Potable Water

Small System Operation and Maintenance Practices

This document is the ninth in a series of best practices related to the delivery of potable water to the public. For titles of other best practices in this and other series, please refer to <*www.infraguide.ca*>.

National Guide to Sustainable Municipal Infrastructure®

NRC · CNRC FCM Federation of Canadian Municipalities Fédération canadienne des municipalités Canada

Small System Operation and Maintenance Practices

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INTRODUCTION

InfraGuide® — Innovations and Best Practices

Why Canada Needs InfraGuide

Canadian municipalities spend $12 to $15 billion annually on infrastructure but it never seems to be enough. Existing infrastructure is ageing while demand grows for more and better roads, and improved water and sewer systems responding both to higher standards of safety, health and environmental protection as well as population growth. The solution is to change the way we plan, design and manage infrastructure. Only by doing so can municipalities meet new demands within a fiscally responsible and environmentally sustainable framework, while preserving our quality of life.

This is what the National Guide to Sustainable Municipal Infrastructure (InfraGuide) seeks to accomplish.

In 2001, the federal government, through its Infrastructure Canada Program (IC) and the National Research Council (NRC), joined forces with the Federation of Canadian Municipalities (FCM) to create the National Guide to Sustainable Municipal Infrastructure (InfraGuide). InfraGuide is both a new, national network of people and a growing collection of published best practice documents for use by decision makers and technical personnel in the public and private sectors. Based on Canadian experience and research, the reports set out the best practices to support sustainable municipal infrastructure decisions and actions in six key areas: decision making and investment planning, potable water, storm and wastewater, municipal roads and sidewalks, environmental protocols, and transit. The best practices are available online and in hard copy.

A Knowledge Network of Excellence

InfraGuide's creation is made possible through $12.5 million from Infrastructure Canada, in-kind contributions from various facets of the industry, technical resources, the collaborative effort of municipal practitioners, researchers and other experts, and a host of volunteers throughout the country. By gathering and synthesizing the best Canadian experience and knowledge, InfraGuide helps municipalities get the maximum return on every dollar they spend on infrastructure—while being mindful of the social and environmental implications of their decisions.

Volunteer technical committees and working groups—with the assistance of consultants and other stakeholders—are responsible for the research and publication of the best practices. This is a system of shared knowledge, shared responsibility and shared benefits. We urge you to become a part of the InfraGuide Network of Excellence. Whether you are a municipal plant operator, a planner or a municipal councillor, your input is critical to the quality of our work.

Please join us.

Contact InfraGuide toll-free at **1-866-330-3350** or visit our Web site at ***www.infraguide.ca*** for more information. We look forward to working with you.

The InfraGuide® Best Practices Focus

Potable Water

In keeping with the adage "out of sight, out of mind", the water distribution system has been neglected in many municipalities. Potable water best practices address various approaches to enhance a municipality's or water utility's ability to manage drinking water delivery in a way that ensures public health and safety at best value and on a sustainable basis. The up-to-date technical approaches and practices set out on key priority issues will assist municipalities and utilities in both decision making and best-in-class engineering and operational techniques. Issues such as water accountability, water use and loss, deterioration and inspection of distribution systems, renewal planning and technologies for rehabilitation of potable water systems and water quality in the distribution systems are examined.

Decision Making and Investment Planning

Elected officials and senior municipal administrators need a framework for articulating the value of infrastructure planning and maintenance, while balancing social, environmental and economic factors. Decision making and investment planning best practices transform complex and technical material into non-technical principles and guidelines for decision making, and facilitate the realization of adequate funding over the life cycle of the infrastructure. Examples include protocols for determining costs and benefits associated with desired levels of service; and strategic benchmarks, indicators or reference points for investment policy and planning decisions.

Environmental Protocols

Environmental protocols focus on the interaction of natural systems and their effects on human quality of life in relation to municipal infrastructure delivery. Environmental elements and systems include land (including flora), water, air (including noise and light) and soil. Example practices include how to factor in environmental considerations in establishing the desired level of municipal infrastructure service; and definition of local environmental conditions, challenges and opportunities with respect to municipal infrastructure.

Storm and Wastewater

Ageing buried infrastructure, diminishing financial resources, stricter legislation for effluents, increasing public awareness of environmental impacts due to wastewater and contaminated stormwater are challenges that municipalities have to deal with. Storm and wastewater best practices deal with buried linear infrastructure as well as end of pipe treatment and management issues. Examples include ways to control and reduce inflow and infiltration; how to secure relevant and consistent data sets; how to inspect and assess condition and performance of collections systems; treatment plant optimization; and management of biosolids.

Transit

Urbanization places pressure on an eroding, ageing infrastructure, and raises concerns about declining air and water quality. Transit systems contribute to reducing traffic gridlock and improving road safety. Transit best practices address the need to improve supply, influence demand and make operational improvements with the least environmental impact, while meeting social and business needs.

Municipal Roads and Sidewalks

Sound decision making and preventive maintenance are essential to managing municipal pavement infrastructure cost effectively. Municipal roads and sidewalks best practices address two priorities: front-end planning and decision making to identify and manage pavement infrastructures as a component of the infrastructure system; and a preventive approach to slow the deterioration of existing roadways. Example topics include timely preventative maintenance of municipal roads; construction and rehabilitation of utility boxes; and progressive improvement of asphalt and concrete pavement repair practices.

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ACKNOWLEDGEMENTS

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Carl Yates, Chairperson
Halifax Regional Water Commission
Halifax, Nova Scotia

Fred Busch, Mayor
District of Sicamous, British Columbia

Sukhi Cheema
Government of Northwest Territories
Yellowknife, Northwest Territories

Norm De Agostinis
Ductile Iron Pipe Research Association
Anjou, Quebec

Tim Dennis
Engineering Services
Regional Municipality of Halton
Oakville, Ontario

David Green
Health Canada, Ottawa, Ontario

Raymond Leclerc
City of Montréal, Quebec

Piero Salvo
WSA Trenchless Consultants Incorporated
Ottawa, Ontario

Doug Seargeant
EPCOR Water Services Incorporated,
Edmonton, Alberta

Ernie Ting
Town of Markham, Ontario

Mike Tobalt
Technical Advisor
National Research Council Canada (NRCC)

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John Braam, Chair
County of Oxford, Woodstock, Ontario

Rick Bomhof
City of Abbotsford
Abbotsford, British Columbia

Dave Duggan
Halifax Regional Water Commission
Nova Scotia

Trail Grubert
Town of Hudson, Quebec

R.A. (Bob) LeCraw
RAL Engineering, Newmarket, Ontario

Ervin McCurdy
Department of Environment
Government of Newfoundland and Labrador
St-John’s, Newfoundland and Labrador

Doug Seargeant
EPCOR
Edmonton, Alberta

George Terry
Ontario Clean Water Agency (OCWA)
Mississauga, Ontario

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Kim Barlishen
Government of Manitoba
Manitoba Water Stewardship
Winnipeg, Manitoba

John Forrest
Public Works Coordinator
Municipality of Huron East
Huron East, Ontario

Michael Wu
Government of British Columbia
Northern Health Authority
Prince George, British Columbia

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Governing Council:

Joe Augé
Government of the Northwest Territories,
Yellowknife, Northwest Territories

Mike Badham
City of Regina, Saskatchewan

Sherif Barakat
National Research Council Canada
Ottawa, Ontario

Brock Carlton
Federation of Canadian Municipalities
Ottawa, Ontario

Jim D'Orazio
Greater Toronto Sewer and Watermain Contractors
Association, Ontario

Douglas P. Floyd
Delcan Corporation, Toronto, Ontario

Derm Flynn
Town of Appleton, Newfoundland and Labrador

John Hodgson
City of Edmonton, Alberta

Joan Lougheed
Councillor, City of Burlington, Ontario

Saeed Mirza
McGill University, Montréal, Quebec

Umendra Mital
City of Surrey, British Columbia

René Morency
Régie des installations olympiques
Montréal, Quebec

Vaughn Paul
First Nations (Alberta) Technical Services Advisory
Group, Edmonton, Alberta

Ric Robertshaw
Public Works, Region of Peel, Brampton, Ontario

Dave Rudberg
City of Vancouver, British Columbia

Van Simonson
City of Saskatoon, Saskatchewan

Basil Stewart, Mayor
City of Summerside, Prince Edward Island

Serge Thériault
Government of New Brunswick
Fredericton, New Brunswick

Tony Varriano
Infrastructure Canada, Ottawa, Ontario

Alec Waters
Alberta Infrastructure Department
Edmonton, Alberta

Wally Wells
The Wells Infrastructure Group Inc.
Toronto, Ontario

Municipal Infrastructure Committee:

Al Cepas
City of Edmonton, Alberta

Wayne Green
Green Management Inc., Mississauga Ontario

Haseen Khan
Government of Newfoundland and Labrador
St. John's, Newfoundland and Labrador

Ed S. Kovacs
City of Cambridge, Ontario

Saeed Mirza
McGill University, Montréal, Quebec

Umendra Mital
City of Surrey, British Columbia

Carl Yates
Halifax Regional Water Commission, Nova Scotia

Relationship Infrastructure Committee:

Geoff Greenough
City of Moncton, New Brunswick

Joan Lougheed
Councillor, City of Burlington, Ontario

Osama Moselhi
Concordia University, Montréal, Quebec

Anne-Marie Parent
Parent Latreille and Associates
Montréal, Quebec

Konrad Siu
City of Edmonton, Alberta

Wally Wells
The Wells Infrastructure Group Inc.
Toronto, Ontario

Founding Member:

Canadian Public Works Association (CPWA)

EXECUTIVE SUMMARY

The purpose of any potable water system is to deliver adequate volumes of consistently high quality, chemically and biologically safe water at adequate pressure to all customers 24 hours a day, seven days a week. This can only be achieved with good design, construction, and inspection practices as well as proper operation and maintenance (O&M).

Recent events contributed to reduced public confidence in municipal water supplies, which led to extensive changes in government legislation and regulations across Canada. A comprehensive O&M program is required to ensure the continuous supply of clean and safe water to the customer's tap. It also helps raise public confidence in the water system, minimizes the frequency of system failures and the duration of outages, reduces the life cycle costs for the system, and promotes continuous improvement among operators.

This document outlines best practices for the O&M of small water systems from the source water to the customer's tap. It is based on a literature review, a survey of selected municipalities across Canada, and input from Canadian water system O&M experts. For this best practice, a small water system is defined as a potable water system that serves a population of 5,000 or less.

