Guidelines on Drinking Water Distribution Systems Best Practices

March 2019

Québec

Information
For general information, contact the Centre d'information
at the Ministère de l'Environnement et de la Lutte contre
les changements climatiques.

Telephone: 418 521-3830
1 800 561-1616 (toll free)

Fax: 418 646-5974
Email: info@environnement.gouv.qc.ca
Internet: http://www.environnement.gouv.qc.ca/index_en.asp

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SUMMARY

Best practices in the operation of drinking water distribution systems contribute to ensuring that high quality water is delivered in sufficient quantity to consumers' taps. The present document was designed to inform municipalities about the various aspects they need to consider. These guidelines are voluntary objectives for improving practices that are not subject to regulation, except for certain elements that are clearly specified.

The best practices that the Ministère de l'Environnement et de la Lutte contre les changements climatiques (Ministère) invites you to implement are presented in the table on the following page. Although all the recommendations in this guide are important to improving water system management, priority should be given to those that are flagged by three stars.

BEST PRACTICES FOR THE OPERATION OF DRINKING WATER DISTRIBUTION SYSTEMS

GENERAL SYSTEM MANAGEMENT	Keep system maps up to date	☆☆☆
	Implement and maintain unidirectional flushing for the entire system	☆☆☆
	Inspect and maintain equipment at regular intervals	☆☆
	Keep rigorous records and manage the data collected	☆☆
	Ensure the integrity of data and remote monitoring of hydraulic parameters	☆☆
	Conserve water without affecting quality	☆☆
	Encourage communication with the public	☆☆
	Implement effective mechanisms for internal collaboration	☆
	Have tools for funding the maintenance and renewal of drinking water infrastructures	☆☆
	Ensure the health, safety and training of workers	☆☆☆
	Plan emergency measures	☆☆☆
WATER QUALITY MONITORING	Take time to establish a good sampling plan	☆☆☆
	Use water quality indicators	☆
LIMITING SOURCES OF INTRUSION AND WATER DEGRADATION	Monitor connections to the system	☆
	Minimize water hammer and pressure transients	☆☆☆
	Reduce risks when water pipes are being repaired	☆☆☆
	Reduce risks associated with system dead-ends	☆
	Monitor the use of all equipment	☆
	Give particular care to reservoirs	☆☆
PRESSURE MANAGEMENT	Strive to maintain a minimum static pressure	☆☆☆
	Determine the system's optimal operating pressures	☆☆
	Limit pressure variations	☆
EXTERNAL USERS	Control access to fire hydrants	☆☆☆

AUTHORS AND COLLABORATORS

Editing and coordination:

Annie Massicotte, Direction de l'eau potable et des eaux souterraines

Yaye Diarra Diouf, Direction de l'eau potable et des eaux souterraines

Donald Ellis, Direction de l'eau potable et des eaux souterraines

Caroline Robert, Direction de l'eau potable et des eaux souterraines

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NOTE TO THE READER

This document presents recommendations and tools to improve operating practices for drinking water distribution systems. Unless otherwise indicated, the elements presented are not legally binding. Before changing practices based on these recommendations, utilities should make sure that they are applicable to their particular situation.

Since the Ministère intends to improve this guide over time, readers of printed copies are invited to ensure that they have the most recent version. Finally, if you have good practices to suggest, implementation examples to share, references to add, or problems to report with regard to hyperlinks, please write to us at the following address:

conception.eau.potable@environnement.gouv.qc.ca.

For questions concerning the application of drinking water regulations, utilities are invited to contact a regional branch of the Ministère. Their coordinates can be found at:

http://www.environnement.gouv.qc.ca/ministere/rejoindr/adr_reg.htm.

CONTENTS

1. INTRODUCTION

Québec's municipal water distribution systems are **under the responsibility of 845 municipalities**.

- In total, these systems serve nearly 7 million people.
- This presents a challenge in managing thousands of kilometres of buried infrastructures that are of critical importance.
- These systems are an essential component of the multi-barrier approach, coming after the protection of water sources and treatment as a risk management tool.

The goal of the present document is to provide water utilities with **an overview of the main concerns to take under consideration** in the operation of a drinking water distribution system.

- These guidelines are particularly aimed at small and medium size systems.
- They were designed to help utilities provide consumers with safe water in sufficient quantity.
- The concerns to consider go well beyond the periodic analysis of water quality, as required by the *Regulation respecting the quality of drinking water* (RQDW).

The need for this document was made apparent by **the many cases of outbreaks due to water contamination by distribution systems[1].**

- There are clearly limitations to water quality control, since contaminants must be in the system before they can be detected. By the time analysis results are received, many people will have consumed contaminated water.
- The sheer size of a distribution system makes it difficult to detect contamination.
- Proper management of the system and the use of best operating practices will together form an additional barrier in protecting drinking water quality.

This document includes:

- Five chapters covering the key areas for which best practices are recommended.
- Each chapter consists of three sections:
  - best practices that are considered essential;
  - certain problem-solving concepts;
  - more advanced practices, to implement when the rest is satisfactory.
- Chapter sections are presented by order of priority, but that order is not absolute, and some elements overlap.

Finally, it should be noted that the recommendations offered here, with the accompanying lists of suggested tools, are presented as a starting point and will be enhanced over time.

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[1] References:

- Institut national de santé publique du Québec (September 2000). *Bilan des éclosions de maladies d'origine hydrique signalées dans les directions régionales de la santé publique du Québec en 1996 et en 1997,* INSPQ, Unité risques biologiques, environnementaux et occupationnels. Accessed at https://www.inspq.qc.ca/pdf/publications/003_BilanEclosions_96_97.pdf.
- Outbreak of *E. coli* at Walkerton, Ontario in May 2000.

1.1 Description

The main components of a water distribution system are illustrated in Figure 1.

The pipes and reservoirs of a distribution system can be thought of as a package made up of a multitude of real or potential openings (water intakes and outlets, joints, leakage points, system accessories) that carries drinking water, a perishable product with a limited storage life (residence time), with or without preservatives (chlorine or chloramines)[2].

1.2 Operating objectives for a distribution system

The two fundamental objectives that should guide decision-making and actions are to maintain the quality of water and to maintain the quantity of water.

Achieving these two objectives should make it possible to:

- minimize service interruptions;
- maintain the protection level[3] required for firefighting;
- minimize contamination risks.

In addition to these objectives, the following concerns should also be taken into consideration:

- controlling costs;
- conserving water;
- offering safe working conditions.

[2] Definition inspired by the InfraGuide of the Federation of Canadian Municipalities and the National Research Council, *Monitoring Water Quality in the Distribution System*, 2005.

[3] See the MAMH document, Guide d'élaboration d'un plan d'intervention pour le renouvellement des conduites d'eau potable, d'égouts et des chaussées : Tableau 20 : Établissement des statuts de l'indicateur EP-8- Protection contre l'incendie-Mesures ou simulation (https://www.mamh.gouv.qc.ca/fileadmin/publications/infrastructures/plan_intervention_renouvellement/guide_plan_intervention.pdf), p. 36

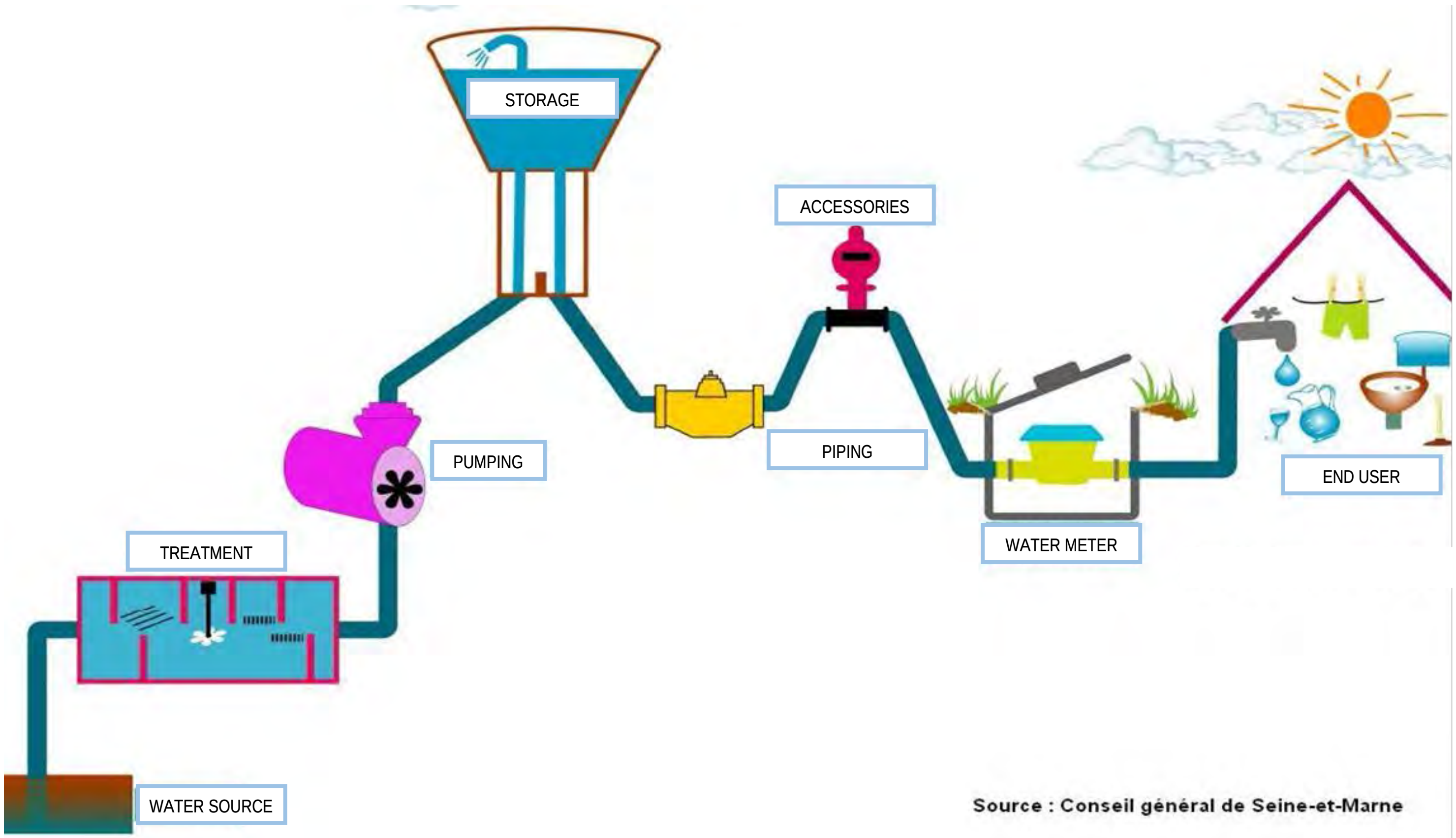

Figure 1 – A distribution system

1.2.1 Maintaining the quality of water

By definition, potable water is free of pathogens, meets the standards for organic and inorganic parameters, is chemically balanced and has desirable properties for consumers.

However, even when these criteria are met at the production facility and where the water enters the distribution system, much can change thereafter:

- Chemical and microbiological contamination: using data from 1981 to 1998, the US Centers for Disease Control and Prevention studied 57 cases of distribution system contamination, and concluded that contamination due to cross-connections resulted in 9,734 cases of illness[4].
- Appearance of a colour, taste or odour: the vast majority of consumer complaints about tapwater concern these parameters. The most common causes include excessive biofilm growth, chlorine, chlorine compounds and chlorination by-products, and corrosion residues.

1.2.2 Maintaining the quantity of water

The primary objective of a distribution system is to provide drinking water in a sufficient quantity to those who are served by the system. In technical terms, utilities must make sure that water is supplied at the right pressure and in sufficient volume to meet the requirements for peak hourly flow, or the combination of maximum day flow and fire flow. Additionally, a constant effort is needed to limit the amount of water being wasted, while always maintaining water quality. Failure to do so entails major problems:

- Poor maintenance of fire hydrants can lengthen firefighter response times and result in greater fire damage. Firefighting delays can also ensue when valves malfunction or are left closed.
- Malfunctions of system equipment in general can result in boil water advisories and water service interruptions being more frequent and of greater magnitude.

Quebecers and Canadians are among the biggest consumers of water in the world. The Québec Strategy for Drinking Water Conservation suggests that measures to reduce water consumption could save up to $2 billion between 2001 and 2021[5].

1.2.3 Upholding the principles of sustainable development

The recommendations set out in this document are directly in line with the following sustainable development principles:

- "*Health and quality of life*" Access to quality drinking water is an integral part of public well-being.
- "*Economic efficiency*" The planning, maintenance and timely renewal of system equipment results in cost savings. For example, maintaining good quality water throughout a system helps to avoid the deterioration of that water

[4] Michael J. MacPhee, *Distribution System Water Quality Challenges in the 21st Century: A Strategic Guide*, AWWA, 2005, 196 p. Note that it is not a simple task to establish connections between waterborne diseases and contamination in a distribution system, and few studies attempt to do so. That is why these statistics date back to the 1990s. There is every reason to consider them valid however, since little has changed since, but even more, conditions may have deteriorated due to aging infrastructures.

[5] https://www.mamh.gouv.qc.ca/infrastructures/strategie/a-propos-de-la-strategie/.

quality, the illnesses it could cause, and the health and productivity costs that would result. Also, active leak detection reduces the need for costly emergency repairs.

- "*Participation and commitment"* Water utilities have everything to gain by putting an emphasis on informing and collaborating with the public, collaborating with municipal workers and promoting the value of work related to drinking water. This fulfills the "*Access to knowledge"* principle.
- "*Prevention"* Maintaining the distribution system helps to prevent the deterioration of infrastructures and the risk of waterborne diseases. Equally, accident prevention and worker safety are essential considerations when work is done on the system.
- "*Responsible production and consumption"* Reducing water wastage is critical in the management of distribution systems. This subject is covered by the Québec Strategy for Drinking Water Conservation, the goal of which is to reduce consumption per person per day, as well as leaks.

1.3 Regulatory framework

The operation of distribution systems is not in itself subject to regulatory requirements, but a framework is provided by a combination of laws, regulations and other official documents:

- Environment Quality Act:
  - Regulation respecting the quality of drinking water and supporting documents;
  - Directive 001 – Captage et distribution de l'eau;
  - Specification BNQ 1809-300: Construction Work – Drinking Water and Sewer Lines – General Technical Specifications;
  - Standard BNQ 3660-950: Safety of Products and Materials in Contact with Drinking Water.
- Fire Safety Act:
  - National Fire Protection Association (NFPA) 25: Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems;
  - NFPA 291: Recommended Practice for Fire Flow Testing and Marking of Hydrants;
  - Guide relatif à la réalisation des réseaux d'eau aux fins de la protection contre l'incendie (Service d'inspection des assureurs incendie).
- Public Health Act;
- Act respecting occupational health and safety;
- Québec Strategy for Drinking Water Conservation (French);
- Régie du bâtiment du Québec (RBQ):
  - Construction Code and Safety Code.
- Guidelines for Canadian Drinking Water Quality.

For the rest, many practices have to do with the state of the art.

1.4 Results expected from good system management

Establishing best practices could benefit your municipality in the following ways:

- Reduce:
    - water losses and the volume of drinking water consumed;
    - customer complaints and non-compliant samples;
    - boil water advisories and public health risks;
    - occurrences of low disinfectant concentrations;
    - costs due to breaks, corrective measures, work crew changes, chemical products, energy consumption, etc.
    - risks of malfunction and its consequences.
- Extend the lifetime of infrastructures.
- Improve knowledge about the system.
- Improve knowledge about the cost of water services.
- Avoid disputes by exercising due diligence.
- Save over the long term, despite the additional cost of preventive measures.

2. GENERAL SYSTEM MANAGEMENT

2.1 Best practices

2.1.1 Keep system maps up to date

Water utilities are strongly encouraged to keep up-to-date maps of the entire system showing all the structures associated with it.

RECOMMENDATIONS:

FOR GENERAL MAPS

- Use a scale of 1:5,000 (no more than 1:10,000).
- Show the elements listed in the table below (with a numbering system for each element).
- Indicate places where problems arise regularly or repeatedly.
- Update general maps on a regular basis (several times a year if possible), based on final maps (as constructed), or during inspections.
- At each update, display the map in a prominent location in managers' offices.

Elements to show on general maps	
Date of last update or correction	Any other appurtenance or important equipment
Drinking water production facilities (location and capacity)	Street names
Pumping stations (location and capacity)	Mixing zones of different water sources
Water mains (location and diameter)	Connection points with other systems
Fire hydrants (location and static pressure)	Pressure zones with piezometric head
Valves	Sampling points for water quality monitoring
Self-regulating pressure devices	System owner
Air vents and check valves	Status of sections of the system (proposed, under construction, existing, using a visual code)
Reservoirs (location and capacity)	Consumption sectors
Booster stations	Problematic locations in the system (quality, pressure, flow) if known

FOR DETAILED MAPS

- Choose a scale of 1:600 to 1:1,200 depending on the size of the municipality.
- Besides the elements on general maps, indicate the following:
    - material and condition of pipes, and their placed-in-service date[6];
    - distances from property lines if not standard;
    - lot numbers;
    - door numbers if possible;
    - location of sensitive buildings (hospitals, schools, daycares, seniors centres, etc.).
- Provide updated maps to field crews once per year.

