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Service activities relating to drinking water supply, wastewater and stormwater systems — Guideline for a water loss investigation of drinking water distribution networks

Activités relatives aux systèmes d'eau potable, d'assainissement et de gestion des eaux pluviales — Lignes directrices pour l'investigation des pertes d'eau dans les réseaux de distribution d'eau potable

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 224, *Service activities relating to drinking water supply, wastewater and stormwater systems*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Water is essential to life and forms part of the environment. Global concern for the state of the environment has identified that water resources are subject to significant pressure from water demand. Large amounts of abstracted water do not reach the intended users. Many water utilities lose large volumes of water through leaks and pipe bursts. Due to increasing urbanization, growing demand, rising costs and ageing distribution networks, water loss is a growing challenge for drinking water utilities.

In addition to the failure rates, the amount of water lost from a network is also an indicator of the condition of that network, which can only be improved through appropriate operation, maintenance and long-term rehabilitation. Still, careful handling of water is a fundamental requirement for drinking water utilities.

Identifying and reducing water loss is an important task in the overall concept of managing of water distribution network assets (see ISO 24516-1:2016, 4.1; 5.8). Minimizing water loss is a major functional requirement in fulfilling the objectives given in ISO 24510 regarding promoting the sustainability of the drinking water utility, protecting the environment and protecting public health and safety.

A system water loss investigation can contribute to the sustainability of drinking water utilities and protection of the environment. It is a critical first step in the establishment of an effective water loss management programme, which is an important activity within the management of water distribution assets. With a successful completion of a system water loss investigation, water utilities can gain an understanding of the current status of the drinking water distribution network regarding non-revenue water (NRW) components (i.e. unbilled authorized use, apparent water loss and real water loss) and begin to formulate a water loss management plan.

Water loss consists of real and apparent water loss. Real water loss includes the treated water volume lost through all types of leaks in pipes and other components of the system, as well as storage tank overflows. It also depends on flow rates, water loss rates, pressure and the average duration of individual leaks and the frequency at which they occur. Apparent water loss covers all types of inaccuracies associated with users' metering and billing, plus unauthorized use (theft or illegal use). Unauthorized use occurs through deliberate actions of authorized or unauthorized users who draw water from the system without permission. Such water loss can take many forms, including illegal connections, illegal reconnections of disconnected users, meter bypasses, meter tampering and illegal connections to fire hydrants. This document deals with the various components of water loss as part of the water loss investigation.

The International Water Association Water Loss Specialists Group (IWA WLSG) has developed terminology, methodology, strategy and diverse tools for water loss management. This document includes and considers these.

The purpose of this document is to establish current know-how in water loss and to set a formalized scope of work for water loss investigation. It also includes an annex that describes relevant technologies and methods.

Service activities relating to drinking water supply, wastewater and stormwater systems — Guideline for a water loss investigation of drinking water distribution networks

1 Scope

This document provides a methodology for undertaking a water loss investigation and establishing general principles for water loss management in drinking water distribution networks in order to improve the sustainability of drinking water utilities and protect the environment by saving water, energy and use of chemicals.

This document establishes a procedure to estimate water loss components through water balance calculations and to define general principles of water loss management. This document deals with the preparation of a water loss management plan for water loss reduction and management projects but does not cover its execution.

This document does not cover bulk drinking water supply systems, but can relate to pumping, storage and transmission within the drinking water distribution network.

This document can be used analogously for non-public supply systems, raw water and industrial water systems.

This document is intended for drinking water utilities and other stakeholders.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
active leakage control
ALC
process of undertaking leakage detection surveys on a targeted or regular basis in order to manage leakage within a *drinking water distribution network* (3.10)

3.2
apparent water loss
unauthorized use of water, such as theft or illegal use of water, and any inaccuracies associated with errors in metering, errors in estimation of unmetered water use and errors arising from the data acquisition and analysis process

3.3
authorized use
volume of metered or unmetered water, or both, taken by registered *users* (3.22), the water supplier and others who are implicitly or explicitly authorized to do so by a water supplier

Note 1 to entry: Authorized use includes domestic, commercial and industrial purposes, including *exported water* (3.12). It also includes billed water and uses that are not billed (e.g. firefighting).