This best practice also provides references where more detailed information on specific practices can be found. These practices are summarized as follows:

- Produce high quality, stable water that is biologically and chemically safe and aesthetically acceptable.
- Know and understand all provincial/ territorial regulations applicable to the operation and maintenance of the water system.
- Become knowledgeable with water system assets and their location.
- Become knowledgeable with the condition of the water system.
- Determine what is needed to achieve the intended level of service.
- Have a plan to upgrade inadequate components.
- Maintain an adequate disinfection residual in all parts of the system.
- Maintain positive water pressures under foreseeable operating conditions.
- Implement a backflow prevention and cross-connection control program.
- Monitor the quality of the water. This includes source water, treatment plant output, in the distribution system and at the point of use (i.e., at the tap).
- Maintain comprehensive system records and documents reporting water quality.
- Ensure proper disinfection and flushing procedures are used for all repairs and new construction.
- Monitor for internal and external corrosion and, if necessary, implement measures to reduce the rate of corrosion.
- Meter water supply and consumption to quantify water losses from the system and, if necessary, implement a leak detection program.
- Maintain the source water intake, dam or wellhead site.
- Maintain the water source, treatment plant, pumping stations, water towers, and reservoirs.
- Exercise and inspect the distribution system valves and hydrants.
- Flush and swab the water mains.
- Use a maintenance management system and geographic information system (GIS).
- Maintain a spare parts inventory.
- Prepare a contingency plan for emergencies.
- Prepare a plan to ensure the financial sustainability of the water system.

The purpose of any potable water system is to deliver adequate volumes of consistently high quality, chemically and biologically safe water at adequate pressure to all customers 24 hours a day, seven days a week.

Detailed records of the system inventory, O&M data, and condition and performance data are invaluable for proper management of the water system.

- Maintain excellent public relations through newsletters, public education, participation in public events, etc.
- Maintain adequate staffing and funding levels to undertake best practice activities and provide training for staff.

Note however, that this best practice is not a replacement for proper engineering and should not preclude or supersede regulatory requirements.

The operators of small water systems should evaluate their current O&M practices against these best practices and establish a priority list for implementation of applicable best practices. However, the first priority of any operator is water quality, and this aspect should guide the setting of priorities.

To ensure the O&M program is effective, several performance measures should be monitored regularly (e.g., the number of adverse water quality test results, the number of water quality complaints, the number of inoperable valves, the number of water main breaks). All O&M practices should be reviewed periodically to ensure they adequately address the needs of the system. To facilitate these reviews, practices should be documented and standard operating procedures developed. Detailed records of the system inventory, O&M data, and condition and performance data are invaluable for proper management of the water system.

1. General

1.1 Introduction

Over 80 percent of Canadian municipalities[1] have a population of 5,000 or less. This best practice outlines the best practice for operation and maintenance (O&M) of small water systems and should be a good resource for O&M staff in small communities. It is based on a review of existing literature, a survey of selected municipalities across Canada, and input from small water system experts.

1.2 Purpose and Scope

This document provides guidance to operators of small water systems regarding best practices for day-to-day activities. It covers most aspects of small water systems from the source water to the customer's tap. Throughout this document, the term "municipality" refers to the owner or operator/maintainer of a small water system.

1.3 How to Use This Document

It is the purpose of this best practice to determine which recommendations are applicable to a small water system, to help develop a plan for improvements, and to implement these improvements in a prioritized manner.

Sections 2 through 5 elaborate on why, what, how, and when, with respect to best O&M practices for a small water system.

Section 2 — Rationale provides justification for this best practice and describes benefits that can be achieved by following it.

Section 3 — Work Description describes a theoretical framework underlying this best practice (what should be done) and goes on to describe specifics of implementing the best practice (how to do the work).

Section 4 — Applications and Limitations describes those most likely to benefit from the best practices in this document, and notes limitations to the application of the best practices to a specific system.

Section 5 — Evaluation elaborates on measures that can be taken to assess a system's performance following the implementation of these best practices.

InfraGuide has published several other best practice documents related to water systems. Some of them include:

- *Developing a Water Distribution System Renewal Plan* (2003b) describes basic approaches to planning the renewal of water systems.
- *Deterioration and Inspection of Water Distribution Systems* (2002a) describes the reasons for deterioration and methods for inspection of distribution facilities.
- *Selection of Technologies for the Rehabilitation or Replacement of Sections of a Water Distribution System* (2003c) describes available technologies and methods for their implementation.
- *Water Use and Loss in Water Distribution Systems* (2002c) describes the basics of water auditing, cost reduction, and accountability.
- *Water Quality in Distribution Systems* (2003d) describes common water quality problems in water distribution systems and how to address them.
- *Establishing a Water Metering Plan to Account for Water Use and Loss* (2003e) describes how to establish and set up a metering plan.

1. Municipality (or municipalities) mentioned in InfraGuide Best Practices, is intended to include all purveyors of public services as well as utilities.

This document provides guidance to operators of small water systems regarding best practices for day-to-day activities.

- *Speed and Quality of Linear System Repairs* (2004) describes how to improve on the speed of detecting leaks and how to carry out quality repairs on distribution systems.

These documents, and others, are available at InfraGuide's Web site: *<http://www.infraguide.ca>.*

1.4 Glossary

Chloramination — The process of disinfecting with chloramines by the addition of ammonia to chlorinated water.

Chloramines — A disinfectant produced from the mixing of chlorine and ammonia.

Chlorination — The process of adding chlorine to water to kill disease-causing organisms or to act as an oxidizing agent.

Chlorine residual (CR) — The concentration of chlorine remaining in water at the end of a specified contact time. The absence of chlorine residual or any significant reduction is an immediate indication of potential water quality or treatment process concerns, and that water is not protected from contamination by microbiological organisms.

Combined chlorine residual (CCR) — The resultant compound from the reaction of chlorine with ammonia.

Cross-connection — A physical connection of a potable water system and a non-potable water system.

CT requirements — The product of the disinfection concentration (C) and contact time (T) required to achieve disinfection.

Haloacetic acids (HAAs) — Commonly occurring by-product of disinfection (with chlorine).

Maximum acceptable concentration (MAC) — Established for parameters which, when present above a certain concentration, have known or suspected adverse health effects. The length of time the MAC can be exceeded without health effects will depend on the nature and concentration of the parameter.

pH — The pH of an aqueous solution is a measure of the acid-base equilibrium achieved by various dissolved compounds. A scale of 0 to 14 is used with 0 being strongly acidic and 14 being strongly basic. By definition, the pH of pure water at at temperature of 25 degrees Celsius is 7.0. pH controls many chemical reactions, including coagulation, disinfection, water softening, corrosion, biochemical reactions, and ammonia removal.

Primary disinfection — A disinfection step, typically accomplished at the treatment plant, designed to destroy/inactivate pathogens in raw water.

Secondary disinfection — Provisions for maintaining a disinfectant residual in the distribution system, after primary disinfection at the treatment plant has occurred.

Trihalomethanes (THMs) — Commonly occurring by-product of disinfection (with chlorine).

2. Rationale

2.1 Background

Operation and maintenance activities do not get as much attention from the public as new construction. However, they are key to the reliable delivery of clean and safe drinking water. For many small water systems, current practices achieve an acceptable level of service, but problems may develop as the system ages or when changes occur in O&M staff. In addition, operators of small water systems often have limited funds to access engineering and technical support. Recent events, which reduced public confidence in municipal water supplies, led to extensive changes in government legislation and regulations across Canada. These regulatory changes and the desire to maintain public confidence are forcing water purveyors, large and small, to modify their practices.

2.1.1 Records and Staffing

Good records of all aspects of a water system are crucial. What was built and why? How has it functioned in the past? Current records provide proof of how the system is complying with regulations.

Small water systems need trained, diligent, and committed management and staff to run smoothly in normal times and to continue functioning during extreme events. Good records also allow effective planning and response during emergencies. Due diligence makes the difference between mediocre and best practices.

2.1.2 Water Quality

The key measure of success in running a small water system is the delivery of adequate volumes of consistently high quality, chemically and biologically safe water, at adequate pressure to all customers 24 hours a day, seven days a week. To maintain this high level of service, care must be taken during all stages of the supply and delivery of the water. Source water protection (i.e., measures to ensure the raw water supply is protected from degradation from any source, including urbanization, industrial, or farming practices) is the first step in producing safe water now and in the future. After the source water is protected, the next step is to treat the water correctly. The treated water must also be protected from degradation in the water distribution system to the point of use.

Distribution systems for most municipalities are designed to supply fire flows and peak hour demands. As a result, during normal conditions, water can spend considerable time in the system before being delivered to the customer. It also usually means the flow velocity in most water mains is very low, which allows particulate matter to settle in the pipe and biofilms to grow on the walls. These conditions are conducive to bacterial growth, particularly if an adequate disinfectant residual is not maintained.

Long residence times can lead to the loss of disinfection residual and degradation of water quality. Long residence times can also increase the risk of regrowth of bacteria and, if more chlorine is added, may result in higher concentrations of disinfection by-products. Occasional high flow rates or flow reversals can cause re-suspension of settled solids or sloughing of biofilms, which can lead to water quality complaints from customers.

2.1.3 Accountability

For several decades, potable water systems were taken for granted in most of Canada. They were always there, thought to be safe, and usually inexpensive. The exceptions were in small communities, often in northern regions, where it was difficult to treat the available source water properly. However, high-profile water system failures in Ontario and Saskatchewan resulted in many people becoming very ill and some people dying. These failures resulted in new regulations and a higher degree of public interest in the water supply. Municipal officials and operations staff also became more aware of their responsibilities, stewardship, and public trust.

2.1.4 CHANGING REGULATIONS

Most provinces and territories have recently changed regulations or are in the process of doing so. Some jurisdictions have also implemented regulations concerning operation certification. Other regulations for utility accreditation are under development.

2.2 Benefits

Owners/operators will:

- be able to reduce the risk to public health;

  reduce the risk of failures/outages in the water system, (i.e., improve system reliability);
- be in a better position to avoid litigation against the municipality, its officers, and staff through demonstration of due diligence;
- be able to prolong the life of their existing water system and maximize the value of any new investments. They may also experience lower power and chemical costs;
- be able to identify areas where their current practices are inadequate and where adoption of these best practices should be considered;
- be able to describe the system components, their condition, and when they might need rehabilitation or replacement;
- be able to manage source water protection and treatment processes to produce clean, safe water;
- be able to evaluate the effect of their distribution system on water quality and the reliability of the water supply.
- be better educated on the benefit of preventive rather than reactive maintenance practices. This may result in an increased awareness of required staffing levels, a reduction in unplanned water supply outages, and a reduction of water quality incidents. Preventive maintenance may also reduce staff costs as unscheduled, call-out, or overtime work is reduced;

- With proper record keeping over time and analysis of the records for trends, operators will be able to see if the overall condition of their system is adequate, or whether any rehabilitation or replacement is required. This analysis may indicate the need for additional investment (i.e., higher user rates) to ensure the system is sustainable over the long term.
- By following these best practices, owners/operators will be better prepared to respond to emergency situations, such as a major weather event, a supply interruption, a major break or an adverse water quality test result.
- Implementation of these best practices will enable owners/operators to better accommodate changes in operation and maintenance staff.

The best practice: Water Quality in Distribution Systems (InfraGuide, 2003) provides guidance on how to maintain water quality, and covers many elements such as water production, backflow prevention, storage facility, valve and hydrant operations, and distribution system operations.