OTHER RECOMMENDATIONS FOR MAPS:

- Do not remove any element from a map without confirming first-hand that it is no longer there. For a buried element, dig to confirm its absence. If the latter cannot be verified, write **not visible** if there is any doubt as to whether the element is present.
- Have a mechanism for validating information.

ADVANTAGES:

- Improve the planning of priority work.
- Have easier access to the correct information, especially in emergencies.
- Accelerate the planning and coordination of work on the system.
- Facilitate the preparation of all other maps (flushing, fire service, ICI, etc.).

TOOLS AVAILABLE:

- Mapping programs.
- EPANET, a hydraulic modelling program that is easy to use and free.
- A georeferenced inventory and a Geographic Information System (GIS) (see section 2.3.4 of this document).

[6] If this information is not available, the year of surrounding buildings construction or the age of fire hydrants can be a good indication of the age of the water pipe.

2.1.2 Implement and maintain unidirectional flushing for the entire system

Flushing dislodges deposits in water mains by raising the flow velocity beyond that of normal operations.

RECOMMENDATIONS:

- Implement a unidirectional flushing program for all water pipes less than 350 mm (14 in)[7] in diameter. As much as possible, carry it out each year. However, to avoid stripping the inner surfaces of pipes, it is important not to flush too often.
- Before flushing, do a field visit to identify potential problems and prevent accidents.
- Determine the right frequency of unidirectional flushing for each part of the system, depending on:
  - the size of water pipes and the flow required;
  - chlorine residual concentration falling too quickly or HPC[8] increasing in a significant or unusual way;
  - areas with uncoated cast-iron pipes (more susceptible to corrosion and bacterial growth due to tuberculation);
  - sections that are physical or hydraulic dead-ends (more susceptible to deposit formation, especially in low consumption areas);
  - consumer complaints.
- As much as possible, coordinate with businesses and industries that require clear water, since water may be discolored during flushing.
- Make sure that the water production facility can produce extra water and that the wastewater treatment facility can handle it.
- Notify the public on days when flushing is done (signs along streets, automated telephone calls, flyers in mailboxes, doorhangers, etc.). Doing flushing at night reduces consumer inconvenience.
- Make sure that the crew performing the unidirectional flushing is trained in accident prevention, has first-aid training and has adequate safety equipment.
- Flushing velocity must be at least 0.8 m/s (2.5ft/s), ideally 1.5 m/s (5ft/s). For cast-iron water pipes, high velocity is important to acheive. However, excessively high flow velocity should be avoided, so as not to destabilize the inner surface of pipes.
- Determine the water quality objectives to be met, e.g. for turbidity (< 1.5 NTU), iron concentration (< 0.3 mg/L)[9] or chlorine residual concentration, etc.
- During the operation, make sure that the pressure does not fall below 140 kPa (20 psi) in the surrounding area or any other point of the system.
- Use the flushing program as an opportunity to note any malfunctions in accessories of the system (fire hydrants, valves, pressure, etc.). This is not however the same as an inspection.

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[7] It is best not to flush water mains of 350 mm (14 in) and more, since the normal speed of flow is generally high enough to limit deposits. Also, the operation of valves is time-consuming, there is a high risk of breaks, and the volume of water is hard to manage. When there is a problem with such water pipes, it is better to use swabbing.

[8] *Guidance on the Use of Heterotrophic Plate Counts in Canadian Drinking Water Supplies*, part of the Canadian Drinking Water Guidelines, Health Canada (2012).

[9] If iron concentration can't be measured precisely, a white container such as a cut-off bleach jug can be used to visually assess if the water coming out is clear.

- Try to take static and dynamic pressure readings each year over at least 10% of the system, alternating inspection locations to cover the complete system over time. Retain certain inspection locations for yearly readings in places that are known to be trouble spots.
- Fill out flushing records and include all the information gathered.
- Inform repair work crews about breaks or malfunction discovered in equipment or pressure readings.
- Dispose of the chlorinated water in accordance with ministerial guidelines (in French) and local municipal regulations.

BENEFITS IN TERMS OF WATER QUALITY:

- To maintain the general quality of water in the system by:
  - reducing or eliminating turbidity, suspended solids, sediments and coloured water due to corrosion and chemical modification;
  - reducing or eliminating tastes and odours due to biological activity;
  - slowing consumption of chlorine residual and reducing disinfection by-products;
  - controlling total coliforms and biofilm.
- To maintain water quality during hydraulic events such as water hammer or reversals of flow direction.

BENEFITS IN TERMS OF WATER QUANTITY:

- Get a better picture of the state of the system and detect malfunctions like valves remaining closed.
- Conserve water main capacity by reducing head losses, and save on pumping energy requirements.
- Avoid obvious malfunctions in backflow preventers, self-regulating pressure valves and other equipment whose control elements can be disturbed in the presence of dirt.
- Operate valves and fire hydrants regularly to verify that they are working properly.
- Update system maps with the data collected.

JUSTIFICATION:

Broadly speaking, there are two types of flushing:

- corrective flushing to fix a specific water quality problem after complaints, exceedances of standards, or work on the system;
- routine flushing to prevent water quality problems. It can be local, for dead-ends where the residence time is especially long, or large-scale, to maintain the system as a whole.

Whichever type is done, unidirectional flushing is known to be effective. It is a cleaning technique that consists of controlling the velocity and direction of water, starting from a pipe that is known to be clean, to the furthest extremities of the system, without contaminating pipes that have been flushed already.

Regular flushing of water pipes is essential to the quality of water in a system. The justifications for it are numerous, including:

- Flushing water mains is a bit like washing dishes! The pipes constitute a “package” for drinking water, a product that is consumed directly and in abundance by the population. The package is below ground, so no one sees what goes on there. An elementary precaution is to carry out regular flushing.
- Since water pipes are designed to meet fire flow requirements, operating speeds are quite low most of the time. This allows the growth of biofilm as well as sedimentation, making water taste bad and become coloured.
- **All** materials used for water pipes, even if approved for drinking water, are non-inert and deteriorate over time. The scaling caused by such deterioration results in the release and accumulation of organic and inorganic contaminants, including arsenic and manganese. These contaminants can be released into the water in significant concentrations, without necessarily being visible to the naked eye, nor detected when sampling is done.

NOTE:
A certain amount of damage may occur when flushing is done, simply because of equipment being operated. It is important to be prepared to deal with it.

TOOLS AVAILABLE:

- Contents taught for OPA certification (*préposé à l’aqueduc*) in the Drinking Water Operator Qualification Program (section 5 – work methods related to the operation of a distribution system).
- Appendix 1 presents two examples of municipalities that have launched flushing programs.

2.1.3 Inspect and maintain equipment at regular intervals

Regular inspection and maintenance are essential for the system to continue working properly.

RECOMMENDATIONS:

- Determine the desired frequency of inspections and maintenance for all system components (see the table in Appendix 2).
- Set objectives for inspection and maintenance (for example, all large valves should be inspected over a 5-year cycle, 95% of valves should be functional, etc.).
- Conduct a detailed inspection of the system at regular intervals.
- Make sure all of the system is inspected at reasonable intervals (every 5 years, for example) depending on its size, the population served and the resources available.
- Maintain equipment following the manufacturer's instructions (which must be carefully kept) or established protocols.
- Record all maintenance work in a **centralized, digital** database.
- Make use of certain interventions (fire, repairs, leak detection, etc.) as opportunities for inspection, recording that this was done.
- Keep an up-to-date inventory of spare parts, based on replacement needs, the availability of parts, the frequency with which they will be used, etc.
- When equipment is replaced, keep any parts from the old equipment that are still in good condition or that could be repaired, especially if they are no longer being made.
- Make sure that spare parts are properly stored, to keep them in good condition, free of contamination and safe from vandalism.
- Hold meetings with all personnel involved in inspection and maintenance, making sure that everyone knows the correct procedures.

BENEFITS:

- Prevent problem situations.
- Maintain reliable service and good water quality.
- Reduce operating costs.
- Respond swiftly to emergency situations.

JUSTIFICATION:

There are different approaches to inspection and maintenance, ranging from "only repair when urgently required" to "do it all on a well-planned cycle". Between those extremes, best practices seek a balance between budget limitations, the availability of human and material resources, and the results desired. Regulatory requirements partly determine the results desired, but so must the need to control costs while avoiding any impairment of the quality of service.

TOOLS AVAILABLE:

- Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, *Deterioration and Inspection of Water Distribution Systems* (2002)
- Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, *Small System Operation and Maintenance Practices* (2005)
- Contents taught for OPA certification (*préposé à l'aqueduc*) in the Drinking Water Operator Qualification Program (in particular section 5 – work methods related to the operation of a distribution system)

2.1.4 Keep rigorous records and manage the data collected

Carefully recording the results of inspections, as well as all work performed, is a best practice to facilitate system management. Additionally, once the data are compiled, you can find connections between different data sets.

RECOMMENDATIONS:

- Fill out inspection, maintenance and repair records as soon as these operations are performed.
- Record observations on the condition of water pipes and on repaired or replaced accessories. The information will be useful for later analysis.
- Add all such records to the file.
- Enter, sort and reorganize relevant data using specialized software, or simply in Excel.
- Prepare graphics with the data to show how they are connected.
- Set targets based on key parameters, such as:
  - reducing complaints by 5% each year;
  - maintaining or making operational at least 95% of fire hydrants.

BENEFITS:

- Build a historical record of the system.
- Base knowledge about the system on information management instead of individuals.
- Facilitate decision making in different situations.
- Facilitate planning for the replacement of pipes and equipment.
- Optimize operations and evaluations of water quality.
- Measure performance relative to the Québec Strategy for Drinking Water Conservation.
- Have documentation at the ready in the event of disputes (complaints, litigation, etc.).

TOOLS AVAILABLE:

- Ministère des Affaires municipales et de l'Habitation (MAMH), *Guide sur l'acquisition de données des réseaux d'eau potable et d'égouts des petites municipalités* (2010)
- Software such as Aquageo, *M36* (free audit software on water loss control from the American Water Works Association), or MAXIMO for asset management and performance improvement
- Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, *Best Practices for Utility-Based Data* (2003)
- Geographic information systems (GIS)
- The Programme d'excellence en eau potable, Réseau Environnement, distribution component (section 2.3.3)
- *M36 Water Audits and Loss Control Programs*, American Water Works Association (AWWA)
- Contents taught for OPA certification (*préposé à l'aqueduc*) in the Drinking Water Operator Qualification Program (especially the appendices)

2.1.5 Ensure the integrity of data and remote monitoring of hydraulic parameters

There are many technologies that can facilitate the management of a distribution system. The SCADA system (for Supervisory Control And Data Acquisition) is one example. It allows the continuous acquisition of data on things like pressure and flow in all parts of the system. It also enables continuous control of the system itself and of water quality, using established parameters like chlorine, pH, turbidity, temperature, etc. Empowered by the comprehensive supervision this provides, utilities can prevent problems before they happen and be more pragmatic in handling emergencies. However, for all of this to work, it is essential to ensure that the data fed into the SCADA system is reliable, whether obtained manually or through remote monitoring. Thus, a methodical approach is required.

RECOMMENDATIONS[10]:

- Samples should be taken in the upper or lateral part of the water main, avoiding air bubbles. Especially important for measuring turbidity.
- Make sure that monitoring instruments are clean, to prevent false results due to accumulated particles diffusing light.
- Verify the instrument's physical integrity (head properly set on the body of the device, optical system, etc.).
- Watch out for errors in software parameters, for example set an alert to appear if a turbidity reading stays the same for too long.
- Set alerts to monitor data integrity (rate of variation alerts, loss of flow alerts, pressure drop alerts, etc.).
- Check the reliability of data coming in from online instrumentation, for example by taking samples in the field.

TOOL AVAILABLE:

- DiagnosticPI: This program detects errors in municipal response plans and ensures the integrity of data in such plans. See https://ceriu.qc.ca/piemq.

[10] MARTIN, B. (May 2017). "Ensure Data Integrity to Optimize Water Quality". *Opflow*, Vol. 43, No. 5, p. 8-9.

2.1.6 Conserve water without affecting quality

Water conservation has become an integral part of distribution system management. To that end, the Québec Strategy for Drinking Water Conservation requires that municipalities adopt a number of water conservation measures. Nonetheless, it is important to ensure that changes to existing practices do not result in lowering water quality.

RECOMMENDATIONS:

- Implement the measures specified in the Québec Strategy for Drinking Water Conservation, including:
  - Each year, report the municipality’s water use on the required water use form.
  - Each year, inspect the flowmeters used for that report (along with other flowmeters when necessary), to eliminate errors of measurement.
  - Install water meters in non-residential buildings, and audit large industrial consumers.
  - Follow the standardized method of calculating the cost of water services.
- Watch out for water conservation methods that could jeopardize quality over the middle to long term.
- Make sure that municipal regulations can be readily and practically applied.
- Make sure that stricter regulations on water use do not lead to risky practices.

PAY SPECIAL ATTENTION TO THE FOLLOWING PRACTICES:

- Efforts to reduce leaks, combined with efforts to reduce water consumption, could lead to longer residence times (and reduced water quality) in the outermost parts of the system (see section 4.1.4). Give priority to high-consumption areas when hunting for leaks or promoting conservation measures like replacing conventional toilets with low-flush models.
- Certain measures, such as regulations against using drinking water for outdoor work, or encouraging the use of private catchment for such purposes, could raise the risk of contaminated water entering the system. For example, water faucets could be mistakenly connected to a greywater recovery system or a non-potable water system. Backflow preventers must be included when installing such systems.
- Reduced flow in sewers can lead to build up and odour problems.

BENEFITS:

- Reduce demand pressure on water sources.
- Lower the costs associated with new infrastructures and their maintenance.
- Maintain the quality of water in the system.

JUSTIFICATION:

The main arguments for reducing the volume of water distributed are as follows:

- less demand pressure on quality water sources;
- better control over increase in water treatment costs at the production facility;

- better forecasting of investment needs to increase production and distribution capacity;
- lower costs for wastewater treatment.

TOOLS AVAILABLE:

- Québec Strategy for Drinking Water Conservation (French):
  - form on drinking water use;
  - model on municipal regulation;
  - model on leak inspection contract;
  - annual report on drinking water use;
  - promotional tools
  - web conferences on the Strategy and its form.
- Water Loss Control Resource Community from the AWWA, which offers free tools for water loss analysis
- Presentations given during the *Journée technique sur les compteurs d'eau et la tarification*, on May 18, 2016 (Réseau Environnement)

2.1.7 Encourage communication with the public

Though often neglected, ongoing communication with the public can raise awareness about the effort that goes into maintaining infrastructures, and about the benefits that citizens enjoy each day.

RECOMMENDATIONS:

- Encourage proactive communication with the public by highlighting positive points about water quality, as opposed to reactive communication, which is generally a response to complaints.
- Set up and promote a citizen relations line for receiving and handling complaints, comments and fault reports.
- Be diligent about answering, and follow up on calls received.
- Give consideration to public opinion in the decision making process.
- Survey users for information that could help the water service meet expectations.
- Calculate and publish the costs associated with water services.
- Explain the purpose and results of work done on the system (rehabilitation plan, leak repairs, water sampling, etc.).
- Whenever work is done on the system, systematically inform the public (work notices, flushing notices, preventive boil water advisories [see below], etc.).
- Build public awareness on water conservation measures, water use regulations, and the importance of protecting the system from contamination.
- Publish the annual report on municipal drinking water quality. Under the RQDW, utilities serving residences have an obligation to produce this report. It is not obligatory to make the report public, but we recommend doing so. Also, municipalities must post their report at their offices, and publish it on their website if any (see section 53.3 of the RQDW for more details).

BENEFITS:

- Promote citizen collaboration.
- Promote responsible consumption.
- Build a positive perception of water quality and municipal services in general.
- Benefit from greater public understanding in crisis situations.
- Make it easier to obtain public consent to borrowing by-laws for water-related issues, etc.

JUSTIFICATION:

Municipal utilities are often hesitant about publishing information on the water distribution system, particularly the results of water quality analyses. They may be afraid that the results could be badly interpreted. At the same time, people expect to have good quality water at all times. When there is an episode of poor water quality, lack of information is the most common cause of public dissatisfaction. Therefore, providing clear and accurate information is the easiest way for a municipality to win the public's understanding and confidence.

NOTE ON ISSUING PUBLIC ADVISORIES

When work on the system requires that an advisory be issued, it is important to use all available means of communication to ensure that those concerned are notified as quickly as possible. Means of communication can include:

- door-to-door;
- automated telephone calls, e.g. using a mass notification system to communicate in real time;
- email distribution lists;
- public awareness campaigns;
- tax statements;
- newspapers and municipal newsletters;
- municipal website;
- social media (Facebook, Twitter, etc.).