Note 2 to entry: The International Water Association prefers the term "consumption" rather than "use".

3.4
background and bursts estimates
BABE
concept using auditable assumptions to calculate the components that make up the annual volume of *real water loss* (3.18)

Note 1 to entry: The International Water Association uses the term "component loss model (CLM)" and states that the CLM is constructed to estimate each type of leakage. Component loss models include BABE estimates.

3.5
background water loss
leaks at joints and fittings, not visible or audible with currently available technology

3.6
billed authorized use
billed authorized consumption
components of *authorized use* (3.3) which are billed and produce revenue

Note 1 to entry: Billed authorized use is equal to billed metered consumption plus billed unmetered consumption, and also known as revenue water. It is a component in the IWA Standard *water balance* (3.23).

Note 2 to entry: The term "billed authorized use" is sometimes referred to as "billed authorized water consumption".

3.7
connection
service connection
set of physical components ensuring the link between a point-of-delivery and the local water main or the point-of-collection and the sewer

Note 1 to entry: For drinking water systems, the term "service pipe" is currently used, but the connection can include components other than the service pipe, such as valves and meters.

Note 2 to entry: For the purposes of this document, the term "service connection" is not related to the point-of-collection and the sewer.

[SOURCE: ISO 24513:2019, 3.3.37, modified]

3.8
current annual real loss
CARL
current best estimate of the average *real water loss* (3.18) over a year, evaluated using the IWA Standard *water balance* (3.23), in the form of volume per year or volume per day

3.9
district metering area
DMA
section in a *drinking water distribution network* (3.10) for which water supply can be discretely measured

Note 1 to entry: There can be more than one district metering area meter measuring the flows at the boundary or the interior of the district metering area.

3.10
drinking water distribution network
asset system for distributing drinking water

Note 1 to entry: Drinking water distribution network can include pipes, valves, hydrants, pumping stations and reservoirs, and other metering and ancillary infrastructure and components.

Note 2 to entry: Pumping stations and reservoirs can be sited either in the waterworks or in the drinking water distribution network.

Note 3 to entry: For the purposes of this document, a drinking water distribution network does not include bulk drinking water supply systems, but can include pumping, storage and transportation to the drinking water distribution network.

Note 4 to entry: For the purposes of this document, “storage tank” is used in addition to “reservoir”.

[SOURCE: ISO 24513:2019, 3.5.12.2.1, modified]

3.11
drinking water utility
whole set of organization, processes, activities, means and resources necessary for abstracting, treating, distributing or supplying drinking water and for providing the associated services

Note 1 to entry: Some key features for a drinking water utility are:

— its mission to provide drinking water services;

— its physical area of responsibility and the population within this area;

— its responsible body;

— the general organization, with the function of operator being carried out by the responsible body or by legally distinct operator(s);

— the type of physical systems used to provide the services, with various degrees of centralization.

Note 2 to entry: The term addresses a utility dealing only with drinking water.

Note 3 to entry: When it is not necessary, or it is difficult to make a distinction between responsible body and operator, the term “drinking water utility” covers both.

Note 4 to entry: In common English, “drinking water service” can be used as a synonym for “drinking water utility”, but this document does not recommend using the term in this way.

[SOURCE: ISO 24513:2019, 3.3.1.1]

3.12
exported water
water which is supplied to the *drinking water distribution network* (3.10) but is then transferred to another drinking water system

Note 1 to entry: Exported water is adjusted for known errors.

3.13
fixed and variable area discharge
FAVAD
concept that interprets the pressure:leak flow relationship

Note 1 to entry: The leak flow can come from a variety of paths which do not necessarily vary with pressure.