Communication of the best practices adopted by the municipality will increase public confidence and satisfaction in the water system, as rates are reset to reflect the sustainability of systems. It will also encourage public involvement in monitoring system performance. This may result in faster detection of problems, reduced risk, and a better overall integrated water quality management program.

2.3 Risks

- Depending on current practices and the desired timeline for implementation of best practices, additional resources (i.e., staff and financial) may be required.
- There could be a lack of support for changes to existing practices from stakeholders (e.g., operators, politicians, and the public) for those systems that

have not experienced significant problems or if resources and funding have to be increased to pay for improvements.

- Some elements of this best practice depend on reliable information about the existing system condition and performance. If data are lacking or if they are unreliable, then predicting trends may be inaccurate and actions may not be effective or efficient.
- In metered systems, increases in water rates to support changes in practices could result in a decrease in water consumption and, if not accounted for in advance, revenue shortfalls. Where wastewater charges are based on metered water consumption, any decrease in water consumption could also reduce revenues generated from wastewater charges.
- Reduced water demand, either because of increased rates, water conservation measures, or reduced leakage from the distribution system, will increase treated water residence time in the distribution system, resulting in greater challenges in maintaining the chlorine residual and controlling disinfection by-products.

Monitoring can support additional endeavours, such as fulfilling regulatory requirements, prioritizing operational improvements, minimizing aesthetic problems/consumer inquiries, developing a pipeline rehabilitation strategy, and many others.

3. Work Description

3.1 What Should Be Done

The best practice for the O&M of small water systems should include the following practices:

1. Produce high quality, stable water that is biologically and chemically safe and aesthetically acceptable.
2. Know and understand all provincial/territorial regulations applicable to the operation and maintenance of the water system.
3. Become knowledgeable with water system assets and their location.
4. Become knowledgeable with the condition of the water system.
5. Determine what is needed to achieve the intended level of service.
6. Have a plan to upgrade inadequate components.
7. Maintain an adequate disinfection residual in all parts of the system.
8. Maintain positive water pressures under foreseeable operating conditions.
9. Implement a backflow prevention and cross-connection control program.
10. Monitor the quality of the water. This includes source water, treatment plant output, in the distribution system and at the point of use (i.e., at the tap).
11. Maintain comprehensive system records and documents reporting water quality.
12. Ensure proper disinfection and flushing procedures are used for all repairs and new construction.
13. Monitor for internal and external corrosion and, if necessary, implement measures to reduce the rate of corrosion.
14. Meter water supply and consumption to quantify water losses from the system and, if necessary, implement a leak detection program.
15. Maintain the source water intake, dam or wellhead site.
16. Maintain the treatment plant, pumping stations, water towers, and reservoirs.
17. Exercise and inspect the distribution system valves and hydrants.
18. Flush and swab the water mains.
19. Use a maintenance management system and geographic information system (GIS).
20. Maintain a spare parts inventory.
21. Prepare a contingency plan for emergencies.
22. Prepare a financial plan to ensure the water system is sustainable.
23. Maintain excellent public relations through newsletters, public education, participation in public events, etc.
24. Maintain adequate staffing and funding levels to undertake best practice activities and provide training for staff.

3.2 How to Do the Work

Operators of small water systems should evaluate their current practices against these best practices and establish an implementation priority list. However, the first priority of any operator should be water quality, and this should guide the prioritization of tasks.

The first priority of any operator should be water quality, and this should guide the prioritization of tasks.

3.2.1 Produce High-Quality, Safe, Potable Water

Operators should ensure that their water treatment plant is capable of properly treating the source water, recognizing that the quality of the source water could vary over a wide range. The quality of the water leaving the water treatment plant should be constant over time, with low turbidity and a stable pH, and should consistently meet all regulatory requirements. Water must be properly disinfected using chlorine, ultraviolet light, and/or ozone, and have sufficient chlorine (or chloramine) to maintain an adequate residual throughout all parts of the distribution system. The water should be aesthetically acceptable, without offensive taste, odour, or colour.

Table 3–1
Asset Identification: Components of the Small Water System

When water quality changes, even if it remains within allowable limits, there may be implications for the distribution system. Water quality may affect the distribution system components along with residential components such as taps, hot water tanks, dishwashers, etc. Warmer water can lead to faster chlorine residual decay rates, and higher pH water can also reduce the effectiveness of chlorine and chloramine as a disinfectant. Higher pH water can increase calcium carbonate precipitation (scaling) with certain source waters. Varying pH can contribute to changes in internal corrosion rates, in some cases shortening the life of the system or producing corrosion by-products, which can be problematic from an aesthetic and possibly a health point of view. For example, varying pH water in unlined iron mains may create rusty-looking or musty-tasting water, and can lead to unacceptably high concentrations of copper and lead.

In addition, some groundwater may have to be treated to reduce sodium concentrations.

3.2.2 Know and Understand All Applicable Regulations

Each water system operator should be aware of and comply with the regulatory requirements of the province or territory. Operators should review new regulations and, if uncertain about their application, ask for clarification from the regulatory agency. Operators should keep copies of all regulations, fact sheets, etc., readily available for reference. When planning a new water project, the operator should review the plan with the regulatory agency at an early stage.

3.2.3 Become Knowlegeable with the System Assets

The operator of a small water system must be knowledgeable concerning all components of the system, including their location. When they apply to a particular system, the following documents should be centrally located and accessible at all times. The operator should be familiar with the documents.

Table 3–1: Asset Identification: Components of the Small Water System

Assets	O & M	Engineering	Regulatory & Financial
■ System maps ■ Valve location sheets ■ Original construction record drawings/as-built plans/blueprints/shop drawings ■ Operations and maintenance manuals ■ Inventory records, tools, and equipment records	■ Source water, treatment plant and distribution system water quality test results ■ Operations and maintenance daily logs ■ Source water protection plan ■ Wellhead protection plan and contaminant source inventory ■ Emergency response plans and contingency plans ■ Flow meter records, pumpage records ■ Hydrant and pump flow tests	■ Engineer's reports and condition assessments ■ Feasibility studies and hydro geological studies ■ Raw water quality assessments/source water characterization reports ■ Design reports ■ Well drilling records (drillers logs)	■ Provincial and federal water regulations ■ Permits to take water/water rights ■ Provincial/federal ministry of environment approvals/certificate of approval (C of A) ■ Capital investment plan ■ Operating permits and conditions

3.2.4 Become Knowlegeable with the System's Condition

The water system operator needs to be fully aware of the condition of all the components of the system. This is the first step in understanding any problems that may be encountered during operation of the system and when planning upgrades or expansions. In many jurisdictions, regulations mandate the need to monitor and document the condition of the system, and require that plans be in place to upgrade any components not performing satisfactorily or not meeting current regulation or code requirements. A well-operated small water system must have maintenance and testing logs and log books, which are used to keep a record of all activities, routine and non-routine, undertaken on the system. The documents and records listed in Table 3–2 should be obtained (as appropriate), reviewed, and acted upon. Any missing information should be taken into account when determining what studies and inspections need to be performed.

Hydraulic studies (including pressure testing, flow testing, water loss studies, C–factor testing, and calibrated computer modelling for pressure, transient analysis, residence time, chlorine residual, and contaminant dispersion, as well as community complaints) can all provide useful information regarding inadequacies in the existing system.

An operational performance assessment performed by a qualified person can identify weaknesses in current O&M activities. The potable water best practice, *Deterioration and Inspection of Water Distribution Systems* (InfraGuide, 2002a), provides guidance regarding water distribution system condition assessments. *Best Practices for Utility-Based Data* (InfraGuide, 2003a), provides additional recommendations regarding data collection and management. (There is more discussion regarding record keeping in Section 3.2.11).

Table 3–2 Documentation Tracking Water System Conditions

In many jurisdictions, regulations mandate the need to monitor and document the condition of the system, and require that plans be in place to upgrade any components not performing satisfactorily or not meeting current regulation or code requirements.

Table 3–2: Documentation Tracking Water System Conditions

Documents	Description
Reports	■ Engineering reports (mandated in some provinces): These describe the current state of the system and any upgrades required to meet current regulations. ■ Inspection: Intake or wellhead (down hole and site), treatment plant, reservoirs, dams, distribution system components (pipelines, valves, and hydrants). ■ System reports: Loss reports, water audits, and leak detection studies. ■ Watershed management implemented plans. ■ Studies: Feasibility and hydrogeological.
Tests	■ Results: Well Water Level Step test, drawdown test, pump and motor tests (capacity, vibration, megohmmeter), calibration, and electrical inspections.
Records	■ Outages, breaks, and repairs. ■ Hydrant flushing records, valve exercise records, maintenance logs, and diaries. ■ Maintenance records: Maintenance logs and diaries. ■ Water quality complaint records. ■ Water main flushing records. ■ Frozen water services list. ■ Well maintenance. ■ Reservoir cleaning.

For most small water systems, operators are the only people able to understand all aspects of the system and should be consulted on the development of plans for investments in system expansion and upgrade.

3.2.5 Determine What is Needed for Intended Levels of Service

Each small water system has a specific mandate, established by the owner or by regulation. The service standards the system should be meeting—water quality standards, aesthetic standards, minimum pressure, reliability, water main break repair response time, standby capacity in case of source water supply disruption (storage) or power supply disruption (standby power)—must be established so system performance can be measured against them and areas for improvement can be determined. Additional recommendations on this topic are available in *Developing Levels of Service* (InfraGuide, 2002b).

3.2.6 Have a Plan to Upgrade Inadequate Components

For most small water systems, operators are the only people able to understand all aspects of the system and should be consulted on the development of plans for investments in system expansion and upgrade. Depending on the condition of the system and the experience and training of the operations staff, external expertise may be required to facilitate development of the plan. Operators should have a plan to address employee and public safety as well as protection of public health.

Improvements should be prioritized based on their cost-benefit ratio in terms of providing safe, reliable water and complying with current and anticipated regulations. The plan may have short- and long-term activities, depending on the situation. In the past, many operators paid insufficient attention to protecting their source water, and did not have source or wellhead protection plans in place. Such plans should be completed as soon as possible. One improvement that may arise from these plans is a groundwater protection policy. They are typically implemented through the planning process, and restrict land uses and activities in the capture zone of the well or wells. For surface water sources, protection of the watershed can usually be achieved by working with other stakeholders and agencies.

When considering improvements to the distribution system, operators should evaluate system reliability, the need for looping and main sizes to reduce residence times or increase fire flows (determined by hydraulic modelling and fire flow testing, chlorine residual testing, and water quality complaint records). Other considerations include rehabilitation or replacement of mains with a limited remaining useful service life. These topics are further elaborated in *Developing a Water Distribution System Renewal Plan* (InfraGuide, 2003b) and *Selection of Technologies for Rehabilitation or Replacement of Sections of a Water Distribution System* (InfraGuide, 2003c).