Using postal mail to publish a one-time, short-term notice is not an effective means of communication, since not everyone checks their mail every day. More specifically, in the case of a mandatory boil water advisory, the Ministère considers that utilities should choose whatever means are most likely to quickly reach the greatest possible number of users. Utilities also have the obligation to contact directly all health and social services facilities that are served by the system, along with schools (including daycares) and detention facilities. (See the explanatory note to section 36 of the RQDW in the *Guide d'interprétation*.)

Concerning the issuance of preventive boil water advisories, utilities should consult with the Direction régionale de santé publique (DRSP) as to how serious a situation should be to require that they be notified. However, when a boil water advisory must be issued for preventive reasons, it is important to notify the DRSP if there is a hospital in the area covered by the notice.

TOOLS AVAILABLE:

- Modèle de bilan annuel de la qualité de l'eau potable (annual water quality report template), available on the website of the Ministère
- Organigram for complaint processing (Appendix 3)
- MAMH, Rapport annuel de l'usage de l'eau potable (annual drinking water usage report)
- International Institute of Aquaresponsible Municipalities - aquaresponsibility certification (a collaboration between Université Laval and INRS-ETE)
- Observatoire national des services d'eau et d'assainissement. Annual report on the price and quality of services (RPQS) (quality indicators for waterworks and sewer systems, France). The following expresses the main reason for producing such an annual report:

  "The RPQS is a document produced each year by every drinking water and wastewater service to inform users as to the price and quality of the service rendered the previous year. It is a public document (once it has been validated by the deliberative assembly of the community) which answers a demand for internal transparency (the service reports annually to the supervisory community, and the Mayor or President presents the report to the deliberative assembly), as well as a demand for transparency to the user, who can consult it at any time at the offices of the service."

- Reekie, L. and A. Fulmer, (August 2015). “Develop Effective Communications About Emerging Contaminant Risks”. *Opflow,* Vol. 41, No. 8, p. 22-24
- Communicating Water’s Value: Talking Points, Tips & Strategies. Part 2: Stormwater, Wastewater, Watersheds (Catalogue #20766), available through the AWWA
- IRIS Mass Notification System: comprehensive system for broadcasting the desired information to clients in a systematic manner (repair notices, boil water advisories, late payment notices, etc.). The linked document provides a thorough list of the system’s functions and benefits: http://useiris.com/useIRIS.pdf.

2.1.8 Implement effective mechanisms for internal collaboration

Management teams for drinking water infrastructures can vary considerably, depending on the size of the municipality. A small municipality may have a single engineer managing all infrastructures, while a large one is likely to have several specialized teams. A point in common tends to be that water production and quality monitoring are the responsibility of staff at the production facility, while maintenance is handled by public works staff.

The quality of a water service depends on multiple factors: the type (or absence) of treatment used, the various operating parameters, and how these activities are managed. There are benefits to establishing communication mechanisms between the different departments.

RECOMMENDATIONS:

- Make sure that one person is responsible for all water-related activities and their management.

Definitions:	manager	=	the person who ensures that the work is done and reports on actions accomplished
	management	=	planning, organization, supervision, control

- Maintain links with elected officials.
- Promote good relations between managers and employees.
- Focus on communication and collaboration between different departments (public works, treatment facility, customer service).
- Use the knowledge possessed by operators to improve municipal practices: their training has given them a wealth of information on the proper ways of doing things.
- Set a goal for all public works staff (operators and forepersons) to take training under the Drinking Water Operator Qualification to earn OPA certification (*préposé à l'aqueduc*).
- Pair beginners with experienced workers to create the conditions for knowledge transmission.

BENEFITS:

- Have one person who is responsible for the entire system; that person will develop a vision of the respective responsibilities of all the teams and how they are interconnected.
- Funding can be obtained more easily.
- Improve the effectiveness of processes.
- Reduce errors in management decisions and in operations on the ground.
- Benefit from everyone's experience.

2.1.9 Have tools for funding the maintenance and renewal of drinking water infrastructures

One of the main challenges for utilities is to collect the funds needed for proper management of the distribution system.

RECOMMENDATIONS:

- For each intervention or activity, assign costs to the appropriate accounting items, to reduce uncertainty about the cost of water services and to avoid having such costs lumped in with other expenses like road maintenance.
- Plan and measure needs for maintenance and infrastructure renewal.
- Work with those in charge of urbanism and municipal finances to ensure that there is sufficient population density to support infrastructure development and redevelopment projects. Population density is the key to having the financial means to ensure the longevity of infrastructures.
- Have a long-term fiscal strategy for infrastructure funding (property taxes, local distribution taxes, fees) and adjust it over time to allow investment in infrastructures while controlling debt.
- Build and maintain relationships with elected officials.

BENEFITS:

- Help obtain the funding required.
- Good planning makes processes more effective.
- Resources are used more efficiently.
- Major investments can be planned for later.

TOOLS AVAILABLE:

- Federation of Canadian Municipalities, *Managing Infrastructure Assets*
- Programme de la taxe sur l’essence et de la contribution du Québec 2014-2018 (TECQ):

  “The government will also continue to support municipalities in their efforts to conserve drinking water. For example, the *Programme de la taxe sur l’essence et de la contribution du Québec 2014-2018 (TECQ)* is available to help municipalities to correct their water systems.”
- Stratégie montréalaise de l'eau: example of long-term planning, with drinking water infrastructure renewal costs (French)
- Coût et sources de revenus des services d'eau: several useful documents (French)

2.1.10 Ensure the health, safety and training of workers

Water system workers encounter many risks in the course of their duties: falling, working in confined spaces and trenches, difficult weather conditions, etc. It is important to give consideration to their working conditions. Also, the effectiveness of interventions depends on the competence and motivation of operators. Knowledge evolves, intervention techniques develop, new tools appear, and it is in the best interests of all that workers be aware of these new developments.

RECOMMENDATIONS:

Health and safety:

- Make supervisors and team leaders responsible for establishing safety rules and making sure that workers follow them (lockout/tagout procedures, confined space entry procedures, signage, etc.).
- Solicit employee initiatives and active participation in implementing health and safety measures.
- Keep up to date of the latest approaches and new measures that could be put in place.
- Invest in equipment that could facilitate work (truck with motorized valve operators, etc.).

Training:

- Make sure that all employees are trained in accordance with the *Act respecting occupational health and safety*.
- Verify the competence of system operators.
- Prepare brief quizzes on working procedures and have workers complete them periodically to refresh their memory.
- See to maintaining and improving their knowledge and skills by encouraging them to participate in:
  - training sessions;
  - webinars;
  - practical courses;
  - exchanges with colleagues in other municipalities.
- Contribute to worker retention by encouraging special recognition for their work by elected officials and unions.

BENEFITS:

- Prevent occupational illnesses, accidents and deaths, and reduce the human and financial costs associated with them.
- Improve the quality of interventions.
- Promote better commitment and greater motivation on the part of workers.
- Develop expertise and knowledge transfer.
- Help with worker retention.

TOOLS AVAILABLE:

- Website of the *Association paritaire pour la santé et la sécurité du travail*, municipal affairs section (APSAM). Examples of standards and prevention, protection and retention measures:
    - Transform confined spaces into isolated danger areas (e.g. certified ventilation and stairs in reservoirs).
    - Have a uniform guardrail system.
    - Wage increases.
- Québec'eau: training portal for water professionals.

2.1.11 Plan emergency measures

Emergencies are always easier to handle if you have an action plan at the ready.

Here are some events for which it is worth preparing an emergency plan:

- water main break or on a single crucial pipe;
- major leak in a tank or reservoir that is part of the distribution system;
- pump failure affecting part of the system;
- system contamination due to backflow or intrusion resulting from back-pressure or siphonage;
- contamination of the water source by a spill that could require closing the water intake;
- epidemic affecting the population (and possibly workers assigned to respond to the emergency);
- water shortage affecting a critical facility, such as a hospital (heating and cooling, toilets, food, laundry, sterilization, dialysis, etc.);
- major fire at a sensitive location (CHSLD, hospital, school, etc.), for which emergency planning should be done in collaboration with the firefighting service.

RECOMMENDATIONS:

- Have an emergency plan for different situations.
- Have service agreements with one or more neighbouring municipalities for disaster readiness (to provide workers, equipment, etc.).
- Make provisions for alternative drinking water supply solutions, e.g. tanker trucks, temporary or permanent connection to a neighbouring system, mobile treatment unit, alternate water source, etc.
- Encourage teamwork for effective collaboration among teams in the event of emergency.
- Prepare employees to deal with emergency situations by conducting simulations or exercises.
- Be sure to have emergency funds.
- Be sure to have insurance.
- Provide for effective means of communication so that citizens can be informed without delay.
- Review the emergency intervention plan each year and update whenever necessary.

BENEFITS:

- Be ready to deal with emergency situations.
- Minimize response times.
- Avoid the need to issue boil water or drinking water avoidance advisories, and situations requiring that water distribution be suspended.

TOOLS AVAILABLE:

- Drinking Water and Wastewater Resilience: website provided by the United States Environmental Protection Agency:
  - Tools and recommendations for increasing the safety of hydraulic infrastructures, to protect the public as well as the environment.
- ISO 24518 - Activities related to drinking water and wastewater services: standard to help water utilities in developing and implementing a crisis management system. Based on the Plan-Do-Check-Act approach (PDCA), to prepare public water services to:
  - deal with crisis situations to ensure the continuity of service in the public water supply and the evacuation and treatment of wastewater;
  - cooperate with all authorities concerned;
  - take into account the natural environment and the impact of disruptions on the health and well-being of the population;
  - communicate effectively with the public to mitigate or avoid panic reactions.

2.2 Specific issues

2.2.1 Managing numerous emergency repairs

Emergency repairs are costly and often difficult, since working conditions are hard to control. Especially in winter, when water mains can be under significant stress, the cold weather, snow and ice complicate interventions. Equipment inspection and maintenance, preventive leak detection, pressure management and worksite supervision can all contribute to reducing the need for emergency repairs, though they are hard to eliminate completely.

2.2.2 Managing water losses and leak detection

It is a constant challenge for water utilities to limit water losses. In order to develop effective strategies, utilities need to know where in the system they are happening. The table in Appendix 8 represents the water balance of a distribution system. It provides a portrait of how water is distributed in the system and where losses may originate.

The causes of water loss include leaks. Active leak detection programs to search for them will result in leaks being located so that repairs can be done. There are different methods of leak detection, including acoustic correlation using hydrophones, non-acoustic methods like tracer-gas detection, camera inspection, and so on. The following information should be gathered about a leak zone: the location of the water pipe, its size, its depth, the type of leak, a visual appreciation of the type of soil (sand, clay, etc.), an estimate of the degree of soil saturation, and so on. This information will make repairs easier.

To facilitate leak management, a yearly estimate should be made of the volume of water losses due to leaks.

TOOLS AVAILABLE:

- AWWA Manual of Water Supply Practices: M36, *Water Audits and Loss Control Programs*

2.2.3 Fighting cyber crime

Water distribution systems can face a considerable range of emergency situations, cyber crime being one of them. There can be many reasons for such attacks, whether monetary (ransom demands) or non-monetary. To protect the system, managers and staff should adopt a number of safe habits.

RECOMMENDATIONS:

- Secure accesses using employee identification, keeping records of their movements, etc.
- Discourage acts of vandalism by setting up fences and security cameras as a dissuasive measure.
- Put strategies in place (standards and procedures) to reinforce security, such as requiring employees to change their passwords frequently.
- Limit access to SCADA and industrial control systems (ICS), or separate the control system from other systems.
- Monitor the passage of information or data from one system to another.
- Restrict the connection of any equipment to the ICS, and when approved, consider it as an ICS component.
- Securely dispose of used equipment to avoid illicit attempts at data recovery.
- Prohibit use of the SCADA system for Internet navigation.
- Prohibit connecting to the system from external portable computers.
- Do not use portable computers specific to the SCADA/ICS system for any other purpose (e.g. personal email).
- Maintain a virtual copy of the system.
- Adapt to sociocultural developments and new technologies.

TOOLS AVAILABLE:

- ANSI/AWWA G430 Standard: sets out minimum requirements for system protection (employees, public, infrastructures)
- ANSI/AWWA J100 Standard on risk analysis and asset protection
- National Institute of Standards and Technologies (NIST*), Framework for Improving Critical Infrastructure Cybersecurity (2017)*, the basic framework for cyber security
- United States Department of Homeland Security (DHS): *Critical-Infrastructure Cyber Community (C3) Voluntary Program*, aimed at raising awareness about cyber security in phase with NIST efforts

2.2.4 Manage consumer concerns

Several factors can make consumers lose confidence in the quality of their drinking water:

- bad tastes and odours;
- discoloured water;
- frequent boil water or do not consume advisories;
- emergency repairs;
- visible deterioration of equipment (buildings, fire hydrants);
- clear and precise information difficult to obtain.

Apart from improving water treatment, several practices in this document could contribute to regaining consumer confidence:

- use one-way flushing;
- maintain good communication with the public whenever work has to be done;
- publish reports explaining problems and the measures taken to fix them;
- keep visible elements looking properly maintained, e.g. by painting fire hydrants;
- issue clear, precise public notices in areas affected by work on the system.

If it is known that some citizens are applying supplemental water treatments, you can launch an information campaign to **set the record straight** on the quality of the water being supplied and whether extra treatment is really needed. You can also recommend that anyone who feels a need for supplementary treatment should contact a certified specialist in household drinking water (SCEPD).

2.2.5 Contracting out or doing work internally

Every water utility has to deal with a limited budget. When an important project comes up, such as installing water meters, you must choose between doing the work internally or contracting it out. The following questions will help guide the decision making process:

- Will the quality of the work be verifiable?
- Can the required quality of work be achieved by internal workers / by a contractor?
- Can the municipality retain control over planning and implementation?
- Will it be easy to incorporate any adjustments needed?
- Would useful data be lost?
- Could expertise developed by internal workers be useful to the municipality – could that expertise reduce costs in the future (maintenance, troubleshooting, etc.)?
- Could the project become a mobilizing element for municipal workers?

Contracted out = verification

Whenever work is to be contracted out, you must ensure that municipal staff will be able to verify, from start to finish, whether it is being done properly. This makes it easier to take steps to have poorly executed work done over, avoiding financial losses.

Internal = rigour

When work is to be done internally, you must ensure that municipal staff will have the time to do it. For example, a municipality may choose, by mutual agreement, to keep staff working through the winter by doing maintenance work on fire hydrants.

2.2.6 Operating seasonal distribution systems

The operation of a seasonal distribution system presents particular challenges. Such systems are at greater risk from water stagnating in pipes and equipment. Rigorous protocols should be followed when closing and reopening such systems. When a seasonal system is connected to a permanent distribution system (whether municipal or private), inadequate procedures could impair the quality of water in the permanent system.

Before returning a seasonal distribution system to operation, the following procedure should be completed, performing each task in the order shown:

- Inspect all components of the system and do any repairs needed.
- Flush the water pipes.
- Clean and disinfect all water storage facilities (contact chamber, reservoirs, cisterns, etc.).
- Disinfect the well (if any) and water pipes.
- Flush again to remove chlorine or until the required residual concentration is reached.
- Before opening the system to consumer use, take bacteriological samples and wait for confirmation that the results show no contamination.

The following points are also very important:

- Use fresh chlorine for disinfection (check the expiration date on the sodium hypochlorite container).
- Remove filters and faucet aerators so as not to clog them during flushing.
- Close hot water reservoirs.
- Do not discharge highly chlorinated water directly into vegetation or aquatic environments (follow the ministerial guidelines on discharging chlorinated water).
- Respect health and safety rules.

The closing of a distribution system is done by draining all elements so as to prevent frost damage. To avoid contaminating the system, do not put in any form of antifreeze. Also, autumn is a good time to perform general maintenance on the system, so you can start again the following spring on the right foot.

TOOLS AVAILABLE:

- Manitoba Water Stewardship, *Seasonal Water System Start-up/Shut-down Protocol*
- ANSI/AWWA C652-11 Standard for the disinfection of water storage facilities

2.3 Going further

Once the basic measures are well established, there are more advanced practices for control and monitoring that a municipality can put in place.

2.3.1 Model the system's hydraulic behaviour

Understanding a system's hydraulic behaviour means being able to predict, as well as possible, the flow rate, pressure, direction and flow velocity in the pipes. Each system is designed to be hydraulically balanced, base on an initial configuration and water consumption. Changes made subsequently will affect the system's hydraulic behaviour. To keep the system balanced, modelling software is indispensable.

RECOMMENDATIONS:

- Before undertaking a more advanced analysis, carefully estimate water consumption in the modelling nodes, since this will have repercussions on all the rest of the study, including the choice of methods for validating the model.
- Make sure you know the status (closed, open) of all valves in the system.
- Review the model regularly and make any corrections needed, especially after major work is done on the system.

