements are in this phase not planned to be implemented thoroughly by the planned DMAs (identified during the preparation of conceptual solutions or other documents), but rather for the main units of the system in order to obtain sufficient information about operating conditions in the water supply system and obtain general information about areas with increased losses (center, outskirts, areas with a newly built network, etc.).

Performing flow and pressure measurements

The following is required for potentially required additional flow and pressure measurements:

- *Initially perform flow measurements in the missing metering points in campaigns of at least three consecutive days with data in continuity (with a 1-minute measurement resolution). All flow and pressure measurements in individual district metered areas have to be done at the same time, measuring both flow and pressure at the same location. In all metering points, the pressure meter has to be installed directly next to the flow meter. Pressure measurement has to be additionally performed in certain locations within DMAs if so required by field conditions or certain knowledge of the department working on the management of water supply system and control of water losses*
- *Perform additional pressure measurements in the missing metering points in campaigns of at least 24 hours with data in continuity in order to check the existence of marked non-stationary events (water hammer simulations) in the system (maximum measurement resolution 0.05 – 0.1 seconds)*

Calibration of the model of current state

Calibrate the preliminary mathematical model of the current state if additional flow and pressure measurements are performed.

The model calibration is to define:

- *Relevant hydraulic characteristics of the mains network and supporting structures*
- *Real hydraulic and operating conditions within the existing system*
- *Real spatial and quantitative distribution of water consumption and water losses*
- *Hourly variations in water consumption in certain parts of the system*
- *Any irregularities in the operation of the existing system (presence of certain elements not registered before, check the operation of certain elements of the system, presence and intensity of water hammers, presence of water theft, etc.)*

Conclusion about the current state of operation of the integrated water supply system

In textual form and in the form of tables and charts describe results (hydraulic and operating conditions of flow, operation of individual elements of the system) obtained on the mathematical model of the current state and point to all the problems and deficiencies in the system, from which the need for further system improvement will derive. The following has to be done:

- *Development of the mathematical model of the current state under conditions of average daily consumption*
- *Development of the mathematical model of the current state under conditions of minimum daily consumption (minimum night consumption)*
- *Development of the mathematical model of the current state under conditions of maximum daily consumption (maximum hourly consumption)*
- *Analysis of results of all the above-mentioned mathematical model simulations, under conditions of average daily, minimum daily (minimum night consumption) and maximum daily consumption (maximum hourly consumption), with primary reference to moments with minimum night and maximum hourly consumption. Reference has to be made to hydraulic and operating conditions of flow (description of problems and deficiencies in the operation of the integral water supply system)*

- *Describe in detail the dependence of operation of structures in the system (operation of pumping stations - e.g. a pump turns on when water in the storage tank drops under a certain level; operation of regulation equipment, etc.)*

Point to incidences of marked non-stationary events in the systems (water hammers) (if detected) and their intensity (according to measurements made) and guidelines to address the issue. On the model of the current state check the operating conditions when establishing DMAs/PMAs.

Mathematical model of the planned operating condition

Analyze the need to extend individual structures in the existing water supply system and/or propose reconstruction of the existing ones by simulating different operating conditions on the calibrated mathematical model of the current state. The potentially modified water supply structure can be expected to result in more balanced and on average lower pressures which will generate fewer water losses.

Special attention shall be paid to the following:

- *Analysis of water demand - define the required future water tanks and their volumes - define the optimum operation of the water supply system in terms of network pressures;*
- *Define the elevation of the planned elements of the water supply system;*
- *Model future water supply structures (pressure boosting stations, pumping and intermediary pumping stations, water tanks, water supply mains) and conduct the required number of preliminary simulations and corrections of the planned inputs by development priorities and by water supply sub-systems, divide the system into water supply zones, foresee pressure regulation;*
- *Correct operating algorithms of existing structures if needed;*
- *Make a simulation of characteristic operating conditions, analyzing different configurations of the water supply system and foreseeable operating options;*
- *Make additional system zoning in terms of balancing network pressures and conveying water into particular zones respecting and analyzing the current state;*
- *Estimate the reduction of losses as the consequence of pressure reduction by individual water supply zone;*
- *Propose priority measures and projects for the construction, rehabilitation and optimization of the condition of the water supply system;*
- *Present the conclusion of the analyses made systematizing the foreseen construction, reconstruction and rehabilitation measures*

Conceptual solution of DMAs

For an efficient pressure management policy and loss reduction prepare a conceptual solution of DMAs/PMAs. Cover the analysis of existing DMAs/PMAs and the overall program that needs to be implemented, consisting of the following activities.