3.14
intermittent supply
drinking water distribution system that delivers water to *users* (3.22) for less than 24 hours in one day

3.15
minimum flow
lowest flow observed in a *district metering area* (3.9) for a *water loss investigation* (3.25) process, taken over a consistent period of time for the investigation

Note 1 to entry: In many *drinking water utilities* (3.11) this is referred to as minimum night flow (MNF).

3.16
non-revenue water
NRW
difference between the volumes of *water supplied* (3.27) and *billed authorized use* (3.6)

Note 1 to entry: non-revenue water includes not only the *real water loss* (3.18) and *apparent water loss* (3.2), but also the unbilled authorized use.

3.17
performance indicator
PI
parameter, or a value derived from parameters, which provides information about performance

Note 1 to entry: Performance indicators are typically expressed as ratios between variables. These ratios can be commensurate (e.g. %) or non-commensurate (e.g. $/m³).

Note 2 to entry: Performance indicators are means to measure the efficiency and effectiveness of a water utility in achieving its objectives.

[SOURCE: ISO 24513:2019, 3.9.6]

3.18
real water loss
physical water loss
amount of water escaping from the pressurized system through all types of leaks, bursts and overflows, up to the point of *user* (3.22) metering or transfer of responsibility to the *user* (3.22)

3.19
system input volume
SIV
total water volume supplied into a drinking water system from all sources, including imported water

3.20
unavoidable annual real loss
UARL
lowest technically achievable annual volume of *real water loss* (3.18) for a well-maintained and well-managed system

3.21
unmetered authorized use
authorized use (3.3) which is not metered and is estimated for billing or *water balance* (3.23) purposes

Note 1 to entry: The term "unmetered authorized use" is sometimes referred to as "unmetered authorized water consumption".

EXAMPLE Unmetered use of water in public institutes such as schools or public gardens.

3.22
user
consumer
person, group or organization that benefits from drinking water delivery and related services, wastewater service activities, stormwater service activities, or reclaimed water delivery and related services

Note 1 to entry: Users are a category of stakeholder.

Note 2 to entry: Users can belong to various economic sectors, such as domestic, institutional, commercial, industrial or resource exploitation (e.g. agriculture, forestry, mining).

Note 3 to entry: The term "consumer" can also be used, but in most countries the term "user" is more common when referring to public services.

[SOURCE: ISO 24513:2019, 3.1.8.4]

3.23
water balance
quantified volume of total water into the system, authorized use (billed and unbilled, metered and unmetered) and *water loss* (3.24) (apparent water loss and real water loss)

3.24
water loss
difference between water supplied and *authorized use* (3.3), consisting of *real water loss* (3.18) and *apparent water loss* (3.2)

3.25
water loss investigation
activities for the collection of information and quantification of the water uses and *water loss* (3.24) from a water system, which include the calculation of a *water balance* (3.24) and *performance indicators* (3.17)

Note 1 to entry: Also known as *water loss* (3.24) audit or *water loss* (3.24) survey.

EXAMPLE Calculation of a water balance and *performance indicators* (3.17).

3.26
water loss management plan
overview of the required activities of a *water loss* (3.24) reduction project, expected benefits, time schedule and budget based on the results of the *water balance* (3.23) and *performance indicators* (3.17)

Note 1 to entry: A *water loss* (3.24) management plan can include pressure control, *active leakage control* (3.1), universal metering and establishment of *district metering areas* (3.9).

3.27
water supplied
provision of drinking water into the *drinking water distribution network* (3.10) for use, calculated as the *system input volume* (3.19) minus *exported water* (3.12)

4 Defining objectives for the water loss investigation

The objectives of the water loss investigation should be aligned with the strategic objectives of the drinking water utility. It should aim at quantifying the volumes of water entering the system, authorized use (billed and unbilled, metered and unmetered) and water loss (apparent water loss and real water loss), through the water balance, calculation of water loss performance indicators and collection of current operational, maintenance and rehabilitation practices. Another objective of the water loss investigation should be to create a water loss management plan (see Clause 13).