BENEFITS:

- Get a finer understanding of how the water is circulating.
- Evaluate different hydraulic behaviour scenarios when changes to the system is considered (among other things, this lets you foresee how users in a given area will be impacted by work).
- Obtain useful data with a limited number of instruments.
- Evaluate the effect of a closure before the work begins.
- Predict residence time and chlorine residual to guide the selection of sampling points. However, you should check the reliability of modelled data by (for example) taking measurements in the field.
- Predict pressures to help reduce leaks and breaks.
- Enable the use of tracing to determine the propagation of a parameter introduced into a given node of the system (for example, to plan sampling in the event of contamination).
- Establish a strategy to limit the occurrence of coloured water by using a higher flow velocity to achieve self-cleaning.

TOOLS AVAILABLE:

- EPANET, easy to use software available free on the Internet
- EPANET-RTX, SCADAWatch: when combined with the SCADA system, these programs let you do real-time modelling
- AWWA Manual M32, *Computer Modelling of Water Distribution Systems*

2.3.2 Divide the system into sectors

Sectorization consists of dividing a system into areas, such that each area is fed by a limited number of inlets (ideally just one) and drained by a limited number of outlets (also ideally one). A problem that can arise when using this method is that it may prevent the supply of sufficient fire flow. The following recommendations can help remedy this.

RECOMMENDATIONS:

- Close off areas using check valves and automatic control valves that can open in a fire situation.
- Consider putting in place one or more entry pipes, to have a backup solution in the event of malfunction. Carefully determine the parameters of the new water pipe.
- Avoid the formation of dead-ends by closed valves. Where dead-end formation cannot be avoided, make sure that the location can be readily accessed for regular flushing.

BENEFITS:

- Enables more effective reaction to events (sector-specific notices, better control of circulation and contamination).
- Prepare water reports based on sectors.
- Better monitoring for leak detection.

TOOLS AVAILABLE:

- Jean Lamarre, “Sectorisation et régulation de la pression de l’aqueduc à Montréal”, *Vecteur Environnement*, March 2015, p. 38-40
- Mathieu Laneuville, “Gestion de la pression d’eau dans les réseaux de distribution”, *Vecteur Environnement*, May 2015, p. 44-50
- Presentation on a sectorization method for drinking water distribution systems, as applied to two Québec municipal systems; available on the website of the Centre d’expertise et de recherche en infrastructures urbaines (CERIU) at: Adaptation d'une méthode de sectorisation des reseaux de distribution d'eau potable et application aux réseaux de deux municipalités au Québec

2.3.3 Join the Programme d’excellence en eau potable – distribution section (PEXEP-D)

The PEXEP-D program helps municipalities improve their performance in providing water services. The goal is to improve the quality of water distributed to users by optimizing operations in municipal systems. The program goes beyond Québec regulations and leads participating municipalities toward excellence in the quality of their drinking water.

The program proposes an optimization based on improving operating practices with minimal capital investment.

The program is based on four parameters for optimizing distribution systems:

- Water quality integrity - by monitoring concentrations of disinfectant residual;
- Physical integrity - by monitoring the break rate of water mains;

- Hydraulic integrity - by managing pressure;
- Usage integrity - by managing leaks.

A detailed guide presents a structured process in which over 20 variables are used to optimize performance. Participation in the program has four main phases: signing up, collecting and compiling data, self-evaluation, action plan.

Throughout the process, tools and technical support are provided to participants. Learn more about the program by visiting the website of Réseau Environnement.

2.3.4 Use a georeferenced inventory and a geographic information system (GIS)

A georeferenced inventory is created by accumulating the geographic locations of all equipment in the system and entering each position in a database[11]. Once the database is linked to a map of the territory, you can add whatever information is relevant for each item of equipment. For example, for a water pipe you would add its diameter, material, placed-in-service date and all interventions carried out since.

It also useful to georeference consumer complaints. This makes it easier to identify problem areas and to manage the problems that arise.

BENEFITS[12]:

- Have detailed information about the system continuously updated.
- Identify priorities more effectively and determine where intervention is needed most urgently.
- Enhance crew selection for field operations (competencies required).
- Reduce the number of errors during interventions.
- Reduce costs.
- Improve management of time and financial resources.

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[11] http://ceriu.qc.ca/bibliotheque/mise-jour-donnees-igd-07 (accessed on June 20, 2016)

[12] McKEON, R. (February 2015). "What Surprising Tasks Can GIS Leverage in Water Utility Operations?" *Opflow,* Vol. 41, No. 2, 8 p.

TOTMAN, D. (2016). "GIS and the 5 Ws". *Rural Water*, Vol. 37, No. 2, p. 31-32.

2.3.5 Improve operations management

The manual *Distribution Systems, Operation and Management, Operational Guide to AWWA Standard G200* is the perfect guide for utilities aiming for high standards in the management and operation of their distribution system. It is full of easy-to-follow examples and includes audit lists that can be adapted to different situations. The benefits for utilities include:

- better understanding of the AWWA G200 standard, to apply it more effectively;
- best practices to adopt;
- management programs for distribution systems;
- equipment maintenance;
- management of human resources.

3. MONITORING WATER QUALITY

It is a well-known fact that the quality of water at the consumer's tap is not necessarily the same as when it entered the distribution system a few hours earlier. The changes it has undergone may be biological, physical and/or chemical, with negative results that are mostly of an aesthetic nature, while the change dynamic is a function of time and space.

Several factors can affect water quality in a system:

- the water supply (quality at the source, treatment)[13];
- temperature and pH;
- water demand (consumption) and residence time;
- pipe materials;
- nutrients (natural organic matter, biofilm, corrosion);
- interstices in which particles can accumulate;
- intrusions (see Chapter 4).

Understanding and monitoring these mechanisms of change are essential to providing good quality water and fulfilling consumers' expectations.

[13] Even with an underground source, it is important to maintain high treatment standards, paying close attention to potential contamination sources and to water quality throughout the distribution system. Ground water sources are not immune from problems, as illustrated by the gastroenteritis outbreak in Havelock North, New Zealand in August 2016: https://www.dia.govt.nz/Government-Inquiry-into-Havelock-North-Drinking-Water#Overview.

3.1 Best practices

3.1.1 Take time to establish a good sampling plan

The RQDW makes quality control mandatory for distribution systems serving more than 20 persons. The amount of sampling required depends on the types of parameters monitored and the number of persons served. Also, utilities must prepare a map locating all the sampling points used and a table of the hydraulic characteristics associated with each.

Sampling is imperative to comply with regulations, its purpose being to monitor the quality of water in the system.

RECOMMENDATIONS:

- Choose sampling points with care, and review them regularly. For example, water from a dead-end in the heart of a residential area could have a high residence time despite not being at the outer limits of the system.
- To ensure that results are representative, rotate some of the sampling points used for microbiological parameters, chlorine residual and disinfection by-products.
- Locate sampling points where problems can arise, not where you can be certain of good results.
- Keep a number of sampling points at key locations in the system, so that you can build a temporal portrait and recognize when a significant variation signals a need for prompt action.
- Use sampling as an opportunity to implement the use of water quality indicators, as described in the next section (3.1.2).
- Take into account the impact of weather events and seasonal changes on water quality, such as snowmelt in spring, heavy rains, drought, etc.

BENEFITS:

- Safeguard public health more effectively.
- Fulfill the spirit of the regulations by showing a genuine concern for the quality of water distributed.
- Ensure the provision of healthy water to all who are served by the system.

TOOLS AVAILABLE:

- Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, Monitoring Water Quality in the Distribution System (2005)
- Spatial considerations for the selection of sampling sites in a water quality monitoring program (see table in Appendix 4)
- Hydraulic modelling of the distribution system can help in the choice of sampling points

3.1.2 Use water quality indicators

Water quality indicators are parameters measured at multiple locations to provide information on the state of the system and the water being distributed.

RECOMMENDATIONS:

- Choose multiple water quality indicators.
- If chlorination is used, maintain a measurable concentration of chlorine residual all the way to the ends of the system (ideally at least 0.1 mg/L for free chlorine residual and 0.5 mg/L for chloramines), while avoiding excessive chlorination at the treatment facility. It is best to add rechlorination stations where needed, thus limiting the formation of disinfection by-products.
- For systems or portions of a system that are not chlorinated, consider monitoring HPC[14], taking care to follow the proper method for conserving samples, since otherwise they will not be representative.
- Use sampling as an opportunity to make on-site measurements of parameters like pH, iron and turbidity, which can be useful indicators.
- Establish protocols for sampling and measuring.
- Train and supervise employees who will do sampling.
- Keep track of how your indicators change through time by putting the results into graphic form.
- Pay serious attention to every positive result for total coliforms, and do a new sampling as soon as possible to confirm their presence if necessary.
- Avoid changing analysis methods, since it can make interpretation of results more difficult.
- Respond actively to results by noting connections between different indicators and correcting problematic situations.

BENEFITS:

- Detect changes in water quality more quickly.
- Detect the sources of contaminant/pathogen intrusion more quickly.
- Have a better understanding of water flow direction.
- Plan unidirectional flushing activities more effectively.
- Act preventively instead of reactively.

[14] According to the U.S. EPA, a HPC below 500 UFC/ml should correspond to a compliant concentration of detectable disinfectant residual. In Great Britain no numeric value is specified, but HPC should not display abnormal changes. Any sudden increase is reason for concern. See also Health Canada's document on heterotrophic bacteria in the list of tools available.

JUSTIFICATION:

Monitoring chlorine residual to verify water quality is now a well-established practice in North America. Other parameters can help in preventing or detecting a number of problems. The following table shows how certain parameters can give clues about the status of the system.

Parameter	Abnormal decrease[15] could indicate:	Abnormal increase could indicate:
Chlorine residual	Excessive biofilm growth. A valve stayed shut after repairs or flushing. Presence of cross contamination.	Higher water consumption. Intrusion of chlorine contamination (e.g. loss of a chlorine plug during repairs). Wrong dosage or a problem at the dosing pump.
Temperature	Presence of cross contamination, e.g. with a refrigerant liquid.	Presence of cross contamination.
pH	Excessive biofilm growth. Presence of cross contamination. - If pH < 6.5, increased risk of corrosion, dissolution of metals and haloacetic acid (HAA) formation.	Wrong dosage at the treatment facility. Presence of cross contamination. - If pH > 8.5, increased risk of scaling through calcium carbonate precipitation, along with trihalomethane (THM) formation and reduced chlorine power.

TOOLS AVAILABLE:

- Guidelines on the Use of Heterotrophic Plate Counts in Canadian Drinking Water Supplies, from the Guidelines for Canadian Drinking Water Quality, Health Canada (2012).
- Federation of Canadian Municipalities and National Research Council of Canada, Monitoring Water Quality in the Distribution System, a Best Practice by the National Guide to Sustainable Municipal Infrastructure.
- Software for compiling data on drinking water quality:
  - CANARY - detect contamination in distribution systems;
  - EPANET-RTX - create hydraulic models and water quality models;
  - Water Security Toolkit (WST) - prepare strategies for responding to contamination.

[15] Abnormal decrease or increase as compared to previously collected data from the same location. A gradual decline in the concentration of disinfectant residual, and a slight increase or decrease of temperature with seasonal transitions, are normal in a system with longer residence times.

3.2 Specific issues

3.2.1 Dealing with a local deterioration in quality

Water quality monitoring or consumer complaints may lead to observing that **a standard has been exceeded** or that **an aesthetic parameter is causing a problem** (taste, odour, colour).

All of the factors listed at the beginning of this chapter can impair water quality. To deal with such problems, here is a suggestion for how to proceed:

- Verify the complaint by having samples analyzed by a recognized accredited laboratory, if possible[16] and if it's not already done.
- Check if changes occured at the production facility serving the area concerned, in the hours or days prior to the complaint.
- Conduct a sampling campaign in a grid form to determine wheher the problem is local or not.
- Check any valves that might have stayed shut after work on the system.
- Check the entry and exit points for that sector.
- Identify possible short-, medium- and long-term solutions.
- In the short term, do a corrective flushing and set up a programmable flush valve if necessary. Be sure to follow the Ministère's Position on the enforcement of Canada-wide standards regarding municipal sewer system overflows.
- In the medium and long term, find funding to correct the problem at the source.

TOOLS AVAILABLE:

- MELCC, Specific interventions concerning various water quality problems
- Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, Small System Operation and Maintenance Practices. Appendix B – Adverse Water Quality Test Flow Chart

3.2.2 Address concerns regarding the presence of manganese

Section 3.2.1 lists a number of reasons why complaints may occur. Some complaints about problems of an aesthetic nature may be due to the presence of manganese. A concentration over 0.015-0.02 mg/L can alter the taste of water and cause it to be coloured. While manganese itself can present a health risk, but at a higher value, the discolouration may indicate the presence of heavy metals adsorbed on the manganese, which can pose a greater health risk. There are several ways in which this can be prevented.

[16] Laboratory accreditation is for parameters that are subject to regulatory standards; however, a complaint may concern a parameter that is not regulated (such as an aesthetic parameter).

RECOMMENDATIONS:

- Pay careful attention to the water source being used.
- Treat water in the optimal manner.
- Clean water pipes regularly.
- Perform regular maintenance on the system.
- Carry out unidirectional flushing proactively, not just after complaints are received.
- Overall, adopt best practices for managing the system.

BENEFITS:

- Fewer complaints.
- Greater public confidence in the water system and the water utility.
- Lower costs due to complaint response (flushing, sampling, consulting services, damage compensation, etc.).

3.2.3 Improve the management of old water mains

Old water pipes that were installed decades ago can cause a deterioration in water quality.

This can be the case with old polyvinyl chloride (PVC) water pipes, generally laid before 1980, and of old pipes or reservoirs whose interiors are lined with epoxy. When present, additional parameters should be monitored (presence of vinyl chloride, taste, odour, etc.), since the compounds released can, over the long term, present risks for consumers. Some municipalities set up automatic or permanent bleeding lines to prevent increase problems associated with these substances.

Also, unlined water pipes made of metal can become corroded, causing the water to take on a rusty colour. Older pipes may also contain lead, which can be leached into the water and create a health risk. Pipes containing lead should be replaced with pipes of a different material. For other old water pipes, the recommended practice is to line them with polyurethane or epoxy, taking into account the guidelines presented in this and other sections. For other solutions regarding lead, see also the *Guide d'évaluation et d'intervention relatif au suivi du plomb et du cuivre dans l'eau potable* (assessment and intervention guidelines on lead and copper in drinking water) on the website of the MELCC at:

http://www.environnement.gouv.qc.ca/eau/potable/plomb/guide-evaluation-intervention.pdf

4. LIMITING SOURCES OF INTRUSION AND WATER DEGRADATION

The numerous connections and other equipment in a distribution system can become entry points for contaminants. Contamination can develop slowly and subtly, as when pathogens grow on biofilm. Contamination can also happen suddenly and catastrophically, as when there is a backflow of water from a plant that uses chemical products. In either case, once a system is contaminated, cleaning it is a considerable undertaking with little time in which to do it. Prevention is therefore the best solution.

4.1 Best practices

4.1.1 Monitor connections to the system

Every connection to the system is a potential source of contamination. Some connections present a greater risk than others, and it is important to keep this in mind.

DEFINITION: cross-connection[17]

A cross-connection is defined as any existing or potential connection, such as a derivation, rider main, removable section, swing joint or any other device or connection, installed permanently or temporarily, connecting a drinking water distribution system to a potentially polluting source. In such connections, two problematic situations can give rise to a flow reversal, bringing non-potable water into the system: ***siphonage*** *and* ***back-pressure****. Siphonage (also called back-siphonage) is when a pressure drop in the drinking water system pulls in water from another source. Back-pressure is when overpressure in the other source pushes contaminated water into the system.*

RECOMMENDATIONS:

- Set up a program to oversee the installation and annual inspection of backflow preventers in all commercial and industrial buildings, and in residential buildings with more than eight apartments or more than two floors, to complement efforts by the RBQ.
- Prioritize higher-risk buildings as defined by the RBQ.
- When water meters are to be installed in industries, businesses and institutions, use the opportunity to install backflow preventers, and follow up by inspecting them annually.
- Adjust municipal regulations to limit accessory connections (sump pumps, fertilization systems, greywater systems, etc.).
- Watch out for backflows at flushing valves as well as water from valve chamber drains connected to the sewer system (see sections 4.1.5 and 4.2.1).
- Pay close attention to temporary flushing during construction work.

[17] "Les dispositifs antirefoulement, numéro spécial", *IMB, Inter-Mécanique du Bâtiment*, La revue officielle de la CMMTQ, 2nd edition, May 2009.

For municipal workers:

- Make municipal workers aware of these problems and encourage them to be vigilant with junctions that could present risks of contaminant intrusion, such as private wells that have not been disconnected.
- Control access to fire hydrants by users other than municipal staff (see Chapter 6).
- Promote the use of backflow preventers when connecting to fire hydrants, depending on the type of use.