3.2.7 Maintain Disinfection Residuals

Primary disinfection in a water treatment plant is standard practice to kill or inactivate microbiological organisms, thereby reducing the threat of waterborne disease outbreak. Once water is treated and enters the distribution system, many mechanisms can contribute to the deterioration of the quality of the water and, in some cases, the water can become unsafe to drink. Some of these mechanisms are discussed below in the sections on maintaining minimum system pressures and preventing backflow. The system may also contain bacteria or other micro-organisms that are present as a biofilm on the walls of pipes or in sediments within the pipes.

Maintaining an adequate disinfection residual (also known as secondary disinfection) and positive pressure of greater than 140 kPa (20 psi) in all parts of the distribution system will help ensure that the water being delivered to customers is safe. Chlorination or chloramination (the addition of ammonia or ammonium compounds to chlorinated water) is recommended (and often mandated by regulations) to protect water quality after it leaves the treatment plant and enters the distribution system. With an adequate disinfectant residual, the water should be as safe as it was when it left the supply facility unless a backflow or breach of the system occurs. Residual monitoring is, therefore, extremely valuable as a relatively quick and inexpensive means to assess the microbiological safety of the water in the distribution system.

Regulations governing operations of water systems and best practices dictate that the operator implement a set plan of action if a chlorine residual test fails (i.e., the residual level of free chlorine measured in the sample is below the regulatory minimum). It is considered a best practice to maintain a target residual-free chlorine level, which is higher than the regulatory minimum in all parts of the water system. The action plan to be implemented if a chlorine residual is lower than the regulatory minimum will be influenced by regulations and operational permits, but should include retesting, flushing, and notification of the medical officer of health, ministry of the environment, and other appropriate regulatory agencies. The plan of action should also outline the procedure to restore the required chlorine residual in the system and prove its presence with retesting. In addition, this action plan should be implemented when the chlorine residual changes suddenly. The action plan should include an investigation of the causes of the reduction in chlorine residual.

Water quality management includes various activities to ensure the water delivered to the customer meets all regulatory and aesthetic requirements set for the system. These activities could include monitoring, analyzing test results for trends, modelling residence time and deterioration of disinfection residual, regular flushing of portions of the system with excessive residence times, and system improvements (such as the installation of looping mains and pressure-reducing valves) to improve circulation and reduce residence time for water in the system.

When chlorine reacts with natural organic material found in some source waters, disinfection by-products, such as THMs[2] and HAAs[3] can form. The concentration of these by-products is regulated in all provinces and territories because, in high concentrations, they can pose a risk to human health. If the operator maintains too high a chlorine residual in portions of the distribution system, and high levels of organics are present, then unacceptably high levels of disinfection by-products may result. The challenge for the operator is to maintain an adequate chlorine residual in the most remote parts of the system (e.g., farthest from the water treatment plant) while not creating too high a chlorine level in the system. Occasionally, structural changes, such as looping, automatic (or manual) flushing, or chlorine booster stations, are required to achieve this balance.

The best practice, *Water Quality in Distribution Systems* (InfraGuide, 2003d) provides additional information and recommendations regarding maintenance of water quality in distribution systems. *Water Chlorination Principles and Practices* (AWWA, 1992a), provides more detail regarding the use of chlorine in water systems.

Regulations governing operations of water systems and best practices dictate that the operator implement a set plan of action if a chlorine residual test fails (i.e., the residual level of free chlorine measured in the sample is below the regulatory minimum).

3.2.8 Maintain Positive Water Pressures

If a part of the system experiences negative pressures (i.e., vacuum), groundwater or soil may enter the system at the location of a leak. Negative pressure can be due to pump failure, pressure transients from a pump starting and stopping, valve operation, or electrical outages. Negative or reduced pressures may also cause backflow (also known as back siphonage). Backflow is a concern when chemicals or non-potable water are drawn back into the distribution system from a customer's premises. Negative pressure in one part of a system may result from pressure transients, or abnormally high flows in another part of the system, such as a water main break, opening several hydrants to fight a large fire, or improper valve operations that can shut down supply to a portion of the system. Pressure transients can also occur if hydrants are opened or closed too quickly.

2. Trihalomethanes (THMs) — Commonly occurring by-product of disinfection [with chlorine].

3. Haloacetic acids (HAAs) — Commonly occurring by-product of disinfection [with chlorine].

A cross-connection occurs when a potable water supply line in a facility is connected to a non-potable line, such as wash water in a barn or manufacturing facility.

Contractors should not be permitted to operate valves or hydrants without approval from the municipality, or diverge from accepted operating practices.

To prevent frequent occurrences of negative pressures in the distribution system, the system needs to be designed to maintain at least 140 kPa (20 psi) during maximum day demand operating conditions, including fire flows. If a portion of a distribution system cannot maintain at least 140 kPa, then a boost station or other measures may be required. Sudden pump stoppages due to a power failure are a common cause of pressure transients. Some small water systems are equipped with hydro-pneumatic tanks to provide positive pressure until a backup generator can start. In other cases, elevated storage can maintain positive pressure without pumps running. These design issues should be considered if any upgrades or expansions are planned, or if negative pressure situations have been identified as a problem.

The risk of contaminant intrusion into the water system is a function of the number of leaks, the frequency and severity of negative pressure situations, and the presence of contaminants in the ground and groundwater surrounding the water mains. Certain measures may be undertaken by the operator to minimize the risk of loss of system pressure.

- Carry out standard O&M procedures for valves and hydrants. Monitor pressure on the upstream or downstream side of a hydrant during flow tests; operate valves slowly to prevent pressure transients; plug drain ports and vacuum out water in hydrants where the water table is high; do not use antifreeze in hydrants since it could be drawn into the distribution system.
- Maintain the distribution system in a good state of repair, to minimize the size and number of leaks and freezing incidents. Have a plan to rehabilitate or replace deteriorated mains.
- Install and maintain surge control equipment at pumps and other critical locations. Surge control devices include air chambers, air/vacuum valves, surge relief valves, check valves, pressure-reducing valves, elevated storage or hydro-pneumatic tanks, pump control valves and variable speed pumps.
- Install and maintain backup pumps and a backup power supply (usually diesel generator sets).
- Ensure underground chambers are cleaned and dewatered to prevent water from entering a vacuum relief valve. Drain chambers to a storm sewer.

3.2.9 Implement Backflow Prevention and Cross Connection Control Programs

Backflow may occur if a customer has a water line connected to a chemical mixing tank or dirty water sink without an air gap or suitable backflow prevention device. Backflow can also occur if a directly connected mixing pump in a private facility generates higher pressures than the water line pressure, and causes flow from the plant into the water system. Private wells and cisterns can also be sources of contamination. A cross-connection occurs when a potable water supply line in a facility is connected to a non-potable line, such as wash water in a barn or manufacturing facility.

Backflow can also occur during improper filling of a water truck. Filling should only be done with a suitable air gap or a reduced pressure backflow device. This, and other risks from hydrant usage, can be mitigated by installing a bulk water station, where an air gap is maintained during all filling operations. The fire department may also introduce contamination if it uses a fire truck in a rural environment (drawing non-potable water) and then hook up the same truck to a hydrant.

The small water system operator should audit the system for potential backflows and cross-connections, and implement a public/industrial user/agricultural user education program. Many water systems require all new non-residential customers to install a backflow prevention device on their domestic sprinkler service lines. It is recommended that a municipality create a backflow bylaw as the first part of a backflow/cross-connection program. *Recommended Practice for Backflow Prevention and Cross-Connection Control* (AWWA, 1999a) provides detailed information on implementing a program of backflow prevention and cross-connection control. Methodologies for Setting a Cross Connection Control Program (InfraGuide, forthcoming) is also an excellent reference document.

3.2.10 Monitor Water Quality

Regulatory Requirements

Most jurisdictions in Canada require the small water system operator to perform tests to confirm the water delivered to customers is chemically and biologically safe in accordance with the Guidelines for Canadian Drinking Water Quality. As noted earlier, testing to prove chlorine or chloramine residual in all parts of the distribution system is a surrogate method of confirming the absence of microbiological contaminants and waterborne disease. Specific conditions on the provincial ministry of environment certificate of approval or permit to operate may dictate more frequent testing or testing for other parameters. Appendix A lists standard water quality tests and typical test frequency and maximum acceptable concentrations for various water quality parameters.

Routine Monitoring Beyond Regulatory Requirements

In some cases, the operator may need to monitor for other parameters (or at higher than regulated frequency) to optimize the treatment processes to ensure delivery of high quality water to the customer. Reasons for additional testing may include specific characteristics of source water (taste and odour), system layout, flows, materials, critical users (e.g., hospitals), contaminated areas (e.g., hydrocarbons can permeate through some pipe and gasket materials under positive pressures) and areas with a history of complaints.

Non-Routine Monitoring

The small water system operator should institute special sampling and testing to assess non-routine events, such as power failure, flooding or very heavy rains in the watershed, receipt of a water quality complaint, a water main break, construction of a new water main, or connection of a new customer.

3.2.11 Maintain Comprehensive Programs

Small water system operators need to maintain water quality testing and complaint records (refer to Appendix D), analyze them, and act on the findings. They also need to maintain records of water main breaks and repairs, unusual events (e.g., extreme weather, natural disasters, power outages), and records of all studies, upgrades, and expansions of the system (water source, treatment plant, reservoir, distribution system).

Operators must be able to refer to historical test and repair data as well as previous studies, reports, and drawings to identify trends over time. Ideally, a water system operator would have a centralized database containing water quality monitoring test results (source water, treatment plant, and distribution), system information (drawings and maps), equipment and pipes (materials, ages, repairs), customer information (usage, contact numbers, complaints, responses to complaints), as well as planning and financial information (growth forecasts, capital and operating budgets, and records of actual operating costs including labour, electricity, chemicals, supplies, and equipment).

Electronic storage of data is preferred over paper-based systems, because it is easier to store and analyze the data and maintain an off-site backup. Paper-based storage systems need to be secure, and consideration should be given to retaining copies of critical information at a second location.

Operations records, including test results, should be retained for at least five years or as specified in provincial regulations. Water quality complaints and repair records are often stored by street address and are

Although this best practice deals specifically with water quality monitoring within the distribution system, it is highly recommended that continuous online monitoring of both chlorine residual and turbidity take place at the entry point to the distribution system.

sometimes referenced by map grid co-ordinates. Some water systems use a geographic information system (GIS), which links databases to computer-based mapping so data can be retrieved by clicking with a computer mouse on a hydrant, valve, or address shown on a map. Others use a global positioning system (GPS) to record the location of new construction or repairs, and map precisely the location of visible appurtenances, such as hydrants, valves, and curb stops. A GIS or GPS may be an option for a small water system if funds are available.

Analysis of source water changes over time can indicate trends that may require changes in the design or operation of the water treatment plant.

A water system operator should review test results and water quality complaints to determine any trends. Analysis of source water changes over time can indicate trends that may require changes in the design or operation of the water treatment plant. Analysis of treated water changes over time can indicate whether the treatment plant is producing the desired water quality and may also indicate problems with some of the equipment.