Establishment of main DMAs

This needs to enable full clarification of the water balance in a business unit. The basic principle to be applied is to measure and log all the flows into or out of a DMA so that comprehensive operating balances can be obtained for each of the DMAs. Adjusting DMA boundaries primarily has to be done according to hydraulic criteria, also respecting the administrative boundaries of business units. Make use of available measurements in DMAs or measurements performed as part of these Terms of Reference.

Establishment of sub-DMAs

Sub-DMAs have to be defined according to the principles of an efficient pressure regulation and control policy. The establishment of main DMAs is the starting point, but with results of hydraulic tests and in particular mathematical model simulations it is possible to make additional improvements with the introduction of sub-DMAs.

Study the pressure level aspect so that the pressure supplied to each DMA meets the current standards (minimum pressure) but does not exceed the critical values that contribute to the evolution of leakage: the objective will be to maintain the maximum level of pressure at a level of comfortable supply with an intention to reduce the pressure to the minimum value possible.

Define pressure management areas to make sure the above objectives are met with the installation of pressure regulation valves at points of supply. Design pressure regulation conditions by taking account of the specifics of consumer modulation.

Establishment of virtual DMAs

The formation of DMAs/sub-DMAs, i.e. the establishment of the metering and monitoring system is essential in order to calculate and analyse the status of losses and the resulting emergency activities. Such an approach in urban units, where a water supply system is not formed as "compartments", but rather distribution mains are at the same time transmission mains, can be problematic for several reasons. In order to form DMAs in such densely urbanized environments, it is very often necessary to form a larger number of meter regulation shafts per each DMA, which has an effect on increasing implementation and maintenance costs. The closure of a larger number of boundary valves changes the system hydraulics, with possible occurrence of insufficient pressures in the "downstream" sections of the system. The closure of a larger number of boundary valves will also lead to increased water retention in the newly formed dead ends, particularly in higher-profile sections, calling for more frequent flushing and monitoring of water quality. The closure of individual boundary valves may lead to the reversal of water flow through individual sections of the network, which may result in the sediment rising from the pipe bottom and water becoming turbid, adversely affecting the service quality. Because of these reasons it is justified to establish "virtual" DMAs. The idea is that the system hydraulics doesn't change or doesn't substantially change, and that at key points within bigger DMAs metering points are established which will not be substantially used for the calculation of water balance within DMAs/sub-DMAs; instead, they will be used for monitoring trends and raising alarms in the event of unusual operating conditions (e.g. increasing night flow which may indicate a new failure or increasing leakage at existing bursts) within a virtual DMA.

ANNEX 2. QUESTIONARY

Name of water service provider:

1. Has a Conceptual Solution been developed for the water supply system you are operating?
   - Answer:
2. What year was the Conceptual Solution developed?
   - Answer:
3. Do you import water from another PWSP?
   - Yes
   - No
4. Do you export water to another PWSP?
   - Yes
   - No
5. Is water supply at risk during dry years?
   - Yes
   - No
6. Have you had water use restrictions during dry years (in the period over the last 10 years) on the system you are operating?
   - Yes
   - No
7. Length of the mains network without service connections (km):
   - Answer:
8. Length of transmission mains (km):
   - Answer:
9. Length of distribution network (km):
   - Answer:
10. Length of house connections (km):
    - Answer:
11. What is the average distance of the water meter from the fence (plot boundary)?
    - Answer:
12. Which pipe materials are represented:
    - PEHD
    - PVC
    - Asbestos cement
    - DUCTILE
    - Cast iron - grey cast iron
    - Steel
    - Other
13. Is there pipe statistics by materials
    - Yes
    - No
14. Average age of the mains network (year):
    - Answer:
15. Is there pipe statistics by age?
    - Yes
    - No
16. Is there pipe statistics by diameter?
    - Yes
    - No
17. Average pressure in the mains network, on the level of the entire system (bar):
    - Answer:
18. Number of connected permanent population (current state):
    - Answer:

19. Number of connected temporary population and tourists in the supply area (current state):
    - Answer:

20. Number of household connections (current state):
    - Answer:

21. Number of economic operators' connections (current state):
    - Answer:

22. Has an economic value of water losses (€/m³ or €/year) been calculated for the current state of the system?
    - Yes
    - No

23. What is the economic value of water losses averaged for the entire system?
    - Answer:

24. With which intensity would you rate the theft of water in the system, as a component of apparent losses?
    - No theft
    - Minor quantities stolen
    - Significant quantities stolen
    - Enormous quantities stolen

25. What kind of protection from water hammer is in place?
    - There is no protection from water hammer in the system
    - Protection from water hammer exists only at the water abstraction site/water intake
    - Protection from water hammer exists only at the pumping stations within the system
    - Protection from water hammer exists both at the water abstraction site/water intake and at the pumping stations within the system
    - Protection from water hammer exists both at the water abstraction site/water intake and at the pumping stations within the system and along the mains network

26. How many air release/intake valves are installed in the network?
    - Answer:

27. How often are the air release/intake valves serviced?
    - Every month
    - Every 3 months
    - Every 6 months
    - Once a year
    - Once in 2 years
    - Once in 5 years
    - Less frequent than once in 5 years

28. Have DMAs been established?
    - Yes
    - No

29. If the answer to the question above is Yes, how many DMAs have you established so far?
    - Answer:

30. How many DMAs are planned to be established?
    - Answer:

31. How many pumping stations (including water abstraction sites/water intakes) have been built in the system?
    - Answer:

32. How many pumping stations have frequency regulation of pump operation?
    - Answer:

33. Is pressure regulation implemented in the system?
    - Yes
    - No

34. How many pressure regulation valves in total are installed in the system?
    - Answer:

35. Out of the number specified above, how many hydraulic pressure regulation valves are installed in the system?
    - Answer:

36. How often are the pressure regulation valves serviced?
- Answer:

37. In what way is the air released from the water supply network?
- Air release is not done
- Air release is done with the help of hydrants
- Air release is done with the help of air release and/or air release/intake valves
- Air release is done with the help of hydrants and air release and/or air release/intake valves

38. How many employees in total are employed in your company?
- Answer:

39. How many employees are employed on system development and maintenance?
- Answer:

40. How many employees actively (on a daily basis) work on water losses?
- Answer:

41. Is there a water loss team(s) established?
- Yes
- No

42. How many water loss teams are active?
- Answer:

43. How many employees are there in each water loss team?
- Answer:

44. How many engineers work on the water loss issue?
- Answer:

45. How many portable flow meters do your water loss teams use?
- 0
- 1-3
- 4-6
- ≥ 7

46. How many portable pressure loggers do your water loss teams use?
- 0
- 1-3
- 4-6
- ≥ 7

47. What kind of equipment for active leakage control do the water loss teams use:
- Correlator
- Geophone
- Noise loggers
- Pipe detector
- Other

48. What is PWSP’s total energy consumption (kWh/year; €/year)
- ☐ Answer:

49. What is PWSP’s total energy consumption for public water supply (kWh/year; €/year)
- ☐ Answer:

50. What is PWSP’s total energy consumption for public wastewater collection (kWh/year; €/year)
- ☐ Answer:

51. How do you estimate future energy consumption after implementation of the planned investment, including extension of water supply and wastewater collection systems and WWTPs, as well as measures to improve the existing systems (kWh/year; €/year)?
- ☐ Answer:

52. Do you have your own power plants built and in operation?
- Yes
- No

53. How many power plants are built and in operation?

- ☐ Answer:

54. What is the capacity of all sources of energy combined (kW)?

- ☐ Answer:

55. What is the total energy production (kWh/year; €/year)?

- ☐ Answer:

56. Do you sell excess energy produced?

- Yes
- No

57. Do you plan to build a new power plant?

- Yes
- No

58. Is there a water balance for the 2020-2024 period?

- Yes
- No

59. Is there a register of failures for the 2020-2024 period?

- Yes
- No

60. How do you prepare the water balance (please select one of the options)?

- The water balance is not prepared
- We have tried to prepare the water balance, but we gave up because we don't know how to separate real and apparent water losses
- We prepare the water balance based on our own format of component analysis
- We prepare the annual water balance in accordance with the IWA methodology
- We prepare the annual water balance in accordance with the IWA methodology and we also use an analysis of 95% data confidence in order to understand the accuracy tolerance

61. How is the abstracted water measured?

- Most of the abstracted water is not measured with flow meters
- More than 50% of the abstracted water is measured with flow meters
- The abstracted quantity of water is measured, but we are not sure of the accuracy of measurement (with some meters more than 10 years old)
- The abstracted quantity of water is measured with mechanical and electromagnetic flow meters which are rarely calibrated (checked for accuracy)
- The abstracted quantity of water is measured with electromagnetic flow meters which are regularly calibrated (checked for accuracy)

62. How is the pressure in the system measured?

- We have no devices in the system to register pressure measurements
- We have several devices to measure and register the pressure values at the pumping and other facilities
- We have several devices to measure and register the pressure values at the pumping and other facilities and we occasionally measure the pressure
- We have several devices to measure and register the pressure values at the pumping and other facilities and we occasionally measure the system pressure with devices to measure and register the pressure values
- We have permanently installed devices to measure and register the pressure values and we continuously control the pressure in the facilities and in the system

63. What is the status of GIS development?

- We haven't got any system maps
- The systems maps that we have got aren't updated
- We have started to regularly update the maps
- The maps are updated, but we don't use the GIS
- We use the GIS and we regularly update the system maps

64. Which GIS modules have you got?

- Answer:

65. Have you implemented a SCADA system?

- Yes
- No

66. Which structures in the system do you control?

- Answer:

67. Is the data collected from the SCADA system stored for many years?

- Yes
- No

68. What is the time increment of the data collected from the SCADA system?

- Answer:

69. Is it possible to remotely change parameters in the structures and valves under the SCADA system (flows, pressures)?

- Yes
- No

70. In what way are leakages and repairs recorded?

- We have no records of system leakage repairs
- We can collect leakage data from the register of work orders of the maintenance department or from the register of reports
- We keep records of repaired leakages with the basic information about the type of repair and pipeline diameter
- We make detailed leakage records, recording the leakage location, pipe diameter, material, type of leakage, as well as dates of detection and repair
- We make detailed leakage records, recording the leakage location, pipe diameter, material, type of leakage, dates of detection and repair, entering everything into the GIS

71. How are the performance indicators used?

- We only use the indicator % of NRW for water losses
- We have tried to calculate the performance indicators, but it is still only the % of NRW that is used
- We regularly calculate the indicators for physical (real) water losses which we present in m^3
- We regularly calculate real and apparent water losses according to the IWA methodology and calculate key indicators
- We regularly calculate real and apparent water losses, key indicators according to the IWA methodology, and we publish them in our official annual reports

72. In what way is active leakage control performed?

- It is only visible leakages that are repaired
- We have leakage detection equipment, but we don't use it
- We have leakage detection equipment and we sometimes use it when there is problem in the system
- Leakage detection equipment is frequently used for reported leakages and sometimes to detect unreported leakages
- We perform regular tests and look for unreported leakages (entire system/yearly or according to measurement by zones)

73. In what way are the DMAs established?

- We have no DMAs and no plans to establish them
- We have started establishing DMAs in the system
- We have a few DMAs and we already have first results in the reduction of water losses
- We have several DMAs, and flows and pressures are sometimes measured using portable meters
- We have several DMAs, and flow and pressure measurement is monitored through the SCADA system and an analysis of indicators is done

74. How long does the repair of leakage on transmission pipelines last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 7 days
- The average repair time is from 7 to 3 days
- The average repair time is from 3 to 1.5 days
- The average repair time is up to 1.5 days

75. How long does the repair of leakage on distribution pipelines last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 7 days
- The average repair time is from 7 to 3 days
- The average repair time is from 3 to 1.5 days
- The average repair time is up to 1.5 days

76. How long does the repair of leakage on house connections last?

- We have no records and don't know the rate at which the leakages are repaired
- The average repair time is more than 14 days
- The average repair time is from 14 to 7 days
- The average repair time is from 7 to 2 days
- The average repair time is up to 2 days

77. How many mains are restored on average per year (m)?

- Answer:

78. How many house connections (a pipe from the connection to the main pipeline to the water meter) are restored on average per year (m)?