The objectives of the water loss investigation should be to provide a rational, scientific framework to assess:

— water loss factors;

— selection of technologies for the assessment of water loss;

— costs of non-revenue water (NRW) components;

— performance indicators of water loss;

— drinking water utility operations;

— water loss management structure;

— appropriate targets for water loss reduction;

— likely activities and budget for water loss reduction projects.

5 Water loss investigation steps

The water loss investigation should include estimations of all water volumes entering and leaving a system, as well as in-depth record and field examination of the drinking water distribution system. Apparent water loss and real water loss estimations can provide valuable information to help assess the operational efficiency of the distribution system.

The water loss investigation is a first step in the establishment of an effective water loss management plan, which should address activities to reduce real water loss and apparent water loss.

The water loss investigation should consist of the following steps:

— determination of scope of the water loss investigation (see Clause 6);

— collection of data and validation methods (see Clause 7);

— calculation of water balance (see Clause 8);

— selection of water loss performance indicators (see Clause 9) and calculation (see Annex C);

— assessment of apparent water loss status (see Clause 10);

— assessment of real water loss status (see Clause 11);

— assignment of real water loss and apparent water loss cost (see Clause 12);

— preparation of water loss management plan (see Clause 13);

— selection of activities for apparent water loss management (see Clause 14);

— selection of activities for real water loss management (see Clause 15).

6 Water loss investigation scope determination

6.1 General

The following parameters should be defined prior to the water loss investigation in order to determine the framework and the extent of the investigation:

— the geographical area of the water loss investigation (6.2);

— the time period of the water loss investigation and tests (6.3);

— the units of each measurement (6.4).

6.2 Water loss investigation area

The boundaries of the water loss investigation area should be defined. Interconnecting points with the surrounding areas should also be defined.

A water loss investigation area may include pumping, storage and transportation within the drinking water distribution network.

A schematic plan displaying the water loss investigation's boundaries should be prepared.

6.3 Time period of the water loss investigation

The water loss investigation should be carried out regularly.

For the water balance calculation, it is usual to cover 12 months in order to minimize the effects of mismatches between meter readings. Nevertheless, the water loss investigation may be complemented with measurements in a shorter period for a detailed assessment of water loss components, although this could mean that errors due to variations in meter reading cycles, volume of leakage and climatic conditions are introduced.

The water loss investigation should be repeated, although the frequency at which this is done depends on the type of measurement and local conditions.

6.4 Units of measurement

Units of measurement should be uniform and consistent throughout the water loss investigation for such aspects as system input volume (SIV), water supplied, water use, pipe diameter, diameter of other appliances and storage tank or reservoir volume. Units of measurement are generally either metric (e.g. litres) or imperial (e.g. gallons or US gallons).

7 Data collection and validation methods

7.1 Data collection methods

Data collection should involve data for water balance calculations and inventory data about the drinking water distribution network. All data sources and collection processes should be transparently documented such that they are replicable and auditable.

Water loss cannot be measured directly but should be estimated. The simplest method of doing this is by calculating a water balance. This is likely to require many assumptions, all of which should be recorded and validated as further data and information become available. Therefore, written procedures for each component of the water balance, containing adopted assumptions, identification of input data characteristics, data sources and methods adopted, should be prepared and followed to ensure that periodic calculation of the water balance is systematic.

The inventory data (e.g. nominal diameter, material, length, year of installation, rehabilitation, type of connection) and condition data (e.g. date, point, type of failure, bedding, depth of cover, extent and depth of external corrosion) should be recorded and assigned as described in ISO 24516-1:2016, 5.4 and 5.5. The resulting maps should be used as a basis for further investigations on water loss.

A schematic plan of the drinking water distribution network should be used, although this may be on a different layer or set of plans, including:

- The drinking water distribution network, beginning with water source through to users.
- District metering areas (DMAs), shown on the plan.
- Identification of all drinking water inputs, whether drinking water utilities' own resources or other sources.
- Definition of the main facilities, including pressure zones, pumping stations, tanks and reservoirs, water treatment facilities and pressure regulating stations, as well as water export connections to neighbouring drinking water systems.
- Identification of bulk water meters, particularly water meters at the entrances to the drinking water distribution network and network zones. For each water meter, a type should be specified, as well as diameter, date of installation and relevant information related to date of servicing, calibration and calibration data.
- List of metered and unmetered water inputs and outputs.