A spatial and temporal analysis of break records will provide an indication of the structural condition of water mains. Analysis of frozen water services and correlation with air temperature records can be used to create a predictive model and allow the operator to issue instructions to specific customers to run their taps to prevent the occurrence of a frozen service.

Records can also be analyzed for water main age and materials, break records and inspection reports, along with information about aggressive soils, to predict the remaining service life of water main segments. This information can be used to plan replacements so they can be budgeted for and co-ordinated with surface road reconstruction or sewer replacement.

The *Best Practice for Utility-Based Data* (InfraGuide, 2003a), provides additional information and recommendations regarding collection and uses of water system data.

3.2.12 Ensure Repars and New Construction Follow Prrocedures

Repairing broken mains, valves, hydrants, and services must be done in a manner that is safe for the worker, the public, and the water customer. During a repair, if the water is turned off, the isolated line is no longer pressurized, and leaks and joints provide an opportunity for contaminant intrusion. The specific site where the break is exposed must be kept sanitary, and all water system components must be disinfected by immersing or swabbing with a chlorine solution or other disinfectant so the risk of contamination is minimized.

On completing the repair, an assessment must be made as to how the line is to be returned to service without risking contamination to the rest of the system. Depending on the nature of the break, it may be necessary to keep the line out of service long enough to disinfect it, charge it with potable water, and test for chlorine residual. As a minimum, the line should be completely flushed through available hydrants or other discharge outlets. The water should then be tested to confirm an adequate disinfection residual before being reconnected to the potable water system. Standard operating procedures for preventing contaminant intrusion, isolation of the work area, repair, methods of disinfection, flushing, monitoring, safe disposal of flushing water (i.e., the water may need to be dechlorinated if discharging to sensitive streams), bacteriological samples, and dechlorination should be developed and implemented.

For new water mains in the system or for connecting new plumbing to the system, very stringent procedures for disinfection, removal of any construction debris following installation (by swabbing or other means), charging the main, conducting leakage tests, proving the main is safe by testing for microbiological quality and chlorine residual, and then connecting, are necessary.
A co-ordinated approach between the water system operator and the plumbing inspector will help ensure proper practices are followed on private property.

American Water Works Association (AWWA) Standard C651–99 describes procedures for disinfection of repairs, new mains, and connections to existing mains. The best practice, *Water Quality in Distribution Systems* (InfraGuide, 2003d), provides additional recommendations.

All repairs and construction should use approved materials. Water system components are expected to provide service for decades, and care should be taken to ensure that approved, durable, and safe products are always used.

The small water system operator will benefit from establishing a standard list of approved products. The water system is easier to operate and maintain if all valves are standardized with respect to the direction to open, all hydrants have the same internal workings, and all pipe materials are standardized. This practice means fewer pipe and clamp sizes, appurtenances, and replacement parts have to be stocked. Water system components should meet appropriate CSA standards and NSF/ANSI Standards 60 and 61. The AWWA also produces standards for water system components, such as valves and hydrants.

3.2.13 Monitor Corrosion

Corrosion of metallic components of the water system causes several problems including water quality complaints (rusty or red water), water quality health risks (elevated lead levels in the water), leaks and breaks, and reduced service life. External corrosion is caused by damage, or lack of protective measures, and by aggressive soils. Corrosion to the inside of metallic water mains can occur if they are unlined and soft, or aggressive waters are present, or the water has a low pH (more acidic). Note that the relative corrosiveness of low pH water is affected by its softness; the softer the water, the more corrosion potential there is for unlined metallic pipes.

Small water system operators should know the pipe age and materials in their system, and monitor for problem areas, which may indicate aggressive soils. Observing the external and internal condition of the pipe at any new connection or break locations will also indicate the severity of corrosion in the system. Where problems are encountered, mitigation measures, such as cathodic protection, can be evaluated for cost effectiveness. Internal corrosion needs to be controlled to maintain water quality and prolong the life of the unlined water mains. Internal corrosion of unlined cast iron water mains can be addressed by corrosion control measures (including managing the pH of the water) and can be prevented by rehabilitating pipes with cement or epoxy. In some cases, it may be necessary to replace metallic pipes and appurtenances.

Lead water services and lead joints on old cast iron pipe can leach lead into the water, particularly when the pH of the water is low or very high (over 8.5). Exposure to lead is considered a health risk. To address this problem, water system owners should implement programs to replace all lead water services and lead jointed pipe. Where systems are known to have lead services, residents should be reminded regularly to run their taps before using the water for drinking or cooking, particularly when the water pH is below 7.

The manual, *Economics of Internal Corrosion Control* (AwwaRF, 2002), can be used to determine the most cost-effective method of addressing internal corrosion. The AwwaRF has also conducted a study specifically looking at rehabilitation and replacement of water services (Boyd et al., 2001[4]). Health Canada is developing a guideline for internal corrosion control (Bernard, 2002[5]).

Where problems are encountered, mitigation measures, such as cathodic protection, can be evaluated for cost effectiveness. Internal corrosion needs to be controlled to maintain water quality and prolong the life of the unlined water mains.

4. AwwaRF Study (Boyd, et al, 2001)
5. Health Canada Guidelines for internal corrosion control (Bernard, 2002)

The potable water best practices, Establishing a Metering Plan to Account for Water Use and Loss (InfraGuide, 2003e), *Water Use and Loss in Water Distribution Systems* (InfraGuide, 2002c), *and Speed and Quality of Linear System Repairs* (InfraGuide, 2004) *provide additional information and recommendations regarding this topic.*

3.2.14 Determine Water Losses From the System

Many small water systems have no (or few) flow meters, and the operator has little information about the distribution of water demands in the system. Metering customer usage and billing based on usage encourages conservation. Strategically placed meters can be very helpful in identifying major leaks within the water system, and fixing these leaks can result in reduced costs for chemicals and electricity. Metering the water drawn from the source and the output from the water treatment plant, plus analysis of customer meter records can provide a good estimate of water use and loss. This includes leakage, worn (underreporting) and unmetered uses, such as bulk water taking, street flushing, water main breaks, water main flushing, and firefighting. Unmetered uses and underreporting meters can be estimated, providing an estimate of leakage from the system. Higher leakage rates cost money and indicate higher risk of contaminant intrusion.

If a small water system has inappropriate water losses (either apparent or real), it may be economically worthwhile investigating the losses and taking action to reduce them. Multi-zone water systems can implement zone pressure monitoring and zone metering to assist in leak detection.

The potable water best practices, *Establishing a Metering Plan to Account for Water Use and Loss* (InfraGuide, 2003e), *Water Use and Loss in Water Distribution Systems* (InfraGuide, 2002c), and *Speed and Quality of Linear System Repairs* (InfraGuide, 2004) provide additional information and recommendations regarding this topic.

3.2.15 Maintain Source Water Intakes, Dams, Wellhead Sites, and Aquifers

If dams, intakes, and wells are remote, they may not be visited frequently by the water system operator. Remote sites may be more susceptible to vandalism and therefore, should incorporate minimum security measures, such as fencing with locked gates. The water system operator should regularly inspect the site and maintain records of the inspections. If the intake is only accessible by diving, inspections should be conducted at least annually. Similarly, wells may require routine rehabilitation to maintain water quality and quantity. A down hole camera inspection and testing may also provide useful information to maintain proper operation. A poorly performing well can generally be rehabilitated, if the problem is detected and acted upon promptly.

The intake, dam, or wellhead should be evaluated and a protection plan developed to identify measures to improve the site. Items to be evaluated include security, safety, contaminant intrusion, wildlife, power supply, access, drainage, erosion, and flooding. In some jurisdictions, regulations mandate submission of intake, dam, and well inspection reports.

3.2.16 Maintain the Water Treatment Plant, Pumping Stations, and Storage Facilities

Small water systems may incorporate a wide range of water treatment methods, equipment, and facilities, depending on the size of the system, when it was constructed, and the nature of the source water for the system. The intended use of the water and the regulations will also determine, to a large extent, what level of treatment is required.

The water system operator needs to ensure the water treatment plant is operating as intended and is producing the desired quality of water. The operator should be aware of seasonal fluctuations in raw water quality that might affect the treatment process. In addition, the operator must regularly inspect, monitor, and maintain the equipment to ensure reliability. Most treatment plants have an O&M manual that gives guidance on operations, maintenance, and inspection procedures. If an O&M manual does not exist, it should be prepared.

The operator is responsible for ensuring that adequate chemicals, cartridge filters, supplies, and spare parts are on hand to allow the plant to operate and carry out maintenance and minor repairs promptly. All activities at the plant must be carried out in a manner that is safe for both the worker and the water supply. As with all other aspects of operation, activities and monitoring at the plant must be properly documented. If the plant includes a laboratory for routine testing, the operator must ensure the lab is properly equipped with supplies and maintained in a clean state.

If upgrades are considered for the water treatment plant, expert advice is usually required. If treatment plant expansion is contemplated, it may be prudent to design parallel systems, so if one side is taken off-line for repair, water treatment capability remains, albeit at a reduced capacity.

Small water systems may also utilize pumping stations and storage reservoirs. These facilities also require that regular inspection, monitoring, and maintenance activities are carried out to ensure reliability. An O&M manual is also recommended to provide guidance on operations, maintenance, and inspection procedures.

3.2.17 Exercise and Inspect Valves and Hydrants

The small water system may have a limited water main network, and every valve may have to be operable to isolate a break in the system. If a valve does not work when needed, the entire system may need to shut down. The operator should ensure that each valve is fully operable. This is achieved by regularly exercising (operating) each valve, inspecting it during the operation, and recording the findings. The operators should know and document the locations of valves for the whole water system, from isolating the source to a section of the distribution system. The location plans should be easily accessible.

Hydrants are critical for fire protection and represent a possible pathway for contaminants to enter the water system. Hydrants, with their isolation valves, must also be exercised and inspected at least annually (or more frequently if required by the provincial fire code), with critical locations (such as the valve at the wellhead) checked more frequently. Air release, vacuum breaker, or pressure-reducing valves should be inspected at least every six months. These valves will usually have an O&M manual, which describes how they are to be inspected and maintained.

Valves and hydrants should always be operated in accordance with standard operating procedures to ensure the operation is done safely and with minimal risk of creating a pressure surge (water hammer) that may lead to negative pressures in the system, stir up sediment in the pipes, or damage some component of the system (such as a water main break). See AWWA (1999b).

3.2.18 Flush and Swab Water Mains

Water mains can accumulate sediment, biofilms, and corrosion-related encrustations over time, and these materials can be entrained in the water during unusually high flows or flow reversals. Even if they are not loosened, these materials can become a refuge for bacterial growth, which can lead to water quality problems. The small water system operator should consider flushing (discharging high volumes of system water out through hydrants) or swabbing (flushing foam swabs through the main and out at a dismantled hydrant) to address water quality concerns in a particular area. Furthermore, operators should consider having a regular program of flushing and swabbing water mains so buildup is removed from the system before it becomes problematic. Flushing is commonly used in low demand areas (e.g., dead-ended mains) to reduce residence time. Swabbing can be used to clean mains to restore their hydraulic capacity.