- Answer:

79. In what way is the consumption by users measured?

- The consumption of water by users is not measured

- Only the big consumers have water meters
- All the big consumers and most of the small consumers (households) have water meters
- All the consumers have water meters except public fountains, public taps, firefighters and other special users
- 100% of water consumers are measured with water meters, with the consumption of water for system maintenance also measured (controlled)

80. How frequently is the consumption by users measured?

- Once a month
- Once in 3 months
- Once in 6 months
- Once a year

81. What is current practice related to the replacement of water meters and age of water meters?

- We have no reliable data on the age of users' water meters
- Many users' water meters are more than 10 years old and we have no program of regular water meter replacement
- We replace only those water meters which are clearly defective
- We have a program of regular water meter replacement, but we don't manage to replace them on time, and there is a considerable number of water meters that are more than 5 years old
- We conduct the water meter replacement program and all the water meters are regularly replaced (calibrated) within 5 years or less

82. What is the state related to the accuracy of water meters?

- All the users' water meters are of accuracy class A and/or B
- All the users' water meters are of accuracy class B and C
- All the users' water meters are of accuracy class C
- All the users' water meters are of accuracy class C and D
- All the users' water meters are of accuracy class D

83. In what way is the user database operated?

- The user (consumer) database hasn't been updated for a long time
- We occasionally update the user database
- The updating of the user database is being improved
- We regularly update the user database together with network visits and field checks
- We have a regularly updated user database connected with the GIS

84. In what way is the reading of consumers' water meters controlled?

- We have no program to control the work of staff reading the water meters
- We rotate the staff doing the manual reading only if we suspect inaccuracies
- We regularly rotate the staff doing the manual reading of water meters
- We regularly rotate the staff doing the reading of water meters, we do random checks, we introduce remote water meter reading
- We use manual/remote water meter readers in the entire system and control the work of staff working on readings and data processing

85. In what way are illegal connections controlled?

- We haven't made any assessments and there is no program to control illegal water consumption
- We occasionally detect illegal connections
- We occasionally detect illegal connections and other forms of illegal water consumption
- We detect and implement the program to locate illegal connections
- We implement the program to locate illegal connections and work on identifying bypass pipes and other forms of water theft

86. In what way are analyses of potential for system pressure management made?

- We don't make analyses of system pressure
- We occasionally measure the pressure in certain parts of the system and try to analyze the results
- We occasionally measure the pressure (minutes), we have an estimate of the average system pressure and we make pressure reduction analyses
- We regularly measure the pressure (minutes and seconds), calculate the average pressure in the system and certain zones, make pressure reduction analyses
- We make regular detailed pressure measurements, we use EPANET or similar software, make analyses of potential improvements in pressure regulation, planning of solutions (manholes, equipment, savings)

87. In what way is the system pressure regulated?

- We have no special regulation of the system pressure in order to control water losses
- We have pressure regulation by managing the operation of pumping facilities
- We have a few pressure regulation areas (zones) with valves (spring, hydraulic), without measurements, no special performance analyses are made
- We have several pressure regulation areas (zones) in the system (with the help of pump frequency control or hydraulic valves), measurements are done and performance analyses are made
- The system is divided into macro and micro pressure regulation areas (zones), methods of advance pressure regulation are used, SCADA-controlled measurements, indicators are calculated

88. In what way is the work in the company organized?

- There is no special department (team) to control NRW
- There is a team (person) to locate leakages, but these people also do other work when needed
- We have a team only to locate leakages, but these people don't make special analyses and reports
- We have a department to control NRW (real and apparent water losses), we make analyses and reports, but there is no special unit/department
- We have a department to control NRW, we make analyses and reports, and there is coordination with the Board (CEO) – regular meetings

89. In what way are different departments in the company coordinated?

- There is no coordination among different departments in the company
- There is occasional coordination (with no special rules or procedures)
- Coordination among some departments has been established for the purpose of efficient water leakage control
- There is regular coordination among departments, coordinated activities are planned and implemented
- We have a special team (or a person) responsible for efficient coordination among all the departments in the company; the Board (CEO) is regularly informed about the plans and results