For citizens:

- Include messages about cross-connections in public awareness campaigns on drinking water conservation as well as other communications with the public.
- Encourage the addition of hose connection vacuum breakers to outside taps, or atmospheric vacuum breakers with automatic draining for taps that remain under pressure for periods of less than 12 hours.
- Pay special attention to automatic sprinkler systems, particularly those with integrated fertilization devices (since they double the potential for contamination). Because they are under permanent pressure, such systems require a backflow preventer with two check valves and inspectable taps, or one considered equivalent, which must also be inspected every year.

BENEFITS:

- Strengthen the protection of drinking water, reducing public health risks.
- Cut down on backflow incidents.
- Reduce system downtime and cleaning expenses due to backflows.
- Display due diligence and compliance with regulations.
- Improve consumer confidence and build awareness about cross-connections.
- Reduce your responsibility in the event of an incident.

JUSTIFICATION:

Since cross-connections are “open doors” through which contaminants can enter the system, many experts give them high priority. Québec’s distribution systems are not immune to cross-contamination incidents, as there are numerous cases on record. Most involved cross-connections with systems where chemical products were in use, or with heating systems from which fluids entered the drinking water due to human error, a pressure differential or mechanical failure.

Examples of what can happen:

October 17, 2006 – Drummondville. An incident in a factory producing mineral supplements for animals led to a chelated zinc mix being pushed into the drinking water of both the building and the municipality.

In normal operations, a mixture of water and chelated zinc is pumped into a silo for drying. On the day of the incident, after washing the silo a worker forgot to close the hot water valve before again pumping mix into the silo. Because the hot water valve stayed open, the mix entering the silo at 698 kPa (100 psi) carried on into the municipal drinking water system, where the pressure was 413 kPa (60 psi)[18].

May 2016 – Lanaudière. Work on a water pipe led to siphonage of a pesticide solution into the municipal drinking water distribution system.

That day, repair work on a water pipe caused a pressure drop in the municipal system. At the same time, a farmer was preparing a pesticide solution, mixing two different products with municipal water. Since his water hose was in the tank where the solution was being prepared, the pressure drop sucked the solution up into the hose and ultimately into the municipal system. A local resident at a nearby house noticed a strong odour and skin irritation when he took a shower, and complained to the municipality. A Do Not Use advisory was issued, followed by a Do Not Consume advisory, as recommended by the regional public health authority and the Ministère. The second advisory remained in place for more than three weeks while the municipality flushed the system, until sampling showed that municipal water was again in compliance with the RQDW.

In the mid-2000s, the efforts of a number of experts working in collaboration with Réseau Environnement, the RBQ and the Corporation des maîtres-mécaniciens en tuyauterie du Québec (CMMTQ) led to the creation of an inspector training program and a coordinating committee for backflow preventer monitoring. This work led to the adoption, in July 2008, of new sections in Chapter III (Plumbing) of the Québec Construction Code, governing connections between buildings and drinking water distribution systems.

Obligations regarding the installation and inspection of backflow preventers:

This responsibility lies on plumbing contractors and the owners of commercial and industrial buildings and residential buildings with more than eight apartments or more than two floors, to comply with the provisions of the *Safety Code* concerning connections to water distribution systems. Such buildings must be protected by backflow preventers in accordance with standard CAN/CSA-B64.10, *Manual for the Selection and Installation of Backflow Prevention Devices*. The standards include selection, installations, maintenance and field-testing of these devices.

Detecting risky cross-connections and installing backflow preventers generally require specialized skills. They must be done by a competent person. Furthermore, installing a backflow preventer does not guarantee protection from backflow and its consequences, so the device should be inspected annually to verify that is working properly.

TOOLS AVAILABLE:

- "Les dispositifs antirefoulement, numéro spécial", *IMB, inter-mécanique du bâtiment*, La revue officielle de la CMMTQ, 2nd edition, May 2009
- Web page of the RBQ on backflow preventers (French)
- Provincial registry of backflow prevention device inspectors (French)

[18] "Les dispositifs antirefoulement, numéro spécial", *IMB, Inter-Mécanique du Bâtiment*, La revue officielle de la CMMTQ, 2nd edition, May 2009.

- Web page of the CMMTQ on backflow prevention devices (French)
- Installing backflow preventers along with water meters (see the municipal regulation on water meters model under the Québec Strategy for Drinking Water Conservation) (French)
- Methods for creating a cross-connection control program, CERIU (French)
- CAN/CSA-B64.10 *Manual for the Selection and Installation of Backflow Prevention Devices*
- CAN/CSA-B64.10.1 *Manual for the Maintenance and Field Testing of Backflow Prevention Devices*
- Contents taught for OPA certification (*préposé au réseau d'aqueduc*) in the Drinking Water Operator Qualification Program
- Cross-Connection Control Manual, United States Environmental Protection Agency
- Municipal regulations of the Ville de Boucherville (French) requiring a backflow preventer for automatic sprinkler systems
- Program of the Ville de Montréal (French) for the installation and inspection of backflow preventers when installing or replacing water meters

4.1.2 Minimize water hammer and pressure transients

Water hammer and pressure transients occur when water encounters an obstacle (such as a valve or water column) and its velocity drops too quickly. The result is a pressure surge upstream and a low-pressure wave that can cause momentary negative pressures downstream.

RECOMMENDATIONS:

- Avoid abrupt, momentary stopping of pumps.
- Follow a protocol for limiting the speed with which valves and fire hydrants are opened or closed.
- Monitor operations by external users, especially industries that draw a heavy flow of water (see section 6.2.2).
- Note any water pipes where the velocity exceeds 2.5 m/s, and see to resolving the problem when work is done on the system.
- Use many devices in parallel to limit pressure variations and maintain a pressure of at least 140 kPa (20 psi) at all times and all parts of the system (see Chapter 5).

BENEFITS:

- Reduce risks of intrusion due to negative pressures.
- Reduce breaks and head losses in the system.
- Reduce the risk of getting substances accumulated in the system back in circulation (particles, biofilm, etc.).

JUSTIFICATION:

Over the tens or hundreds of kilometres of a water distribution system, countless events occur each day that could cause water hammer and pressure transients. The magnitude of a water hammer depends on many factors, including flow velocities, water pipe materials, topography, the mass of water being pumped, variations in demand across the system, the amount and distribution of air in the system, the presence of elevated storage, pump operation, and the adequacy of surge control equipment.

Until recently, water hammer has mostly been a concern because it can break equipment and dislodge particles, making the water cloudy. However, research shows that the low-pressure waves caused by water hammer can pull untreated water into the system. The potential for contaminant intrusion depends on many factors, including the number and size of leaks and orifices (including air valve chambers), the frequency, duration, and magnitude of pressure transients, and the presence and concentration of contaminants in the vicinity of leaks and orifices[19].

For example, when an electrical spike causes pumping at the treatment facility to stop momentarily, a low-pressure wave propagates through the system, potentially causing transient negative pressures in elevated areas. Openings in the system such as cracks and loosened joints, as well as flooded suction valves in air valve chambers, surge relief chambers, and so on, then become entry points for untreated

[19] Federation of Canadian Municipalities and National Research Council of Canada, InfraGuide, *Water Quality in Distribution Systems*, 2003.

water to be pulled in from the groundwater, urban runoff or a leaky sewer line[20].

TOOLS AVAILABLE:

- Contents taught for OPA certification (*préposé au réseau d'aqueduc*) in the Drinking Water Operator Qualification Program (section 5 – work methods related to the operation of a distribution system, part 8.6.1 – Procedures for opening and closing valves)

[20] Gabrielle Ebacher, *Évaluation du risque pour la santé publique associé à l'intrusion en réseau de distribution suite à une baisse de pression transitoire*, doctoral thesis, École polytechnique de Montréal, 2012.

4.1.3 Reduce risks when pipes are repaired

When water pipes are being repaired, they become vulnerable to contaminant entry, since pressure is reduced and openings are created.

RECOMMENDATIONS:

- Categorize each repair by the conditions observed at the site of the break (see Appendix 5).
- Follow the recommended procedures for each type of repair (see Appendix 5).
- Open the fire hydrant **completely** when depressurizing the water pipe, to avoid siphonage of untreated water from an unblocked drain.
- Pump water out of the trench to prevent it from rising over the bottom of the water pipe.
- Disinfect the water pipe and all equipment beforehand using a 1% Cl_2 solution, even if disinfection of the entire pipe is planned.
- Take whatever precautions are necessary to prevent equipment from getting dirty during storage, operation or installation.
- Only use lubricants that are approved for use in drinking water, avoid contact between lubricants and drinking water as much as possible, and keep lubricant containers clean.
- When a water pipe is under low pressure, use water as a lubricant when installing a repair coupling.
- Have tools and equipment that are dedicated for repairing water pipes.
- When a water pipe under repair is to be left open without surveillance, seal it by installing a cap.
- Never forget that when a water pipe is depressurized or open to the air before or during repair, it can become a health risk. This makes it crucial to apply sanitary procedures during and after repair (disinfection, optimal flushing before returning the pipe to service, etc.).
- When returning a pipe to service, be sure to evacuate air from the highest point, since pressure control valves are sensitive to accumulations of air.
- Make sure that in each public works crew, at least one employee is competent within the RQDW, and is in charge during the work.
- Take advantage during the repair work to note useful information about the state of the pipe and the equipment used, the type of break and the repairs carried out.
- At all times, make worker safety a priority (protection equipment, shoring of trenches, handling of water pipes that may contain asbestos, etc.).

BENEFITS:

- Maintain the quality of water in the system.
- Prevent contamination.
- Reduce the need for preventive boil water advisories and systematic sampling during work (reducing costs, disturbance and citizen concern).
- Reduce occupational illness and work accidents.

JUSTIFICATION:

There are real risks of contamination when water pipes are under repair, depending on the size of the break. Small breaks can be repaired without depressurizing, so with this sort of break there is little risk of microbiological contamination entering the system. However, if contamination does occur due to inadequate precautions, chlorine dose and contact time required for adequate disinfection can lead to additional delays or require a boil water advisory. The pathogens to watch out for include protozoans, bacteria and viruses, as well as potential contaminants from the soil or the water pipe itself.

At the other end of the scale, some breaks are very large and have catastrophic repercussions when they occur on a water main. These events can cause the pressure to drop at locations quite far from the break, and can last for a while if valves or sections of pipe have to be replaced. Microbiological and chemical contaminants can be drawn into the system, not only at the break itself but wherever there was a loss of pressure.

Swift action in response to major breaks, and preventive planning for minor repairs, can help limit the risk of contaminants entering the system. Making work crews aware of the importance of this issue, developing optimal methods for different situations, and keeping repair equipment in good condition, will all facilitate repair work when it has to be done.

TOOLS AVAILABLE:

- A list of repairs that can be done under pressure is included in the contents taught for OPA certification (*préposé au réseau d'aqueduc*) in the Drinking Water Operator Qualification Program (section 5 – work methods related to the operation of a distribution system, part 5.2 – repair work performed on a pressurized water main, low pressure).
- ANSI/AWWA C-651-14 Standard, Disinfecting Water Mains, presents best practices for the disinfection of water mains.

4.1.4 Reduce risks associated with system dead-ends

Low circulation at endpoints can allow organic matter to accumulate, setting up favourable conditions for microorganisms to develop and for disinfection by-products to be produced.

RECOMMENDATIONS:

- Minimize dead-ends by having distribution system laid out in grid or loop wherever possible.
- When water quality problems keep recurring, do frequent flushes or install the appropriate flushing equipment (see section 2.1.2).
- Establish a suitable flushing frequency.
- Make sure that the discharge pipe for flushed water does not run directly into a sewer. It can be directed toward a rockfill or fitted with a backflow preventer (which must be inspected regularly).

BENEFITS:

- Maintain water quality throughout the system, including endpoints.
- Improve the reliability of the system.

In special cases, for example to prevent freezing in a pipe that is above the frost line, one possibility is to loop the flush line from an endpoint back into the system (using a pump), promoting circulation while reducing the amount of water wasted. This solution can solve several problems at once, but has to be done carefully (for example, flush water that has left the system must not be looped back into it).

4.1.5 Monitor the use of all equipment

Equipment like pumping stations, reservoirs, booster stations, rechlorination stations, valve and air valve chambers, control chambers and fire hydrants, should be constantly monitored by the workers using them or working nearby, since they are all potential entry points for contaminants.

RECOMMENDATIONS:

- Use surveillance cameras at appropriate places (critical points, vandalism zones).
- Make municipal workers aware of the importance of paying attention to signs of deterioration when doing maintenance, repairs or just checking out the system.
- Watch for the presence of stagnant water or mold, joints that are not watertight, and broken or rusted protective screens.
- Put prevention measures in place to keep water from accumulating in chambers containing equipment (pumps, valves, etc.), especially where backflow could occur (air valve, air vent, etc.):
  - Make sure they drain properly (see section 4.2.1).
  - Install moisture detectors or alarm floats.
  - Reinforce watertightness.
  - Identify chambers that are susceptible to flooding and plan a pumping schedule.
- If the pumping station is above a drinking water well or reservoir, make sure that generators and fuel tanks are installed outside, in a watertight confinement basin (without drain), to avoid contaminating both the water supply and the environment in the event of a leak. As a safety measure, the confinement basin should have a volume corresponding to 110% of the volume of fuel. It should be empty at all times. Careful attention should be paid to the nature of the liquid when the basin is emptied, so it can be disposed of in the proper manner.

BENEFITS:

- Maintain the quality of water in the system.
- Reduce risks related to the physical integrity of equipment being impaired.

JUSTIFICATION:

Unprotected access to equipment is an invitation to vandalism or terrorism. Ventilation pipes that are not covered by a screen can let animals in and create unsanitary conditions.

If shelters and chambers are not adequately vented, or if water accumulates in them, their inner walls can become soiled by mold. Equipment will rust and deteriorate in such conditions.

Air valves and air/vacuum valves, especially at high points of the system, can present a direct risk of contamination if there is a pressure drop and they are submerged in flooded chambers. Air valve and vacuum valve chambers in areas where the water table is high, or in the path of runoff water, are more susceptible to repeated flooding[21].

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[21] Gabrielle Ebacher, *Évaluation du risque pour la santé publique associé à l'intrusion en réseau de distribution suite à une baisse de pression transitoire*, doctoral thesis, École polytechnique de Montréal, 2012.

TOOL AVAILABLE:

- Étanchéisation des chambres: Gabrielle Ebacher, *Évaluation du risque pour la santé publique associé à l'intrusion en réseau de distribution suite à une baisse de pression transitoire*, doctoral thesis, École polytechnique de Montréal, 2012.

4.1.6 Give particular care to reservoirs

Reservoirs must be kept in good condition. Continuous monitoring of the quality and quantity of water in such storage facilities is a precious management tool.

RECOMMENDATIONS:

- Inspect reservoirs regularly to:
  - Verify their physical integrity (cracks, leaks, etc.), making sure that openings are well protected (screen, complete seals, etc.).
  - Check the locks on ladders and access doors to prevent vandalism.
- During inspections, carefully note anything that could be harmful to water, public health or worker safety.
- Take the proper safety measures when inspecting reservoirs by boat (confined space entry procedures, flotation vest, rescue craft, etc.).
- Establish a cleaning frequency based on the experience of previous cleanings.
- Use mechanical cleaning (shovel, vacuum robots, divers, etc.) to avoid contaminating the reservoir, and use cleaning products that are certified NSF 60 (safe in drinking water).
- Ideally, make sure that water enters and leaves the reservoir by different pipes, particularly in the case of water towers.
- Make sure that water circulates as effectively as possible in the reservoir, to avoid stagnation zones where water quality can deteriorate.
- Do not keep water in a reservoir for longer than a month without renewal[22].
- Have a competent professional assess external corrosion (especially if there are metal losses).
- Always set up safety barriers around hatches, and follow procedures for working in confined spaces.
- Limit sources of intrusion into reservoirs by restricting use of the land above them.

BENEFITS:

- Maintain the quality of water in the system.
- Reduce the risk of work accidents.

[22] Standard NF EN 1717: Protection against pollution of potable water in water installations and general requirements of devices to prevent pollution by backflow.

JUSTIFICATION:

For several reasons, reservoirs offer the right conditions for contaminants to enter the system:

- Since they are often underground and are not under pressure, rainwater and groundwater can get into them.
- Animals can get into air vents and overflow pipes, as can mold, leading to unsanitary situations.
- Residence times can be longer due to inadequate water mixing, leading to poor quality water that sooner or later ends up in the system.

In sum, it is important to be vigilant with reservoirs.

TOOLS AVAILABLE:

- ANSI/AWWA C652 Standard - Disinfection of Water Storage Facilities
- Chapter 11 of the *Guide de conception des installations de production d'eau potable*: http://www.environnement.gouv.qc.ca/eau/potable/guide/documents/volume1.pdf
- Appendix 6 on the inspection of water storage facilities

4.2 Specific issues

4.2.1 Drains in buildings and system equipment (valve chambers, booster stations, pressure control chambers, fire hydrants, etc.)

Drains are a potential source of intrusion that cannot be ignored, representing a risk of contamination entering the water system and of contaminated air affecting workers. On the other hand, undrained water in buildings and distribution system equipment can also be a source of contamination and other problems (pump damage, corrosion, ice, etc.). Consequently, drains should be managed by finding the option with the least harmful consequences.