Uni-directional flushing is the most effective method of flushing a water distribution system. A uni-directional flushing program should start at the source and progress into the system from the largest to the smallest mains in a systematic manner. It achieves greater benefit with less water than random flushing of hydrants. A flushing program requires

The operators should know and document the locations of valves for the whole water system, from isolating the source to a section of the distribution system.

A maintenance management system will help the operator plan and implement routine maintenance and will facilitate record keeping of planned and emergency maintenance activities.

notifying users, monitoring adjacent system pressures (to avoid negative pressures), testing water quality after flushing, managing traffic around work sites, and maintaining public safety (especially where hydrants are discharging). To achieve biofilm removal, the flow velocity through the main must be at least 1.5 m/s. This flow rate requires lots of water for larger diameter water mains. If the system cannot provide that water, and maintain at least 20 psi (140 kPa) throughout the system, then flushing will not be effective for biofilm removal, and swabbing may be considered.

Swabbing can be undertaken in the same manner as flushing, and requires less water; however, it takes more time and is more costly. The swabs must be introduced into the main before they can be flushed in a certain direction, usually via disassembly at a hydrant and temporary installation of swab launchers. Care must be taken to ensure that the swab does not have any opportunity to travel in the wrong direction and get lost in the system. Swabs should be moving at a minimum velocity of 0.75 m/s to gain maximum benefit (effectively agitate the water for debris removal and to provide effective contact with the pipe wall). Velocities above 0.9 m/s enable the swab to ride over debris. Swabs come in varying degrees of density, with the denser swabs being more abrasive on encrusted mains, but they are harder to launch and retrieve. Pigs (which are like swabs but rigid and much more abrasive) should only be used as part of a relining or other rehabilitation program, and are not recommended for routine maintenance activities.

3.2.19 Use a Maintenance Management System

A maintenance management system is a tool used to record and plan maintenance activities. Computerized systems are available for any size system and offer trend analysis and reporting. A maintenance management system will help the operator plan and implement routine maintenance and will facilitate record keeping of planned and emergency maintenance activities. Preventive maintenance may also reduce staff costs as unscheduled call-outs or overtime work is reduced.

3.2.20 Maintain a Spare Parts Inventory

Water system operators must maintain an adequate inventory of spare parts, equipment, repair clamps, pipes, and valves along with proper tools to allow prompt response to breakdowns. Operators should evaluate what critical or long delivery parts should be stocked and estimate demand based on historical usage of parts and the historical life of equipment. As a minimum, one of each spare part item (e.g., valve) should be stocked for each 10 km of water main in your system. Where geographic proximity makes it feasible, water departments/ utilities in adjacent municipalities may want to share an inventory of some spare parts to reduce inventory cost and storage requirements. It may be possible to arrange with suppliers/dealers to stock some spare parts in convenient locations. In addition to spare parts, it is essential to have on hand the tools and equipment needed to do the work.

3.2.21 Prepare a Contingency Plan for Emergencies

Water systems must be reliable under all operating conditions. The small system operator should know how the system responds to unusual operating conditions. This knowledge can be challenging to obtain. The small water system operator can develop a series of “what if” scenarios (e.g., “What if we have an ice storm and lose power for three weeks?”) and note the relative risk, and likely consequences that could occur for each event. The higher-risk or higher-consequence events can be prioritized, and response plans developed for each scenario. One method of learning how the water system will perform under unusual conditions is hydraulic modelling. A computer model can be created and calibrated with actual hydrant flow tests. Then the model can be used to represent various emergency scenarios.

Many of the unusual operating conditions experienced with water systems also involve the fire department. As partners in providing fire protection for the municipality, operators need to share knowledge of the water system based on past experiences and the findings of current study activities, and agree on standard operating practices (e.g., for hook up to hydrant, shut down hydrant flow, fire pump operation).

Operators should meet regularly with the stakeholder teams (e.g., public health, fire, regulatory agency personnel, and large customers), develop emergency response plans, contingency plans, and public/media contact protocols. In most jurisdictions, regulations dictate who is in charge in the event of an emergency. This should be discussed and understood by all stakeholders. If there is a local emergency operations centre, the water department should be an active member.

Emergency preparedness involves learning from past events and being aware of how to respond quickly when an event unfolds. Whenever an event is underway which may pose an unusual operating condition, a licensed operator should be assigned to monitor and operate the water system components, and report on the event. Advice on planning for emergencies can be found in *Emergency Planning for Water Utilities* (AWWA, 1999c).

Another study and planning area for the water system is the evaluation of risk of water system contamination by physical disruption or terrorist attacks. Vulnerability assessments should be conducted on all components of the water system. Considerations that arise from these assessments include controlling access, access alarms, and performing security background checks on all staff.

3.2.22 Prepare a Financial Plan to Ensure System is Sustainable

Small water system operators are the principal individuals concerned with the way the system functions on a daily and long-term basis. Operators should know the unit cost of production of water, including staff, electricity, and chemical costs. Operators should also know the regulatory requirements in their province/territory regarding management of water systems, which may include mandated financial planning for the full life cycle costs of their systems. Operators should also develop short- and long-term capital spending plans for all components of their system (source water, water treatment plant, distribution system) and provide input to capital budgets. *Investment Parameters for Municipal Infrastructure* (InfraGuide, 2003f) and *Alternative Funding Mechanisms* (InfraGuide, 2002d) provide additional information and recommendations regarding this topic.

3.2.23 Maintain Excellent Public Relations

Operators should provide prompt and courteous customer service. The importance of customer confidence and satisfaction is increasing as water costs increase, and in light of recent events in Canada. Operators should establish standard operating practices for recording, addressing, and following up on customer water quality or other complaints.

The importance of customer confidence and satisfaction is increasing as water costs increase, and in light of recent events in Canada.

It is important to maintain communications with customers and other stakeholders. Operators should make available to their customers routine water quality test results. Operators should communicate with customers before shutting off the water, explain the reason for the shutdown and predict the duration of disruption. For some customers, such as home dialysis patients, research facilities, and many food-processing industries, water disruptions can be critical. Other stakeholders include the medical officer of health, ministry of the environment, regulatory agencies, fire department, major industries, conservation authorities, non-governmental organizations, *Staff should be encouraged to participate in technical organizations, such as the Canadian Water and Wastewater Association, Canadian Society for Civil Engineering, and American Water Works Association.*

and special interest groups. Operators should follow a media response protocol when any event occurs which warrants or may attract media attention.

3.2.24 Maintain Adequate Staff Levels

Water distribution system O&M staff are critical in delivering safe drinking water to the public. Staff are mandated to provide safe drinking water and, therefore, they need to know how to do this and how to react when something goes wrong. Water systems are changing, and regulations are becoming more complex. Ongoing training is required for O&M staff to develop and maintain proficiency. All training should focus on each work activity's impact on water quality in all parts of the water system. A training-needs analysis for each staff member should be conducted to determine what gaps exist in their capabilities and then arrange training to address the gaps. Training should be relevant to the system being operated, and records maintained of all training completed. Staff should be encouraged to participate in technical organizations, such as the Canadian Water and Wastewater Association, Canadian Society for Civil Engineering, and American Water Works Association.

Regulatory requirements for operator certification and training vary across the country, but the requirement to provide chemically and biologically safe water is the same everywhere. Municipalities should know what certification requirements are in place, or scheduled for implementation in their province or territory, and the ministry of environment or health can be contacted to find out where training and exams are being offered. Municipalities should recognize that certification takes time and, therefore, should maintain a sufficient number of certified staff.

Utility accreditation, or recognition that the entire water system meets a high standard, is one way to demonstrate to staff and customers that a municipality is very serious about its responsibility as a supplier of safe water. The AWWA recently published Standard G200 (2004a[6]), which outlines uniform performance standards for distribution systems operation and management. The AWWA has also developed the QualServe[7] program which promotes continuous improvement of water utilities. In addition, the International Standards Organization (ISO) is developing a standard for service activities related to drinking water supply systems and wastewater systems (TC 224[8]).

6. G200–04, AWWA *Standard for Distribution Systems Operation and Management* (First Edition, May 2004)
7. QualServe is a voluntary quality improvement program designed exclusively for water and wastewater utilities. Website address is: *<http://www.awwa.org/science/qualserve/>*.
8. ISO TC 224 "Service activities relating to drinking water supply systems and wastewater systems" has the "ISO/TC 224 information brochure" in English and French. Website address is: *<http://www.acepu.ca/freepub_e.asp>*.

4. Applications and Limitations

4.1 Applications

The small water system operator or municipal official needs to understand what their system does and what it should do, and then develop a plan to implement the applicable best practices. (Professional guidance may be necessary.) However, some practices may not apply. For instance, if a water system does not provide fire protection and is not designed to, the fire protection aspects of the best practices in this document will not apply.

4.2 Limitations

4.2.1 System Design

These best practices cannot overcome inherent deficiencies in design. For example, a direct filtration process (i.e., no clarification stage) will not adequately treat high turbidity or highly coloured water. Similarly, a system not designed to provide fire protection cannot achieve this level of service. It is important to establish the realistic capabilities of a small system and deal with design limitations in a planned program of upgrades.

4.2.2 Sound Engineering Practices

This document is a guideline of best practices used across Canada in varying size systems, with various water sources and under various climatic conditions. As a guideline, this best practice is not a replacement for proper engineering investigation and design, which should be undertaken to assess problems or for any planned improvements to a water system.

4.2.3 Regulations

This best practice should not preclude or supersede specific requirements imposed by regulations or other applicable legislation.

As a guideline, this best practice is not a replacement for proper engineering investigation and design, which should be undertaken to assess problems or for any planned improvements to a water system.

5. Evaluation

The following points describe several performance measures that can be used to evaluate the effectiveness of the practices outlined in Section 3.

Are there reductions:

- In the number of regulatory non-compliances?
- In the number of water quality complaints?
- In the number of non-compliant samples obtained from the system?
- In the number of boil water orders/advisories?
- In the number of unplanned service interruptions?
- In the cost for corrective measures?
- In costly reactive investigation time?

In order to track the system performance over time, performance measures may be expressed as a function of some baseline parameter such as volume of water supplied, length of watermain, or number of customers. An example would be the number of water quality complaints per customer served. Care must be taken when comparing the performance measures against those of other municipalities since conditions in each system can vary.

Overall, are there improvements in general water quality?

Is there an increase in confidence and competence among operations and maintenance staff? Do they have the resources to do their job adequately? Is job satisfaction increasing, as indicated by reduced sick time and reduced staff turnover?

Is the amount of time spent on reactive or emergency maintenance falling as a percentage of time spent on planned maintenance activities? Is the average time to repair a break and return service to customers appropriate?

Are emergency planning activities being developed or updated with full participation of key stakeholders? Are the plans being tested annually and improved?

Are long-range capital budgets established which, if funded, will sustain the water system as it ages and needs upgrading or replacement?