— Location of major water users.

— Databases of all meters, connections, DMAs, pressure-reducing valves and other major control valves.

7.2 Data validation of water balance calculation

7.2.1 Validation methods

As part of the data collection process, the accuracy of existing data should be assessed for all inputs and missing data should be identified. Initial validation of the water balance components may be undertaken through examinations of available records for any evidence of errors, detection of missing data and confirmation of correct methods for calculating the water balance from those records.

Advanced validation of data should be employed as soon as is feasible, as this provides a greater understanding of uncertainty in the water loss investigation. Additional validation methods may include the following:

— verification or calibration tests of bulk flow meters, including flow meters used to measure exported or imported water;

— verification of SIV data transfer integrity from primary measurement via secondary signal conversion to final archived value (if applicable);

— data-mining and detailed analysis of the SIV database to identify data gaps and anomalies;

— utilization of DMAs for zonal water balance and minimum flow analyses;

— field or bench accuracy testing of user meters;

— data-mining of the water use database to analyse and quantify the impacts of lag-time between timestamp for supply measurement and timestamp for water use measurement;

— analysis of water use history for profiling of meters, user classes, zero and inactive accounts, use by type, measured versus billed use, meter right-sizing and verification of use summary report totals;

— detailed analysis of user account inventory for verification of revenue-dependent field values such as rate code and meter size;

— analysis of water use for unmetered user data;

— field investigation of inactive accounts and other potential sources of unauthorized use;

— analysis and cross-referencing of any geographic information system and user databases for unauthorized use indicators;

— temporary hydrant metering for verification of estimated flow rates used in determining authorized, unmetered use volumes;

— pressure logging for refinement of average system operating pressure calculations.

Various technologies are available for use during the data collection stage to provide more reliable data. The accuracy of measurement devices, particularly meters, should be taken into account in the calculation of the water loss variables.

See Annex J on the effects of uncertainties in data. ISO 24510:2007, Annex C, also discusses uncertainties in data.

7.2.2 Data quality

Data quality should be checked to ensure that it fulfils the requirements stated in ISO 24516-1:2016, 5.4.2 (e.g. compatible, accurate, consistent, current, credible). If that is not the case or if insufficient data exists, schemes should be prepared to include all relevant parts of the system. Missing or unrealistic data should be identified.

Sources should be identified and uncertainties should be quantified for the calculation of the water balance and related performance indicators. Sources of uncertainty can include primary instrumentation, data conversion, communication, data archival and retrieval, as well as the investigator's interaction with the data and the extent to which estimations are utilized. When quantifying uncertainty, at least the following should be considered and accounted for:

— instrumentation in situ conditions;

— instrumentation management practices;

— data management practices;

— methods and instruments used in tests.

Uncertainty should be estimated quantitatively for water balance components and water loss performance indicators. See, for example, the confidence-grading scheme in ISO 24510:2007, Annex C. Quantitative assessments of uncertainty should be based on the uncertainty propagation theory.

7.2.3 Practices rating

The extent to which best management practices are employed in a drinking water distribution network can improve reliability of the underlying data used to execute the water loss investigation. Qualitative scoring or rating systems may be utilized to assess and benchmark the robustness of practices in place, and may include practices for water loss programme management, management of supply measurement instruments, management of user meters, estimation of unmetered use, information systems, data management, monitoring and analysis.

8 Water balance calculation

8.1 General

The water balance summarizes the components of water supply, water use and NRW, thus providing accountability. This is possible as all water placed into a distribution system is supposed to equal, in theory, all water taken out of the distribution system.

NOTE With the balance proposed, only direct distribution to users is considered for estimation of revenue water.

A water balance should be performed as defined in the steps listed in 8.2, see also Table 1.