90. In what way is the water leakage control program planned and implemented?

- We don't make any plans or reports on the implementation of water leakage control activities
- We make implementation plans for annual water leakage control activities, but no special reports on results are prepared
- We make implementation plans for annual water leakage control activities and special reports on results are prepared
- We make implementation plans for annual water leakage control activities, we define objectives, and special reports on results and performance are prepared
- We have a multi-annual strategy of activities with an assessment of objectives, based on which we plan our annual activities, prepare reports on results, and a regular annual external audit is performed

91. In what way is the program of annual reconstruction of water supply system planned and implemented?

- Answer:

92. In what way are the staff working on water leakages trained?

- We don't implement targeted staff training
- Occasionally a small number of people attends conferences, fairs, events and lectures
- We occasionally conduct staff training in order to improve their know-how (including practical work), but without any special plan; we procure expert literature
- A plan and schedule of the regular acquisition of new know-how for all the key jobs has been prepared; effort is made that this is implemented in accordance with the plan
- The company budget has reserved funds for the regular staff training, literature, conferences; a training program is implemented in accordance with the multi-annual strategy; annual implementation reports are prepared

93. Have short- and long-term improvement measures been defined?

- Short-term measures have been defined
- Both short- and long-term measures have been defined
- Neither short- nor long-term measures have been defined

94. Which of the improvement measures are foreseen?

- Optimizing the use of water abstraction sites
- Establishing new pressure zones with pressure reduction in parts of the system
- Replacing the existing spring valves for pressure regulation with hydraulic valves
- Introducing remote reading of water meters
- Establishing DMAs
- Extending and upgrading the SCADA system
- Digitizing the water loss management system

95. What is the estimate of costs of system improvement measures aimed at the reduction of water losses (€)?

- Answer:

96. Is water supply expected to be at risk during dry years/months in relation to the development plans?

- Yes
- No

97. Are there limitations in the capacities of the main water supply routes in relation to demand (today)?

- Yes, during summer months
- Yes, unfavorable conditions throughout the year

98. Do you expect limitations in the capacities of the main water supply routes during increased demand?

- Yes, during summer months
- Yes, unfavorable conditions throughout the year

99. Are there limitations in the available water supply quantities in relation to demand (today) and identified capacities of the abstraction site?

- Yes, during summer months
- Yes, unfavorable conditions throughout the year

100. Do you expect limitations in the available water quantities in relation to the expected increase in demand and identified capacities of the abstraction site?

- No
- Yes, during summer months
- Yes, unfavorable conditions throughout the year

101. If there are limitations in available quantities at the abstraction sites (current or planned state), do these refer only to the quantity or to both quantity and quality of water?

- The limitations refer to quantity
- The limitations refer to quality
- The limitations refer to both quantity and quality

102. If there are limitations in available quantities (current or planned state), do you have the possibility to increase the available quantities at the existing or planned abstraction sites?

- Yes, at the existing abstraction sites by expanding the abstraction permit
- Yes, by opening up new identified abstraction sites
- No, there are no identified abstraction sites

ANNEX 3. CALCULATING AVERAGE PRESSURE

One of important steps in defining objectives in the reduction of real losses is to define Unavoidable Real Annual Losses (UARL). These are mostly losses of water due to water leaking from mains but of very low intensity which is almost impossible to locate with the application of standard methods and instruments except by chance or when their intensity increases over time (background leakage). They are defined by empirical equations (shown below) that include the following relevant parameters: the length of transmission and distribution mains (without service connection pipes), the number of service connections, the length of service pipes (after the property line up to the customer meter), and the average operating pressure.

$$\boldsymbol{UARL = \frac{18 \cdot L_m + 0,8 \cdot N_c + 25 \cdot L_p) \, x \, P_{av}}{L_m} \; (l/km \, of \, mains/d)}$$

$$\boldsymbol{UARL = \frac{18 \cdot L_m + 0,8 \cdot N_c + 25 \cdot L_p) \, x \, P_{av}}{N_c} \; (l/service \, connection/d)}$$

Where:

- L_m - Mains length, transmission and distribution mains (km)
- N_c - Number of service connections
- L_p - Total length of service pipes - from property line to meter (km)
- P_{av} - Average operating pressure (m)

As shown above, the UARL depends on several factors, very important among them being the number of service connections in the system. It is important to point out that the term “service connection” is used and that it represents a link from one connecting pipe (from a joint or a direct connection to the street main) to the consumer, i.e., to the first water meter, because that is also part of the main under the responsibility of the PWSP managing the system. However, in the above equation for the calculation of UARL it is important to understand that the calculation of the service connection length includes only part of the service connection from property line to the meter. In practice there are frequent errors in understanding the service connection length with the calculation including the total length from connection to the street main to customer meter.

Some countries and PWSPs around the world have introduced modifications into UARL calculation:

$$\boldsymbol{UARL = (6.57 \cdot L_m + 0.256 \cdot N_c + 9.13 \cdot L_p) \, x \, P_{av} \; (m3/year)}$$

where unlike the earlier equation defined according to the original IWA methodology, the parameter L_p is defined as the length of all service pipes as pipes in the ownership of the water service provider that connect the water network main with the service connection for the water service user. In other words, the service connection is defined from connection to the street main to the meter, unlike the same parameter in the equation according to the original IWA methodology where the service connection is defined from customer property line (most often a fence) to the meter.

In any case, from the above formulas it can be concluded that the calculation of average pressure directly affects the calculation of unavoidable annual real losses. Since the occurrence of water losses will depend on a number of parameters such as: number of connections - locations of frequent leakage, mains profiles and types of material, mains length, etc., it is necessary to consider standardizing the calculation of average pressure using one of the criteria.

ILI presents the ratio of the CARL (Current Real Annual Losses) to the UARL (Unavoidable Real Annual Losses) and is described with the following formula:

ILI = CARL / UARL

ILI is one of the basic indicators to monitor the state of water losses and inappropriately often is also the parameter for the achievement of objectives when investing in water supply systems. It is recommended that this indicator is at the beginning not used on the national level, but rather that it is used to monitor PWSP efficiency in implementing loss reduction activities and to compare PWSPs in their water loss management efficiency. In order for this monitoring to be as credible as possible, it is proposed that the calculation of average pressure is standardized.

Average pressure can be determined by identifying topography and by measuring pressure. However, with the advance of mathematical models, this calculation can be improved and standardized. The Loss Reduction Action Plan and the earlier National Loss Reduction Program have recognized the need to develop detailed hydraulic models based on quality GIS-based knowledge of water supply systems. For practically all bigger water supply systems such model has been developed or will be developed, and it is possible to define the standard for the calculation of average pressure using the hydraulic mathematical model.

The calculation of average pressure has to be based on the results obtained from the mathematical model. In order to obtain average pressure by each node, it is necessary to form a model with an average day scenario, i.e. a day with average annual water consumption according to all the analyzed categories and average annual value of non-revenue water.

The calculated average pressure value for each section ($P_{av,i}$) is obtained by summing up the average pressure values at section ends and dividing the sum by 2.

$$\boldsymbol{P_{av,i} = \frac{P_{av,i} + P_{av,i+1}}{2}}$$

The total sum of the products of multiplication of the average pressure at each section ($P_{av,i}$) and its length (l_i) for each water supply system/DMA is divided by the total length of the water supply system/DMA, thus obtaining the average pressure by each system/DMA.

$$\boldsymbol{P_{av,system/DMA} = \frac{\sum_{i=1}^{n} P_{av,i} \times l_i}{\sum_{i=1}^{n} l_i}}$$

Since the water supply network length is the most standard parameter (consumption - small and big consumers change more frequently), it is recommended that the average pressure is calculated using the above methodology.

In addition to ILI, this method of average pressure calculation needs to be used for the other of 4 key indicators which will be used to monitor and assess public water service providers - l/service connection/day/m of average pressure.

24HR01 CROATIA: SUPPORT TO REDUCE WATER LOSS WITHIN THE REFORM OF THE WATER SECTOR – PHASE 2

ACTIVITY 1

SUBACTIVITY 1.1.

REPORT ON PREPARATION OF A PROPOSED UTILITY LOSS REDUCTION ACTION PLAN TEMPLATE

December 2024