Appendix A: Standard Water Quality Tests

Table A–1
Standard Water Quality Tests Parameters

Table A–1 : Standard Water Quality Tests Parameters

Test Parameter	Test Frequency**	Normally Acceptable Range
Source Water		
Turbidity	■ Every month for non-GUDI[9] source water ■ Continuous for surface water and GUDI well source water	Depending on the treatment process: ■ Conventional filtration: < 40 NTU ■ Direct filtration: < 20 NTU ■ Slow sand filtration: < 10 NTU ■ Cartridge/bag filtration: < 5 NTU
* Inorganics and organics as listed in local regulations	■ Every 12 months if the source water is surface water ■ Every 36 months if the source water is groundwater	As prescribed in local regulations
E-coli or fecal coliforms	Every week	< 1 (Below detectable)

Notes:

* If a test result exceeds half of the standard prescribed for the parameter in local regulations, the frequency for that parameter should be increased to once every three months.

** Test Frequency — In some jurisdictions the test frequency may be determined by the regulatory agency taking into account site-specific conditions

9. GUDI — Groundwater Under Direct Influence of surface water.

A. Standard Water Quality Tests

Table A–1 Standard Water Quality Tests—Treatment Plant

Table A–3 Standard Water Quality Tests—Treatment Plant Output

Table A–2 : Standard Water Quality Tests—Treatment Plant Output

Treatment Plant Output		
Chlorine/combined chlorine residual	Continuous	■ 0.5 to 1.0 mg/L CR[10] or as required to achieve optimum ■ 0.2 mg/L (or min. 0.05 mg/L) within the distribution system ■ 0.5 to 1.5 mg/L CCR[11] or as required to achieve optimum 1.0 mg/L (or min. 0.25 mg/L) within the distribution system ■ MAC[12] or CR — 4 mg/L ■ MAC for CCR — 3 mg/L
Turbidity	Continuous	Less than 0.5 NTU
(1) E-coli or fecal coliforms (2) Total coliforms, and (3) General bacteria population expressed as colony counts on a heterotrophic plate count (HPC)	Every week	< 1 (Below detectable)

Table A–3 : Standard Water Quality Tests—Distribution System/Customers

Distribution System/Customers		
Chlorine/combined chlorine residual	Every day	■ Greater than 0.05 mg/L CR ■ Greater than 0.25 mg/L CCR
Chloramines	Every 12 months	Less than 3 mg/L
THMs	Every 3 months	Less than 0.1 mg/L
Lead*	Every 12 months	Less than 0.01 mg/L
Nitrate/Nitrite	Every 3 months	Less than 10 mg/L — Nitrate Less than 1 mg/L — Nitrite
Sodium	Every 60 months	Less than 20 mg/L
Fluoride	■ Every day if the system provides fluoridation ■ Every 60 months if the system does not provide fluoridation	■ 0.5 — 0.8 mg/L normal acceptable range ■ 1.5 mg/L MAC
(1) E-coli or fecal coliforms (2) Total coliforms and (3) General bacteria population expressed as colony counts on a heterotrophic plate count (HPC)	■ 8 samples plus 1 per every 1000 consumers per month, of which two (2) samples every week ■ 2 samples per week where UV-based disinfection is provided (point of entry systems only)	< 1 (Below detectable)

10. CR — Chlorine residual

11. CCR — Combined chlorine residual

12. MAC — Maximum allowable concentration

Appendix B: Adverse Water Quality Test

Table B–1: Adverse Water Quality Test and Possible Course of Action

No.	Adverse Water Quality Test	Possible Cause	Possible Course of Action
1	Chemical		
1.1	Exceeding any health-related chemical parameter	■ Source water contamination/spill ■ Treatment failure ■ False test	■ Perform all regulatory notification/action ■ Switch to alternate/backup supply ■ Check raw water supply for possible source of contamination/spill ■ Contact environment ministry, local health unit for advice/assistance ■ Check function of treatment system ■ Retest ■ Undertake more detailed investigations as necessary
1.2	Disinfection by-products (THMs)	■ Inadequate water treatment (precursors, organic matter) ■ Excessive detention time ■ Excessive chlorine use ■ High pH ■ Inappropriate chlorine injection location	■ Remove naturally occurring organic matter through enhanced treatment ■ Use an alternative primary disinfectant or add ammonia after sufficient contact time to create chloramines ■ Optimize pH adjustment for balance of corrosion control and DBPs ■ Obtain assistance from environment ministry and/or a water quality expert ■ Properly operate storage facilities to ensure adequate turnover of water ■ Properly operate distribution systems (e.g. routinely flush mains) ■ Consider design changes to system (e.g. loop mains)
1.3	Low disinfectant (Cl2) residual	■ Inadequate disinfection dosage/residual ■ Poor source water quality (high DOC—dissolved organic carbon) ■ Inadequate water treatment ■ Excessive detention time ■ Contaminant intrusion ■ Poor maintenance and repair practices ■ Poor distribution system design ■ Ageing distribution system ■ Pipe contamination due to poor transportation, handling, storage, and installation practices	■ Check treatment system ■ Increase chlorine dosage ■ Flush system ■ Implement biofilm control program ■ Properly operate storage facilities to ensure adequate turnover of water ■ Properly operate and repair distribution systems ■ Rehabilitate/replace water mains ■ Use appropriate disinfection procedures for new mains and repairs ■ Install chlorine booster stations or add ammonia to create chloramines (which are weaker oxidants but last longer in the system) ■ Deliver pipes with end caps ■ Swab system ■ Consider design changes
1.4	Lead and copper	■ Internal corrosion ■ Unstable water ■ Low pH in water	■ Implement corrosion control treatment ■ Raise treated water pH ■ Raise treated water alkalinity (e.g., add soda ash to create buffer activity) ■ Consider alternate corrosion inhibitors to pH and alkalinity adjustment ■ Flush regularly ■ Educate public ■ Rehabilitate/replace water services ■ Use approved materials

(cont'd.)

B. Standard Water Quality Tests

Table B–1
Adverse Water Quality Test and Possible Course of Action (cont'd.)

Table B–1: Adverse Water Quality Test and Possible Course of Action Flow Chart (cont'd.)

No.	Adverse Water Quality Test	Possible Cause	Possible Course of Action
1	Chemical		
1.5	pH instability and scale formation	■ Inadequate water treatment ■ Excessive detention time in cement pipes ■ Unstable water	■ Take daily water samples and test pH. Obtain expert assistance if the problem cannot be readily resolved ■ Control blending of water sources ■ Properly operate distribution systems ■ Consider design changes
1.6	By-products of linings and coatings	■ Leaching of chemicals ■ Unstable water	■ Use approved materials ■ Properly cure Disinfection by-products (THMs)
2	Microbiological		
2.1	E-coli or total coliform	■ Chlorination/disinfection system failure ■ False positive sample ■ Wellhead contamination ■ Distribution system contamination/backflow	■ Perform all regulatory notification/action ■ Check disinfection system ■ Increase chlorine residual ■ Flush system ■ Retest ■ Eliminate source of contamination ■ Shut down source and use alternate/backup supply ■ Ensure positive pressures ■ Identify and eliminate any potential back pressure sources ■ Clean storage tanks every other year
2.2	Waterborne disease	■ Inadequate water treatment (i.e., filtration) ■ Inadequate primary disinfection ■ Contaminant intrusion ■ Backflow from non-potable sources ■ Poor maintenance and repair practices ■ Main breaks ■ Inadequate disinfection of new mains/equipment ■ Terrorism or vandalism	■ Maintain adequate disinfectant residual ■ Maintain positive water pressures (try to maintain above minimum 140 kPa) ■ Implement backflow prevention program ■ Control valve and hydrant operations ■ Properly operate storage facilities ■ Properly operate and repair distribution systems ■ Use appropriate disinfection procedures for new mains and repairs ■ Provide security ■ Consider design changes

Table B–1: Adverse Water Quality Test and Possible Course of Action Flow Chart (cont'd.)

No.	Adverse Water Quality Test	Possible Cause	Possible Course of Action
2	Microbiological (cont'd)		
2.3	Worms/ insects	■ Inadequate water treatment ■ Poor design/construction/ maintenance of storage facilities ■ Inadequate flushing/swabbing program ■ Problems with water intake in unfiltered systems	■ Properly operate storage facilities to ensure adequate sealing at all times ■ Regularly monitor, inspect, and maintain storage facilities ■ Check water intake for holes through or around screens ■ Consider design changes
3	Aesthetics		
3.1	Taste and odour	■ Poor raw water quality ■ Inadequate water treatment ■ High disinfectant (chlorine) concentrations ■ Excessive detention time ■ Blending of chlorinated and chloraminated water ■ Stratification during ammonia addition for chloramination ■ High disinfectant (chlorine) concentrations ■ Internal corrosion of unlined mains ■ Excessive detention time ■ Leaching chemicals from water main linings	■ Upgrade treatment—select optimum process ■ Maintain adequate disinfectant residual ■ Flush/swab water mains ■ Properly operate storage facilities ■ Properly design and operate distribution systems ■ Implement corrosion control treatment ■ Rehabilitate/replace water mains ■ Use approved materials that are suitable for Canadian climate (e.g., paint) ■ Ensure ration of chlorine to ammonia is maintained ■ Ensure linings are cured properly in new water main construction ■ Consider design changes ■ Consider treatment changes (e.g., GAC)
3.2	Colour and Appearance	■ Inadequate water treatment ■ Excessive detention time ■ Internal corrosion of unlined mains ■ Excessive detention time ■ Sediment in water mains	■ Control blending of water sources (i.e., before mixing water from different sources, ensure testing is conducted first.) ■ Implement corrosion control treatment ■ Rehabilitate/replace water mains ■ Eliminate dead ends ■ Flush/swab water mains

Appendix C: CT (Concentration X Time) Concept

Multiple barriers are the best approach to eliminate enteric bacteria, viruses, or other waterborne pathogens. Physical characteristics of the water, especially temperature, pH, and turbidity can have a major impact on disinfection and pathogen removal. For example, inactivation rates increase two to threefold for every 10°C rise in temperature. When temperature is close to 0°C, as is often the case for surface waters during the winter in Canada, the efficacy of disinfection can be seriously impaired. Some disinfectants are pH-dependent and may be ineffective when water is alkaline. An increase in pH from 6 to 9 reduces the effectiveness of free chlorine by a factor of three, but pH has little impact on the effectiveness of ozone or chlorine dioxide. An increase in turbidity from 1 to 10 NTU has been shown to result in an eightfold decrease in disinfection (free chlorine) efficacy (effectiveness).

The efficacy of disinfection can be predicted based on knowledge of the residual concentration of disinfectant, temperature, pH (for chlorine only), and contact time to the first customer (AWWA, 1999b). This relationship is commonly referred to as the CT concept, where CT is the product of "C" (the residual concentration of disinfectant, measured in mg/L) and "T" (the disinfectant contact time, measured in minutes). Therefore, a concentration of 1 mg/L residual disinfectant applied for 30 minutes equals a CT value of 30. The CT influences the sizing and design of contact chambers or storage facilities to ensure that water is in contact with the disinfectant for the required amount of time.