RECOMMENDATIONS:

- For the management of drains in system equipment (apart from fire hydrant drains), choose among the following solutions in the following order:
  - Ideally, drains should be directed into an external rockfill situated above the water table and at least three metres from a sewer pipe.
  - If the above solution is impossible, the drain can be connected to a stormwater sewer (preferably), otherwise to a combined sewer, but never to a sanitary sewer:
    - Additional protection is essential; for example, install a high-risk backflow preventer designed for drinking water systems.
    - The upstream part of the backflow preventer must be connected to a P-trap containing enough water to prevent sewer gas from contaminating the chamber.
    - Make sure that the clapper only opens with a certain head of water, but not so much that the chamber would have to fill for the clapper to open (e.g. in the case of a backflow preventer at the exit of a discharge well).
    - Make sure that there is a vertical distance between the bottom of the chamber and the top of the sewer to which the drain is connected.
    - Such installations must be tested for compliance during installation, and be included in an inspection routine for all backflow preventers. Annual maintenance of sensor-equipped chambers for monitoring and controlling drinking water distribution system, and regular inspection of other chambers, should be planned. If annual inspection is impossible due to a lack of resources, the frequency should be as high as possible due to the vulnerability of chamber equipment.
- In the case of fire hydrant drains, they should not be connected to sewer pipes of any sort. Depending on the water table at each location, here are the best solutions:
  - If the water table is always lower than the hydrant drain, a rockfill of sufficient volume is needed for nearly instant drainage from the fire hydrant. The rockfill should be at least three metres from any sewer pipe.
  - When the water table is above the drain, it is important to seal off the drain hermetically to prevent water from seeping in. Since the hydrant can no longer drain freely, it must be identified as such so that it can be pumped dry before the onset of frost, as well as after any winter use. Never use antifreeze in a fire hydrant.

BENEFITS:

- Reduce the risk of contaminated water entering the system.
- Prolong the lifetime of equipment.
- Offer safe working conditions for operators.

JUSTIFICATION:

In addition to fire hydrant drains, priority must be given to managing drains on system equipment so that water is discharged to where drainage will be effective, with minimal risk of contamination. However, when the preferred solution is impossible, the least harmful alternative is to connect to a stormwater sewer, or if necessary a combined sewer. This is because:

- Leak orifices and submerged air vents become sources of contamination whenever a pressure transient occurs (see section 4.1.2).
- Runoff and shallow groundwater that enters such equipment can be contaminated with pesticides and pharmaceutical products, microbiological pathogens of fecal origin, and hydrocarbons.
- It is crucial that air vent chambers not become flooded.
- Water can cause rust damage, render equipment inoperable, deposit contaminated sludge on chamber floors, and impair the safety of workers by promoting mold growth and making floors and ladders slippery.
- In winter, standing water turns to ice, which workers must remove before equipment can be used or serviced.

Although connecting a drain to the storm sewer or combined sewer will eliminate accumulated water and avoid the problems described above, a backflow preventer MUST be installed to avoid the risk of contamination. That risk is very real, because:

- Climate change means that pluviometric events will become increasingly extreme. In future, storm and combined sewers will be subjected to ever more extreme, unpredictable and unprecedented events.
- Urban runoff continues to be a significant source of contamination by pesticides, pharmaceutical products, microbiological pathogens of fecal origin, and hydrocarbons.

4.2.2 Managing fire hydrants: handling, maintenance and winterizing

Fire hydrants are useful for fire protection as well as for temporary water supply when work is being done on a nearby part of the system. Wear, weather exposure, cold temperatures, uncontrolled use, and available flow are all challenges to keeping them working properly.

RECOMMENDATIONS:

In general

- Provide training to all municipal workers who may have to operate a fire hydrant.
- Always use a hydrant valve to control the flow from a fire hydrant.
- Inspect hydrants at least twice a year (in winter and fall).
- Record inspection dates, the procedures employed and any follow-up done.
- Carry out the necessary inspections at the appropriate time (see Appendix 2): inspection can be done by a contractor if municipal workers are busy with other things.
- Perform complete maintenance every 5 years, or if a break is found during inspection. Some municipalities do this in winter to give employees year-round work.
- When hydrants have to be painted, use colour code NFPA-291 to identify the available flow, as shown in the table below, and prohibit the use of other colours.
- Identify fire hydrants by the flow they can provide during firefighting; this information is needed by both the Fire Service and insurance inspectors.
- Number and identify each fire hydrant on a signpost showing their number and flow class.
- Replace fire hydrants or install new ones in accordance with the level of protection desired.
- Clear the area around hydrants of all obstacles.
- Before installing any hydrant that was previously connected elsewhere, disinfect it, then flush it after installation.
- Make sure that flushing is done according to AWWA standard C651 on disinfection.

- **Colour code for fire hydrants under NFPA-291**

Class	Available flow with a residual pressure of 140 kPa (20 psi)	Colour code
AA	5,680 L/min or more	BLUE
A	3,780 L/min to 5,680 L/min	GREEN
B	1,900 L/min to 3,780 L/min	ORANGE
C	1,900 L/min or less	RED
-	Not measured	YELLOW

In winter

- Just before winter, do a brief inspection of all fire hydrants.
- Pump hydrants dry after any winter use.
- Do not use antifreeze, since there is a risk of it entering the system.
- During the winter, inspect any fire hydrants that are likely to freeze.

BENEFITS:

- Maintain the quality of water in the system.
- Ensure the availability of water for firefighting.
- Reduce the number of breaks.

JUSTIFICATIONS:

- A fire hydrant to which a hose is connected that leads into a swimming pool (for example) would be an open door to contamination if pressure were to drop in the system.
- A badly operated hydrant can break, causing transitory pressure variations, undermining the ground around it, or even causing a backflow of sand into a water pipe that is being depressurized.
- Hydrants with leaks or that do not drain automatically are susceptible to freezing in winter.
- When cold temperatures continue for an extended period, the mechanism can freeze, rendering the hydrant unusable.
- Under section 6.4 of the National Fire Code of Canada 2010:
  - Fire protection systems that use water must be inspected, tested and maintained in accordance with standard NFPA-25, Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems.
  - A fire hydrant must at all times be free of constructions, works, plantations or obstructions within a radius of 1.5 m.
  - No one may use a municipal fire hydrant without obtaining prior authorization from the head of the public works service or designated representative.
- Under section (c) of objective #2 of the *Orientations du ministre de la Sécurité publique en matière de sécurité incendie* (2001), a minimum flow of 1,500 L/min for 30 minutes must be available for firefighting in low-risk buildings.

TOOLS AVAILABLE:

- Contents taught for OPA certification (*préposé au réseau d'aqueduc*) in the Drinking Water Operator Qualification Program (section 5 – work methods related to the operation of a distribution system, part 10 – fire hydrants)
- MRC Abitibi-Ouest, *Programme d'évaluation, de vérification et d'entretien des bornes-fontaines*
- NFPA-291: Recommended Practice for Fire Flow Testing and Marking of Hydrants
- NFPA-25: Standard for the Inspection, Testing, and Maintenance of Water-Based Fire Protection Systems
- AWWA, Manual of Water Supply Practices M17, *Fire Hydrants: Installation, Field Testing and Maintenance, 2016*

4.2.3 Managing the freezing (and thawing) of water pipes

The conditions under which water pipes tend to freeze are:

- water pipes above the frost line;
- insufficient water circulation;
- periods of intense cold.

RECOMMENDATIONS:

- Calculate or measure the depth of the frost line to determine when automatic purging is advisable to reduce the risk of freezing.
- Use either the steam method or the electric method when a water pipe has to be thawed:
  - The steam method is safest, but takes longer.
  - The electrical method is fast, but presents a real risk of causing fires. For this reason it is prohibited to use the electrical method to thaw frozen pipes in a gas station, near flammable materials, or in any dangerous location, pursuant to Chapter V, Electricity, of the Québec Construction Code.
  - It is a good idea to stay informed about the most current practices with these methods and to ensure that the work is done respecting state of the art procedures.

4.2.4 Take into account the deterioration of water pipes

The condition of water pipes can have a significant effect on drinking water quality. Interactions between water and the different materials of which pipes are made can result in the latter degrading over time, while also altering the water quality by corrosion, contaminant release, etc. Corrosion or tuberculation on the inner surfaces can lead to a gradual loss of pressure or flow. Corrosion can also cause leaks to some extent. Corrosion-related parameters must therefore be monitored and controlled, including pH, alkalinity, conductivity, phosphates, silicates, calcium, metals, and so on. An action plan can use the results to minimize deterioration.

The table below presents the different materials used, a few types of potential deterioration, and recommendations for avoiding or dealing with them.

Materials of water pipes	**Potential deterioration**	**Recommendations**
Ductile cast iron	- External corrosion	- Polyethylene lining - Electrical insulation - Install water pipes correctly
Malleable cast iron	- Internal and external corrosion - Circumferential cracking	- Cement-mortar lining
Steel	- Internal corrosion - External corrosion	- Cement-mortar lining - Polyethylene lining - Cathodic protection
PVC	- Permeation and degradation due to hydrocarbons	- Do not use on soils contaminated by petroleum products
Prestressed concrete (PCCP)	- Deterioration due to sulfates	- Water pipe lining

4.2.5 Disconnecting a water pipe

It is important for municipalities to have regulations to ensure that water pipes are decommissioned with state of the art procedures.

RECOMMENDATIONS:

- NEVER decommission a water pipe by just closing a valve, since it will inevitably become a source of contamination or leaks.
- Disconnection should be done at the feeder main, not at the street pipe.
- As much as possible, remove the water pipe from the ground and dispose of it properly.
- Completely remove all appurtenances attached to the abandoned pipe (valves, fire hydrants, etc.).
- Seal off any abandoned water pipe that cannot be removed from the ground, following the procedures in section 10.6 of specification BNQ 1809-300.

4.2.6 Managing a system when disaster occurs (power failure, flood, etc.)[23]

Disasters and extreme events that might occur should be given consideration in the management plans of water distribution systems. Such events include floods, snow storms, drought and other weather hazards. For example, in 2011 and 2012 there were two major hurricanes, Irene and Sandy respectively. Events like that can have a serious effect on water quality, weakening consumer confidence while making costs skyrocket. There are many ways for management to do better when such events occur.

RECOMMENDATIONS:

- Prepare work crews and all personnel for these risks.
- Do long-term planning for these events and train staff accordingly.
- Inspect equipment regularly, including pumps, valves, and so on.
- Keep a good distance between the locations of monitoring sensors, since an extreme event could affect one area before the others.
- Have redundant or interconnected systems such as multiple reservoirs, to have a backup solution in the event of a power failure.
- Make sure that you are ready to inform the public quickly and effectively should the need arise.
- Be prepared to issue boil water advisories, or take any other measure needed, on short notice.
- Plan for a potential increase in the volume of sediment to manage and how to dispose of it should an extreme event occur.
- Remember the importance of good communication (between work crews as well as with users) and of good coordination.
- Be ready to give the public an estimate of how long it will take for service to return to normal.
- Debrief as soon as possible after the incident or event, to learn from it and be better prepared for the next event.

[23] These recommendations draw on the document “Water Quality Impacts of Extreme Weather-Related Events” from the Water Research Foundation.

5. PRESSURE MANAGEMENT

The water pressure in a distribution system serves a double purpose: while ensuring the supply of a sufficient flow, it offers protection against the intrusion of pathogens from the soil or connections to the system. Pressure management includes planning, monitoring and the operational measures that are used to maintain pressure throughout the system.

Static pressure is the force per unit of surface exerted by water against the inner walls of the distribution system. It is generally expressed in kilopascals (kPa) or pounds per square inch (psi). It is measured using a manometer installed on either a valve or a fire hydrant, **without water flowing out**.

Dynamic pressure is similar to static pressure, but is exerted when water is moving. It is measured using a Pitot tube placed **in the centre of flow**, and is acquired from measurements of flow or water velocity.

5.1 Best practices

5.1.1 Strive to maintain a minimum static pressure

Maintaining a minimum static pressure helps to prevent the intrusion of non-potable water.

RECOMMENDATIONS:

- **For a system without fire protection**, maintain a pressure at all points of the system (measured at the water pipes) of at least 140 kPa (20 psi) under all flow conditions except emergencies.
- **For a system with fire protection**, maintain a pressure at all points of the system (measured at the water pipes) of at least 140 kPa (20 psi) under the least favourable of the following conditions:
  - Peak hourly flow
  - Maximum day flow + fire flow
- Define the minimum pressure to maintain at all times depending on the area served (high or low point of the system), the time of day (night pressure, day pressure) and the type of buildings served (residential, multistorey, commercial, industrial, etc.).
- Equip all automatic pumping stations with a remote signaling system to indicate whether the station is operating normally or is out of service.
- Issue a preventive boil water advisory if the pressure drops significantly, or if there is a known or suspected intrusion of water contaminated by microorganisms (see Appendix 5).

JUSTIFICATION:

The water pressure in a pipe protects it from backflow and intrusions. When the pressure drops, the water in taller buildings could flow back into the system, and all connected equipment, unless their service lines are protected by backflow preventers.

1 metre of water (3.28 ft) = 9.8 kPa = 1.42 psi

Thus, 14 metres of water (46.2 ft) = 140 kPa = 20 psi = 3-4 storey building

These values can help municipalities adjust their minimum pressures based on the height of connected buildings that do not have a booster pump.

The minimum value of 140 kPa does not necessarily offer complete protection against backflow risks. Depending on the height of the buildings served, a pressure of 140 kPa may not be enough to prevent water in the building from returning into the system. For example, a height of 14 metres (46.2 ft) should be calculated from the water pipe in the ground. If the water pipe is 2 m (6 ft) underground, a pressure of 140 kPa would prevent water in a building of 12 m (39 ft, or 3-4 storeys) from re-entering the system. But if the building is higher, there is a risk of backflow. This is why backflow preventers should be installed in all buildings of three or more storeys.

When only residential buildings of 1 or 2 storeys are served, it could be acceptable to have lower pressures occasionally, but the minimum pressure targeted should be 140 kPa.

5.1.2 Determine the system's optimal operating pressures

Each system has optimal operating pressures depending on the topography, the water demand exerted by consumers and how much territory is covered. A balance must be found between pressures that are too low, which could have adverse effects on water quality and consumer satisfaction (service pressure, tap flow, etc.), and pressures that are too high, which exert excessive forces on joints, causing leaks, breaks and water losses.

RECOMMENDATIONS:

- Keep pressures in the system between 410 and 550 kPa (60 and 80 psi), without going below 240 kPa (35 psi) [24].
- Limit the maximum pressure at building entries to no more than 500 kPa (73 psi)[25].
- Limit the maximum pressure at all points of the system to no more than 760 kPa (110 psi).

However, it is important to take into account the pressure variations that can occur in a system. In some cases, the pressure intervals suggested above would have to be adapted to the situation, such as a topography with significant changes of elevation.

[24] Ten State Standards (Water Supply Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, *Recommended Standards for Water Works*, 2012)

Feffer, A., D. Baker, R. Moore, T. Wagner and B. Gresehover (February 2016). "Remote Data Monitoring Improves Distribution System Efficiency And Maintenance", *Opflow,* Vol. 42, No. 2, p. 10-14.

Partnership for Safe Water. (2011*). Self Assessment Guide for Distribution System Optimization,* p. 216.

[25] Brière, François G. (2012). *Distribution et collecte des eaux*, 3rd edition, Presses Internationales Polytechniques, 597 pages.

5.1.3 Limit pressure variations

Pressure variations can make a system susceptible to pressure transients, causing an increase in breaks and leaks as well as water quality problems due to backflows and intrusions.

Excessive pressures can be caused by:

- pressure reducing valves not working correctly;
- maladjusted valves;
- increased hydraulic head at pumps;
- higher water level in a reservoir;
- inadequate dimensions of water mains.

Low pressures can be caused by:

- maladjusted valves;
- reduced hydraulic head at pumps;
- lower water level in a reservoir;
- greater water demand;
- breaks and leaks on water mains;
- undergoing repairs;
- firefighting;
- a breakdown or stoppage of the pumping system.

RECOMMENDATIONS:

- Use variable speed pumps.
- Carefully choose pressure reducing valves to avoid pressure variations at low flow.
- Adjust reducing valves carefully in areas with strong pressure variations at high flow.
- Rigorously inspect and maintain pressure reducing valves.
- Limit the variation between high and low water levels in a reservoir whose function is to maintain pressure in the system. The variation should never be more than nine metres.
- Locate and control booster pumps so that:
  - the pumps do not induce a negative or abnormally low pressure in the suction side (hydraulic upstream);
  - the pressure downstream of the pumps is at least 140 kPa when the pumps are operating normally;
  - the automatic pressure valve on the suction side is set to a minimum of 35 kPa;
  - the valve’s automatic open and close system has enough margin between the restart and shut-off pressures to prevent the pumps from stopping and starting on an overly short cycle;
  - a bypass pipe can be used.
- Where possible, use gravity distribution to reduce the risk of hydraulic transients.

BENEFITS FROM ALL OF SECTION 5.1:

- Maintain the quality and quantity of water in the system.
- Prevent intrusions via siphonage and back-pressure, whether from groundwater or connections to the system.
- Supply an acceptable water flow to consumers' taps.
- Protect equipment on the system.
- Reduce leaks and breaks.
- Reduce energy costs.

TOOLS AVAILABLE FOR ALL OF SECTION 5.1:

- Ten State Standards (Water Supply Committee of the Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers, *Recommended Standards for Water Works*, 2012)
- François G. Brière, *Distribution et collecte des eaux*, 3rd edition, Presses Internationales Polytechniques, 2012, 597 pages
- Various works from the AWWA on the computer modelling of water distribution systems (M32 Manual), distribution systems operation and management (AWWA G200-15 standard), etc.

5.2 Specific issues

5.2.1 Managing pressure drops

Water distribution systems can experience significant drops in pressure, even null pressures. These can be caused by a number of factors, including those presented in section 5.1.3.

RECOMMENDATIONS:

- Prepare an action plan for dealing with pressure drops. It should accommodate variables like how low the pressure falls, how long the situation lasts, and the area affected.

BENEFITS:

- Aim for swift intervention suited to the situation.
- Avoid confusion and improvisation on what should be done, to avoid any impairment of water quality and to protect the health of consumers.

JUSTIFICATION:

Loss of pressure in a distribution system can result in a backflow of water from connected buildings, with the potential for various kinds of contamination. Section 4.1.1 gives an overview of what can happen when the pressure falls or becomes null.

A common cause of depressurization is the repair of a broken water pipe, which can lead to siphonage. In this case contamination from microorganisms can come from the surrounding groundwater. However, the potential sources of contamination are many, so the response to each event should be determined by its importance (how long it goes on, which area is affected and the lowest pressure reached). A brief but dramatic loss of pressure in an industrial area could pose a major risk of contamination, while a longer event in a residential area may have no consequences at all.

An action plan for each area, or for the network as a whole, would specify which actions to take for the most common or most frequent low-pressure events, and could be adapted and updated for particular events. Intervention plans could include making an on-site inspection, checking the water quality in the area affected (on site measures or analysis of samples), checking for activities that could have caused the pressure drop (filling a water tank, firefighting, etc.), performing a one-time flushing, issuing a preventive notice (boil water or do not consume advisory), and so on.

Section 4.1.3 sets out the risks associated with repairing broken pipes, procedures to follow, and recommended approaches. Appendix 5 presents a decision tree on how to categorize a break and what actions should be taken.

5.2.2 Perform fire flow tests

Fire flow tests are done to find out how much water is available at any point of the distribution system, to validate the hydraulic model, and to confirm that equipment is working properly in an area with a different pressure range. Flow tests are required by insurance companies to ensure that there is sufficient fire flow (e.g. for buildings equipped with a sprinkler system), but they also provide information about the general state of the system.

RECOMMENDATIONS[26]:

- Conduct pressure measurements at least once a year when inspecting hydrants.
- Make sure that during flow tests, pressures do not fall below the minimum values required (140 kPa or more), particularly at high points in the system.
- Before starting on a given hydrant, make sure that its valves can be operated: there is no point in taking all the equipment to the hydrant if its valves don't work.
- Check whether the hydrant is damaged or tilted: if so, it may have been struck by a vehicle or have moved due to frost action.
- Do not assume that valves are watertight, since a leaking valve could have put the hydrant under pressure. Just in case, open the cap carefully, protecting yourself (and passersby) in case it is blown off by the pressure.
- Make sure the valves are completely open during the test.
- Open and close valves slowly to avoid causing a disturbance in the water flow (generating turbidity or colour) or water hammers (a break could occur if valves are closed too quickly).
- Pay attention to where the water will go during the test, to avoid flooding property, destroying landscaping or causing complaints. Photographs of the surroundings before and after tests can facilitate response to complaints. If a hose is used to direct the water to a storm sewer or combined sewer, be sure to attach it firmly, both to the hydrant and at the outlet end, which otherwise could snake around and cause damage or injury. Do not use a rigid pipe for this purpose, since it could exert a stress on the hydrant.
- Warn consumers that there could be some impairment of water quality (colour) due to the higher velocity of water in the street pipe.
- Make sure that work is done safely, for the sake of both the workers (operating the hydrant, managing traffic, etc.) and for passersby.
- Conduct flow tests on the entire distribution system every ten years, or whenever needed to identify problem spots.

TOOLS AVAILABLE:

- *M17 Fire Hydrants: Installation, Field Testing, and Maintenance*, an AWWA manual
- *NFPA-291: Recommended Practice for Fire Flow Testing and Marking of Hydrants*

[26] Adapted from "Flow Tests Reinforce Reliable Hydrant Service", *Opflow*, Vol. 41, No. 6, June 2015, p. 16-18.

5.3 Going further

Here is an example of a more advanced measure that would contribute to better pressure management.

5.3.1 Reconditioning pumps

Reconditioning pumps can be a good way to extend their lifespan, reduce repair costs and save on energy. A study at an American water production facility found that when a Belzona lining was applied to the impeller and volute, and new sets of bearings and seals installed, the energy required for pumping was reduced by 2%. A cost-benefit study could be done before doing something similar[27].

[27] *AWWA G200: Distribution Systems Operation and Management*, p. 67.

6. EXTERNAL USERS

The expression “external users” refers to all entities that have occasional needs for drinking water, such as to fill a truck or reservoir. It can also include permanent needs, such as private systems connected to a municipal system.

6.1 Best practices

6.1.1 Control access to fire hydrants

Fire hydrants serve a number of purposes, both for internal users (municipal workers) and for external users. Thus, attention must be paid to reducing the risk of damaging equipment or degrading water quality.

RECOMMENDATIONS:

- Establish municipal regulations to control the use of fire hydrants, and apply physical protection measures, e.g. by installing seals on them.
- Municipal regulations should include an obligation, for owners of private systems, to maintain the hydrants they use and to conduct annual pressure tests in their system.
- When municipal work is done by a contractor, make sure that the workers are competent to operate fire hydrants correctly.
- Reserve tank filling to hydrants where there will be less disturbance to the system, and make sure that filling operations are done by competent persons. For example, tank filling could be restricted to a hydrant that is near or in the yard of the public works building and that is equipped with a gate valve, a backflow preventer and a meter if necessary.
- Provide for the installation of a water meter and backflow preventer on any hydrant supplying a worksite, and bill for water use along with the cost of installing and removing the equipment.
- Do not connect to a fire hydrant on a water main.
- Only connect to a hydrant whose connection pipe is equipped with an isolation valve.
- Draw up a standard agreement by which the user accepts responsibility for breakage or equipment theft.
- Provide a backflow preventer for riskier uses.

BENEFITS:

- Reduce breakage on fire hydrants and the system.
- Reduce pre-winter inspection time.
- Reduce disturbances to the system as well as citizen complaints.
- Reduce the risks of contamination by users or due to pressure drops caused by using the hydrant.
- Control the quantities of water consumed, which must be included in the annual water report.
- Reduce contamination risks.

- Reduce the risk of freezing and flooding.
- Reduce costs.

JUSTIFICATION:

The list of potential uses for fire hydrants is extensive:

- fire protection;
- flushing the system;
- car wash;
- filling pools and basins, spraying skating rinks;
- watering large areas;
- supplying temporary systems on construction sites;
- amusement park facilities;
- graffiti removal;
- analysis and characterization of the distribution system;
- pumping station maintenance;
- filling tank trucks, street cleaners, etc.;
- supplying dust suppression equipment on demolition sites;
- preparing chemical products such as pesticides.

Section 4.2.2 discussed having municipal workers perform these operations. The situation is more complicated when they are done by external users, since it can be hard to find out who is responsible. Nonetheless, the municipality is always responsible for the quality and quantity of water distributed.

TOOLS AVAILABLE:

- See the examples in Appendix 7.

6.2 Specific issues

6.2.1 Pay careful attention to firefighters' pumper trucks

An emerging concern in the protection of drinking water distribution systems is the use of high pressure pumps by firefighters. Fire pumpers can be interconnected and can use multiple fire hydrants to optimize firefighting. They can generate a higher pressure than is provided by the system, and **unless the necessary precautions are taken**, can cause water to flow back into a hydrant. The result can be a backflow of contaminated water, since the tanks and hoses of firefighters are not made for drinking water, and can come in contact with various chemical products. Also, the powerful suction of a pumper truck can cause a significant pressure drop in the system.

6.2.2 Manage industrial users

Water hammer is a frequent occurrence with industrial users, since they exert a heavy water demand and will quickly operate valves and pumps in response to process needs. They are served by large-diameter water mains, so municipalities have every reason be concerned about the effects of their operations. The simplest solution is to make them aware of the importance of closing valves and operating pumps in the proper manner, to avoid potential breaks as well as backflows, which could affect them as well. Another solution is to have elevated storage tanks on industrial sites. The tanks fill at night, and help to reduce water hammer events when demand increases.

7. CONCLUSION

The benefits of adopting best operating practices are numerous, both for the water utilities and for all who receive water services. For municipal utilities, the present document is an opportunity to reflect on practices they may have adopted already, as well as others that are worth considering. It may be necessary to set priorities to determine which ones would give the greatest benefit within the limits of available resources.

APPENDICES

APPENDIX 1: EXAMPLES OF USING A UNIDIRECTIONAL FLUSHING PROGRAM

Unidirectional flushing at L'Assomption (22,000 people served, 144 km of water pipes)

In the last few years, the municipality has introduced a unidirectional flushing program. The main benefits are as follows:

- Know and improve the quality of water in the distribution system.
- Reduce the number of citizen complaints about rusty water.
- Gain a better understanding of the water distribution system.
- Know the condition of street valves to prevent potential problems (valves clogged, hard to operate, defective, etc.).

At L'Assomption, unidirectional flushing improved control and maintenance of the system, and is now considered a "must" procedure performed on a regular basis.

Unidirectional flushing at Victoriaville (42,000 people served, 290 km of water pipes)

Knowing the benefits to gain from setting up a unidirectional flushing program, Victoriaville has included the following elements in its program:

- Annual unidirectional flushing of all water pipes up to 300 mm.
- The operation is used as an opportunity to update information about the system.
- Identification of particular areas that require flushing twice a year.
- Occasional use of iron concentration as an indicator of when flushing should continue because tubercules are still washing out.
- Information obtained during flushing is used by the engineering department to plan the rehabilitation of pipes by contractors.

APPENDIX 2: SUGGESTED CHARACTERISTICS TO INSPECT, AND FREQUENCY OF INSPECTION OR MAINTENANCE DEPENDING ON COMPONENTS[28]

Equipment	Suggested frequency	Characteristics to note and inspect
Self-regulating pressure device	Maintenance every 2 years	**Safety valve** Adjust tension of spring depending on maximum pressure desired **Pressure control valve or pump control valve** Clean the strainer Manual simulation
Valve housing		Note: contents (valve, drain), plug diameter, depth Inspect: height of water, condition of housing
Fire hydrant	Inspection after use Brief inspection in spring (make sure there is no winter damage) Full annual inspection with leak detection Brief inspection before winter Full maintenance every 5 years	Note: access, make and model (year, mechanism, number of outlets and their diameter, flag), diameter of water pipe Inspect: general condition, detailed condition (paint, hook, watertightness, protection post, operation, condition of appurtenances, mechanism, drain, etc.), depth of water table Isolation valve: see valve housing and isolation valve
Valve chamber	Schedule depending on context	Note: form, type of construction, contents (valve, vent, drain, corporation stop, bypass, measurement chamber) Inspect: condition of chamber (cleanness, infiltration, mold, structure)
Clapper (backflow preventers)	Once a year	Note: location, make, model, year, diameter Inspect: create a pressure differential (upstream pressure lower than downstream pressure) and listen to sound of clapper closing. The clap sound should not be abnormally loud.
Visible joint	When digging is done	Tightness

[28] Contents taught for OPA certification (*préposé au réseau d'aqueduc*) in the Drinking Water Operator Qualification Program.

Equipment	Suggested frequency	Characteristics to note and inspect
Air vent	Annually (more often if you know the chamber could be flooded)	General condition of vent (corrosion, accumulation of water, mechanism functional, watertightness, float not pierced) Open the bleeder valve and check the flow. If only water comes out, the vent is working. If air comes out, the vent is blocked. Change gasket seals Sanding and painting
Reservoir	Schedule depending on context	See section on reservoirs (section 4.1.6)
Isolation valve	Schedule depending on context	Note: make and model, year, mechanism, method and direction to open, record (operation, maintenance, repair) Inspect: condition (operation, watertightness, breakage, etc.), initial position (open or closed)

APPENDIX 3: MODEL ORGANIGRAM OF COMPLAINT PROCESSING

Request – Complaint

Origin of request

Gives an indication as to the frequency of the complaint
(a call to the plant or the office indicates that the person may have submitted a complaint previously).

- *Citizen relations division (311)*
- *Call centre*
- *Direct call to office/plant*
- *Interservices*
- *Head office*
  - *Supervisor*

Document the request

Gather any relevant information to suggest one or more hypotheses as to the cause of the complaint.

Tools:

Geomatics: Identify location of complaint and nearby streets, check the characteristics of the distribution system (material, diameter, valve, etc.) in that area.

Complaints DB: Check database to see if the complaint is new or not, check any past complaints from that complainer, street or neighbourhood, look into recent events.

Contact P.W.: Contact the public works supervisor for the problem area, or the section supervisor, to find out whether any flushing, inspection or other work was done.

Colleagues: Ask colleagues for any relevant information, whether past or present.

Break record: Check whether any recent work was done in the area (water pipe break?).

Water shut-off: Check for any water shut-off request from the public works service or the engineering service.

Modelling: Do a hydraulic simulation to find the chlorine residual, flow direction, pressure, etc.

Drinking water DB: Check database for any anomaly that might have occurred during water treatment.

Work list: Go over the list of work underway by the engineering service to see if any repair work is planned.

Possible nature of request

- *Colour*
- *Odour*
- *Pressure*
- *Particles*
- *Taste*
- *Lead*
- *Quality doubts*
- *Information needed*
- *Questions, concerns or symptoms*

Open and enter details in database

Call the complainant

Possible cause of request

- *Dissolved air*
- *Water heater*
- *Dead-end*
- *Electrical spike*
- *Media*
- *Interior plumbing*
- *Work/repair on pipe*
- *Information needed*
- *Design of system*
- *Hydraulic dead-end*
- *Heavy consumption*
- *Unidirectional flushing*
- *System in disrepair*
- *Quality doubts*
- *Chlorine*
- *Sink drain*
- *Leak*
- *Ozonation off*
- *Valve left shut*
- *Broken water pipe*
- *Construction*
- *Service line*
- *Fire hydrant use*
- *Valve broken (shut)*
- *Elevated area*

Settled by telephone

Send complementary information by email or regular mail (if necessary). Also, for health-related complaints refer to Info-Santé

Meeting

- Need a sample and analysis
- Make an appointment with the citizen
- Note any information on interior plumbing (diameter, materials, etc.)
- Check if water entry valve is fully open
- Check the age of the water heater
- Assess the need to sample in surrounding area, especially if the cause is unknown

Sampling

- Take a bacteriological control sample
- Identify the bottle with the sampling location, write the date, free Cl_2^- and the temperature
- Deliver sample to laboratory

Sample results

- Inform citizen of the results
- If not in compliance with the RQDW, inform supervisor

Analysis

- Assess the situation regarding levels of iron, free Cl_2^-, abnormal colour, low pressure, biofilm, etc.
- Should measures be taken?

  Request for public works:
  - Inspect valves
  - Install a flush valve
  - Replace service line
  - Flushing

  Request for engineering:
  - Request repair or looping

  Request for citizen:
  - Check interior plumbing (drain, aerator, materials, entry valve, leak on the private side, water heater, etc.)

Fill out complaint form in database

- Enter information
- Print out complaint
- Append any relevant documents
- File

Follow up if necessary.
Notify when requested measures are carried out.
Take new samples and redo analysis if necessary, until situation is normal.
Follow up with the citizen.

APPENDIX 4: SPATIAL AND TEMPORAL CONSIDERATIONS FOR SAMPLING SITE SELECTION IN A WATER QUALITY MONITORING PROGRAM[29]

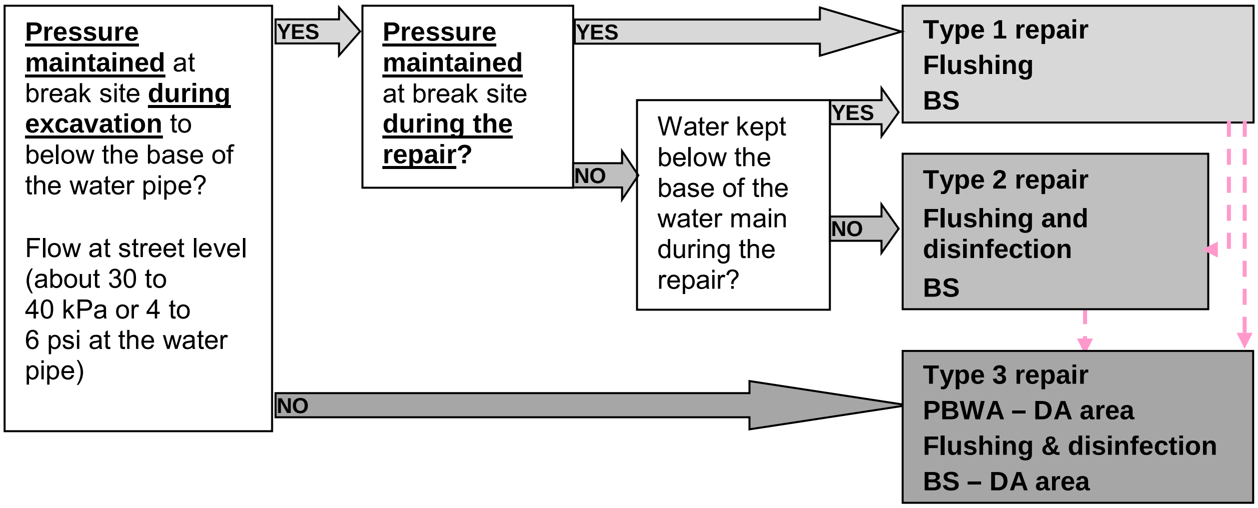
Water quality monitoring parameters	Factors influencing the presence of a parameter in the distribution system (DS)	Spatial and temporal elements to consider for monitoring
Alkalinity	Interactions with DS materials, water mixing	- Materials of water pipes - Contact time with certain materials - Mixing zones
Bacteria **Heterotrophic plate count (HPC)** Good indicator because always present. Their numbers give an idea of stagnation, tuberculation, disinfectant residual concentration, and the availability of nutrients **Total coliforms** If present, must search for the source and manage the problem	Growth is encouraged by stagnation in an environment with a low level of disinfectant residual. Can also be introduced through backflow, siphonage and faulty connections	- Hydraulic dead-end - Reservoirs, tanks and water towers - Low pressure periods - Connection to large consumers with potential for backflow
Conductivity	Mixing of water sources, intrusion	- Mixing zones with different sources of water
Residual chlorine and chloramine	Possibility of kinetic degradation based on history of chlorine demand. New sources of chlorine demand due to intrusions into the system. Effect of temperature and pH changes on kinetics.	- Contact time - Hydraulic dead-end - Storage (reservoirs) - Low pressure zones - Materials of water pipes (effects of pH and corrosion) - High pressure zones (booster station areas) - Mixing zones
Chlorine dioxide or chlorite	Typically, a rapid kinetic degradation (limited residence time)	- Near water treatment facility (short to medium distance)

[29] Adapted from *Distribution System Water Quality Challenges in the 21st Century: A Strategic Guide*, Michael J. MacPhee, American Water Works Association, 2005, p. 24.

Water quality monitoring parameters	Factors influencing the presence of a parameter in the distribution system (DS)	Spatial and temporal elements to consider for monitoring
Disinfection by-products: • trihalomethane (THM) • haloacetic acid (HAA)	Formation kinetics based on time, pH, temperature in DS depending on each disinfectant (chlorine or chloramine); potential for mix of water in DS; influenced by rechlorination in DS	- Contact time - Storage conditions (open, elevated or underground reservoir) - Type and presence of disinfectant residual - Variations in pH and temperature - Mixing zones
Metals	Introduction via corrosion (or leaching) and introduction by sorption (general term that includes absorption and adsorption) when present in treated water (manganese, arsenic, lead, copper, iron)	- Materials of water pipes - Variations in water quality conditions like pH, alkalinity, dissolved solids, hardness, oxidizer and temperature - Mixing zones - Contact time with materials
Nitrite	If chloramine is used in stagnant conditions, with pH moderately alkaline and temperature > 15° C	- Storage with stagnation - Hydraulic dead-end - Zones with low level of disinfectant residual
pH	Changes in pH happen for many reasons, including corrosion, biofilm growth, storage (aeration) and dissolution of the water pipe lining	- Materials of water pipes - Storage (reservoirs) - Zones with different levels of disinfectant residual - Mixing zones
Temperature	Temperatures vary in DS, particularly in elevated reservoirs, and these changes affect water quality parameters that are governed by kinetics or biological activity	- Storage (reservoirs) - Mixing zones

APPENDIX 5: CATEGORIES OF PIPE BREAKS AND REPAIR RESPONSES[30]

Decision tree for determining a repair category



Legend

PBWA: Preventive boil water advisory

BS: Bacteriological sampling

DA: Determine area for advisory and sampling based on depressurization area beyond site of break (less than 140 kPa or pressure required in the area)

BE VIGILANT FOR SIGNS OF CONTAMINATION

If at any time during a repair:

- a sudden pressure drop occurs in the system (can suck in contaminated water)
- pressure falls below the required value upstream or downstream from the break site
- water in trench is or becomes contaminated, in the presence of sewer water for example
- etc.

IF SUCH SIGNS ARISE:

Repair type 1 => type 2

- if pressure upstream and downstream from site of break remains ≥ 140 kPa (20 psi)

Repair type 1 => type 3

- if pressure upstream or downstream from site of break is < 140 kPa (20 psi)

Repair type 2 => type 3

[30] Inspired by the approach described in *Effective Microbial Control Strategies for Main Breaks and Depressurization*, Report #4307a, Water Research Foundation & Drinking Water Inspectorate, 2014, 60 pages.

Table of actions to take

Before repair	Type 1	Type 2	Type 3
Notify the public about work	Yes	Yes	Yes (preventive boil water advisory in the area required based on pressure loss upstream or downstream from the break) Also notify the regional public health authority if deemed necessary based on the size of the area affected[31]
Measure pressure at the break site, upstream and downstream[32]	Yes	Yes	Yes
Reduce flow at the break site	In a controlled manner using valves	In a controlled manner using valves	Complete closure of water pipe in a controlled manner using valves
Disinfect equipment needed for the repair	Yes	Yes	Yes

[31] See text box in section 2.1.7 (Note on the Publication of Public Notices).

[32] It is important to maintain positive pressure in the water main to avoid backflow or contamination. A minimum pressure of 140 kPa (20 psi) should be maintained throughout the system. Pressure can be monitored at the break site by visually assessing the flow at the break until the fire hydrant chosen to check the pressure is opened. Make sure that the fire hydrant is at a higher elevation than the break site. Pressure can also be measured upstream and downstream from the break site depending on resources available.

During repair	Type 1	Type 2	Type 3
Maintain pressure *during excavation* to below the water pipe	Yes Minimum: positive pressure[33]	Yes Minimum: positive pressure	No Zero pressure
Keep water level below the water pipe	Yes	Yes, as much as possible	Yes, as much as possible
Maintain pressure at the site of the break *during the repair*	Yes Minimum: positive pressure No If water level remains below the water pipe during repair	No	No
Monitor water quality[34]	Yes Free chlorine residual (& turbidity if possible)	Yes Free chlorine residual (& turbidity if possible)	Yes Free chlorine residual (& turbidity if possible)
Stay vigilant and document signs of possible contamination	Yes *If there are signs of contamination:* Go to type 2 if pressure upstream and downstream of break site is ≥ 140 kPa (20 psi) Go to type 3 if pressure upstream or downstream of break site is < 140 kPa (20 psi). See also actions to take before this type of repair	Yes *If there are signs of contamination:* Go to type 3 (see also actions to take before repair in the type 3 column)	Yes

[33] The pressures indicated are measured or observed on a fire hydrant at street level, or about 3 m above the repair.

[34] A good tool for monitoring water quality is a portable colorimeter. The frequency of monitoring depends on the objectives and the equipment available in the field. It is recommended to carry out chemical dechlorination until reaching the chlorine concentration that is usually present in the system. Turbidity should also be monitored until RQDW standards are met.

After repair	Type 1	Type 2	Type 3
Flush water pipe at 1 m/s for at least 3 times the volume of the water pipe	Yes, the flushing will be less effective if there is tuberculation[35]	Yes, the flushing will be less effective if there is tuberculation	Yes, the flushing will be less effective if there is tuberculation
Disinfect water pipe[36] if flushing speed is at least 1 m/s	No	Yes Unidirectional disinfection (CT ≥100 mg·min/L[37] or higher depending on level of tuberculation in water pipe)	Yes Unidirectional disinfection (CT ≥100 mg·min/L or higher depending on level of tuberculation in water pipe)
Disinfect water pipe if flushing speed does not reach at least 1 m/s	No	Yes Unidirectional disinfection (CT ≥1000 mg·min/L [38] or higher depending on level of tuberculation in water pipe)	Yes Unidirectional disinfection (CT ≥1000 mg·min/L or higher depending on level of tuberculation in water pipe)
Sample water before return to service, testing for total coliforms and *E. coli* bacteria, and measure free chlorine residual	Not necessary, but a good precautionary measure (The water pipe can be returned to service while awaiting analysis results.)	Yes (Before returning to service, it is recommended to await analysis results.)	Yes (Before lifting a preventive boil water advisory, must wait for analysis results.)
On return to service, advise users to flush plumbing before using water	No (but still a good practice)	Yes	Yes
Measure free chlorine residual once return to service is completed	Yes, and try to reach at least 90% of the free chlorine residual target for that area	Yes, and try to reach at least 90% of the free chlorine residual target for that area	Yes, and try to reach at least 90% of the free chlorine residual target for that area

[35] Ideally, flush velocity should be under 1.6 m/s to avoid destabilizing the water pipe by the removal of tubercules.

[36] Section 4.3.2 of ANSI/AWWA C652 allows spray disinfection for large-diameter water mains. After cleaning, spray disinfect such water mains and wait 30 minutes before filling them and taking samples (*AWWA Journal*, October 2015, Vol. 107, No. 10).

[37] Value obtained from a document of the Water Research Foundation (WRF), *Effective Microbial Control Strategies for Main Breaks and Depressurization,* 2014, page xix. It is recommended to disinfect at 5 mg/L chlorine for 20 minutes.

[38] Because the required flushing speed is not achieved, you must raise the CT value considerably during unidirectional disinfection. For this reason the WRF suggests a CT of 1500 mg·min/L. However, low-concentration disinfection over a longer period is preferable to a high concentration over a short period to reach the values specified above, to avoid exposing the population to high concentrations of chlorine.

APPENDIX 6: INSPECTION OF STORAGE FACILITIES

The following questions are for evaluating the management of storage facilities.

For gravity tanks:	YES/NO
Are the storage tanks covered or made in such a way as to prevent contamination?	
Do overflow pipes, vents, and drainage or discharge pipes face down, and are they covered with a screen?	
Are all tanks inspected regularly (ideally every year)?	
Is there sufficient storage capacity for the system?	
When needed, do the tanks provide sufficient pressure throughout the system?	
Are the interior linings of the tanks in good condition, and are they safe for drinking water (NSF 61 or NQ 3660-950)?	
Is the tank panel watertight and locked?	
Can the tank be isolated from the distribution system?	
Is there adequate safety equipment (cage stairs, approved safety belts, etc.) to climb onto elevated tanks?	
Is the site fenced, locked or otherwise protected against vandalism?	
Are storage tanks disinfected after repairs are done? Is the standard disinfection procedure correctly described and followed each time?	
Are procedures for equipment disinfection followed when the tanks are inspected by divers?	
Is there a program for regularly cleaning sediments from storage tanks, including deposits on lateral walls?	
For hydro-pneumatic tanks	YES/NO
Is there sufficient storage capacity for the system?	
Are sensors and other equipment adequate, operational and well maintained?	
Are internal and external surfaces of the pressure tank in good condition?	
Are tank stands/supports solidly built?	
Does the low-pressure trigger ensure adequate pressure throughout the system?	
Is the pumping cycle acceptable (no more than 15 cycles/hour)?	

APPENDIX 7: EXAMPLES OF BEST PRACTICES FOR THE USE OF FIRE HYDRANTS

Use of fire hydrants by external users in Bécancour (12,000 people served, 323 km of water pipes, 754 fire hydrants)

Twenty years ago, Bécancour introduced a fire hydrant inspection and maintenance program. Set out in a forty-page document, it specifies the objectives to achieve and the procedures to follow. It was last updated in May 2014. The topics considered include **controlling the use of fire hydrants and drainage elements by external users**, with the prime objective of minimizing the risks of equipment damage and undesirable disturbances to the drinking water distribution system.

To that end, the municipal regulations stipulate that fire hydrants cannot be used without first applying for a permit. The applicant contacts the public works service and pays the requested fee ($75 in 2015). At the scheduled time, municipal employees install a gate valve on the fire hydrant and the applicant can then use it. When finished, the applicant notifies the municipality and the gate valve is removed. However, those wishing to fill water tanks are directed to the water treatment plant.

Since these regulations were put in place, on average 20 permits per year have been requested. Additionally, five users including the Port of Bécancour have concluded agreements for regular use.

The following page presents Appendix 5.1 (in French) of the fire hydrant inspection and maintenance program, which is the permit for fire hydrant use that external users must complete before connecting to a fire hydrant.

VILLE DE BÉCANCOUR
SERVICE DES TRAVAUX PUBLICS
DIVISION DES OPÉRATIONS

ANNEXE 5.1
PERMISD'UTILISATION D'UN POTEAU D'INCENDIE

REQUÉRANT	
Nom	
Adresse	
Téléphone	

REPRÉSENTANT	
Nom	
Adresse	
Téléphone	

LOCALISATION DU POTEAU D'INCENDIE			
No Poteau d'incendie		**Rue**	
Adresse la plus près			
Secteur			

PÉRIODE D'UTILISATION		USAGE
Début		
Fin		

TARIFS		
Poteau d'incendie à manipuler		**75,00$**
Dépôt / Consommation d'eau	**M³ à $**	**$**

Montant à payer	

Émis par	
Date	

ENGAGEMENT DU REQUÉRANT	
À titre de représentant du requérant, le soussigné, après avoir pris connaissance de la « procédure d'utilisation des poteaux d'incendie par des tiers », déclare en accepter le contenu et s'engage à y observer les conditions décrites	
Signature du représentant	
Date	

INSPECTION	
Inspecté par	
Date	
Observations	

03G-04.03.00-PR.95-47 **Mise à jour : 2010.02.18**

Fire hydrant inspection at L'Assomption (22,000 people served, 144 km of water pipes)

For some years now, the municipality established a fire hydrant inspection program. The principal benefits have been as follows:

- Dynamic and static pressures are known for all fire hydrants.
- Each hydrant is identified by a signpost using the NFPA code (mandatory for fire services).
- Fire hydrants susceptible to freezing were located, providing a list of hydrants to drain before winter.
- Fire hydrants susceptible to freezing are visibly identified as such, so that in winter they can be drained after each use, avoiding breaks.
- The technical specifications of each fire hydrant are known.
- Fire hydrant anomalies are recorded, so that priorities can be set for interventions and repairs.
- A complete record is kept of each intervention: each fire hydrant is listed and located in the software used for mapping the system, and each inspection or repair is entered into the same program.

Inspection and use of fire hydrants at Victoriaville (42,000 people served, 290 km of water pipes, 1655 fire hydrants)

For some years now, the municipality introduced a fire hydrant inspection program. Its principal elements are as follows:

- Detailed inspection of fire hydrants once a year, including operating them.
- Summary inspection of hydrants two or three times a year, which can include operating them.
- Restoration of fire hydrants (full kit) every five years.
- Records carefully kept up-to-date, with management of the data collected.
- Fire hydrants with inadequate drainage were identified, so their drains can be blocked and routinely pumped out before winter.
- Winter inspection of hydrants with inadequate drainage.

Additionally, Victoriaville has stipulated that only municipal employees may operate equipment connected to the distribution system. External users have to fill their tanks at the drinking water production facility, under the supervision of the station operator. The city also created a filling area at the wastewater treatment plant, and street-cleaners now fill up with treated wastewater instead of drinking water.

APPENDIX 8: WATER BALANCE DIAGRAM[39]

Volume entering the system	Exported or distributed water	Consumption			Water generating income
Produced from system sources	Exported water	Billed exported water			Yes
	Distributed water	Authorized consumption	Billed authorized consumption	Billed consumption with meter	Yes
				Billed consumption without meter	
			Unbilled authorized consumption	Unbilled consumption with meter	No
				Unbilled consumption without meter	
		Water losses	Apparent losses	Inaccuracies of customer meters	
				Unauthorized consumption	
				Errors due to systematic data processing	
			Real losses	Losses from pipes and service lines	
Imported				Losses and overflows at reservoirs	
				Losses between the service line and customers' meter	

Van ARSDEL, J. H. (May 2017). "System Size Can Determine Water Loss Control Challenges", *Opflow*, Vol. 43, No. 5, p. 16-18.

[39] Known uncertainties and errors are taken into account in the calculation.

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Québec