Table C–1: Deactivation Credits

		Log Removal Credit	
No.	Treatment Technology	Giardia	Viruses
1	Conventional filtration	2.5	2
2	Direct filtration	2	1
3	Slow sand filtration	2	2
4	Cartridge/bag filtration	2	0
Minimum requirements for treatment:		3+	0 to 2+

The best practice should incorporate the CT concept and aim at achieving the following minimum benchmarks:

Groundwater – 2 log (99%) viruses inactivation

Surface water – 2 log (99%) cryptosporidium inactivation

– 3 log (99.9%) giardia inactivation

– 4 log (99.99%) viruses inactivation

The operator should contact the regulatory agency to confirm appropriate standards in their province or territory.

The minimum requirement for disinfection (see Table C–1) will be the difference between the minimum requirement for treatment and the log removal credit from filtration. The contact time corresponding to this minimum requirement should ensure that not more than 10 percent of the influent water would pass through the disinfection process. This time is usually known as T_{10}. The ratio between T_{10} and the calculated hydraulic time T depends on the baffle condition. The poorer the baffle condition (e.g., no baffles, low length/width ratio, high velocity), the lower the T10/T ratio is, whereas for a perfect (plug flow) baffle condition the T_{10}/T ratio is 1.

For more detailed information on this topic, see (AWWA, 1991) and (US EPA, 1999b).

Appendix D: Sample Forms

SAMPLE

Name of Municipality

Community Complaint

File ID: ....

Location Name: ....

Name of Person with Complaint: ....

Address: ....

Town/City: .... Province: ....

Postal Code: ....

Date of Complaint: ....

Time of Complaint: ....

Nature of Complaint

Noise	Visual	Odour	Taste
....	....	....	....
Colour	Pressure	Service Problem	Other
....	....	....	....

Description

....

....

Action Taken:

....

....

Was the Source of the Problem Identified? ....

If "yes", Describe: ....

Remedial Action Required? ....

If "yes", Describe: ....

Table D–1
Water Main Flushing and Disinfection

SOP: # ....

Rev.: # ....

Issued: ...dd/mm/yy...

Pages: # (total in SOP)

....

SAMPLE

STANDARD OPERATING PROCEDURE (SOP)

(Name) Treatment Plant

Water Main Flushing and Disinfection

This best practice has been developed after review and taking into consideration

the best practices developed in the industry by the following organizations: Water Environmental Federation (WEF), American Water Works Association (AWWA), Ontario Water Works Association (OWWA), National Research Council (NRC), Canadian Water and Wastewater Association (CWWA), and the California State Water and Wastewater Manuals. Each best practice must be vetted through your internal review team of municipal or operational water, wastewater, and compliance staff.

All new sections of water mains must be thoroughly flushed, disinfected, and tested for bacteriological quality before water can be used by customers. All water mains taken out of service for inspection, repair, or other activities that might lead to contamination of water should be flushed or disinfected before they are returned to service.

Flushing

Water main flushing is done initially to remove any debris or dirt left in the pipe after installation. After installation is completed, the distribution should be maintained by flushing at a minimum frequency of once per year. Swabbing may be required if the integrity of the distribution system cannot be maintained by flushing.

Procedures

- One or more fire hydrants should be used for flushing so a velocity of at least 2.5 ft/s (0.8 m/s) to an ideal of 3.5 ft/s (1.1 m/s) is obtained in the pipe.
- This flow rate should be maintained so there has been two to three complete changes of water in the pipe, and the water leaving the hydrant is visibly clean. Please see the chart below for pipe diameter and number of hydrants required to flush effectively.
- Record the free chlorine residuals at the end of flushing to ensure they are at the 0.2 mg/L range with the minimum being 0.05 mg/L, and record this information on the hydrant log if applicable or in the CMMS.
- A record of the hydrant performance should be kept on an individual basis and records maintained in the CMMS.

Table D–1: Water Main Flushing and Disinfection

Pipe Diameter		Minimum Required Flow Rate*		No. of Hydrants Required Open**
Inches Millimetres		GPM L/S		
4	100	100	6	1
6	150	200	13	1
8	200	400	25	1
10	250	600	38	1
12	300	900	57	2
16	350	1600	100	2

NOTES:

* Based on 2.5 ft/s (0.76 m/s) at 40 psi (280 kpa) pressure.

**Based on a hydrant with one 2 1/2 in. (63 mm) outlet.

Water Disinfection

All new water mains and parts must be disinfected with some form of chlorine before put in use. The common forms of chlorine used in disinfection operations are liquid chlorine, sodium hypochlorite solution, and calcium hypochlorite granules or tablets. Most common forms are sodium hypochlorite and calcium hypochlorite.

Calcium Hypochlorite Tablet Method (HTH)

- This method is mostly used for new installations. Workers must take care to keep the pipe clean during installation, because the main cannot be flushed before it is disinfected. If it becomes difficult to keep the pipes clean during installation, then this method should not be used so the line can be flushed prior to disinfection.
- Please note that this procedure should not be used on solvent-welded plastic or on screwed-joint steel pipe, because of the danger of fire or explosion from the reaction of the joint compounds with the calcium hypochlorite.
- The HTH tablets should be placed in each section of pipe and fire hydrant as the work progresses. The tablets are usually glued to the top of the pipe with an epoxy resin, in sufficient quantities to produce a chlorine residual of 25 mg/L after the pipes have been completely filled with water.
- The tablets are placed at each end of each section of pipe. You must bleed a small amount of water to ensure the chlorinated water has contacted all sections of the pipe.
- Filling the pipe should be done at a velocity below 1 ft/s (0.3 m/s) or the tablets will be dislodged.
- Once the water main has been filled and the chlorine residual recorded.

Table D–2: Calcium Hypochlorite Tablet Method

Pipe Size in IN.	Pipe Size in MM	No. of Tablets per Pipe Length
4	100	1
6	150	1
8	200	2
10	250	3
12	300	4
16	400	7

Table D–2 indicates the number of 5 gram calcium hypochlorite tablets required to produce a chlorine residual of 25 mg/L in 20 ft. (6 m) pipe lengths.

- Granules of HTH may also be used instead of tablets. Granules can be placed at the start of the first section of pipe and at each branch main and at 500 ft. intervals. The volume of granules is in the table below.

Table D–3: Calcium Hypochlorite Tablet Method

Pipe		Calcium Hypochlorite GranulesGranules	
Inches	Millimetres	OZ	GM
4	100	1.7	57
6	150	3.8	113
8	200	6.7	200
10	250	10.5	300
12	300	15.1	430
14 and larger	350 and larger	D*2 x 15.1	D*2 x 427.9

NOTES:
* D is the inside pipe diameter in feet D = D/12.
For further information, please refer to (AWWA,1999a).

Hypochlorite Disinfection

Calcium hypochlorite and sodium hypochlorite are generally used for disinfecting water mains. Before disinfection, it is advisable to flush the system if possible to ensure all contaminants and debris have been removed. Ensure adequate drainage has been provided during flushing and disinfection. A concentrated chlorine solution is usually injected through a corporation stop that has been installed close to the valve that connects to the existing water system. At this time, the chlorine can be added two different ways: as a continuous feed system or using a slug.

D. Sample forms

Table D–2
Calcium Hypochlorite Tablet Method

Table D–3
Calcium Hypochlorite Tablet Method

D. Sample forms

Table D–2
Calcium Hypochlorite Method.

Table D–3
Quantity of HTH required to produce 50 mg/L chlorine residual.

- Using a continuous feed method, water is slowly added to the pipeline at the same time the chlorine solution is added by using a chemical feed pump. You will need to capture the flow of water volume by measuring the water exiting from the fire hydrant at the end of the line or by metering the flow entering the system. The chemical feed rate should be set so it will produce a concentration of about 50 mg/L when mixed with the incoming water.
- Continue to feed both water and the chlorine solution until you can measure at least a residual 25 mg/L in the flow at the end of the line. (Remember to dechlorinate highly chlorinated water before it enters the surrounding environment.) Please see Table D–2 for hypochlorite addition.
- Once you reach the minimum 25 mg/L, stop pumping and allow the pipe to stand 24 hours. Before you stop pumping, it is a good idea to exercise all hydrants on the system and ensure they are all adequately disinfected. Once pumping has stopped, you should operate all line valves to ensure adequate disinfection.
- If you are unable to maintain the minimum residual of 10 mg/L after 24 hours, you will need to flush and repeat this procedure until you have ensured the system is free from contamination.
- Using the slug method, water with a high concentration of chlorine is created, then added slowly to the pipeline.
- The concentration of the slug must be a minimum of 100 mg/L and the slug must be moved through the pipe slowly to achieve contact of a least three hours as it moves through the system.
- As the slug moves through the system, fire hydrants should be operated to ensure they are disinfected.
- Monitoring at various points ensures you maintain a high residual and indicates if disinfection has been successful.
- Once the slug has reached the end of the line and is being dechlorinated, the line and all hydrants must be flushed to ensure all traces of the highly chlorinated water are removed.

NOTE:
The high chlorine residual used in this method can be a hazard to the environment if not dechlorinated properly. Great care should be taken in dechlorination procedures. This method is generally used for larger water lines where a continuous feed method is not practical.

Table D–2: Calcium Hypochlorite Method.

Pipe		Calcium Hypochlorite Granules	
Inches	Millimetres	OZ	GM
4	100	1.7	57
6	150	3.8	113
8	200	6.7	200
10	250	10.5	300
12	300	15.1	430
14 and larger	350 and larger	D*2 x 15.1	D*2 x 427.9

Table D–3: Quantity of HTH required to produce 50 mg/L chlorine residual.

Pipe Diameter		Amount of Hypochlorite Granules per 100 Ft (30.5M) of Pipe	
Inches	Millimetres	Lbs	Kg
4	100	0.04	0.02
6	150	0.09	0.04
8	200	0.17	0.08
10	250	0.26	0.12
12	300	0.38	0.17
14	350	0.51	0.23
16	400	0.67	0.3
18	450	0.85	0.39
20	500	1.05	0.47

NOTE:
The preceding procedures were developed based on AWWA (1999a). See also Ontario Ministry of the Environment, 1987, Bulletin 65–W 4, Chlorination of Potable Water Supplies and 2001 Bulletin B13–3, Ontario Drinking Water Standards. (Revised January 2001, PIBS # 4065e.)

SAMPLE LETTER

BACKFLOW PREVENTION TEST

Date . . . .

Dear . . . .:

Our records show that we have not received the annual test report(s) of the following backflow prevention assemblies.

Type.. Serial No. ....

Location . . . .

. . . .

In order to comply with the (enter Municipality name), Bylaw . . . . backflow preventers must be tested annually by a licensed tester.

Accordingly, you are required to have such equipment tested within 30 days from the date of this letter and return the attached inspection report to our office.

On completion of the test, a tag showing the date of test, the name and licence number of the tester shall be displayed adjacent to the backflow preventer or attached to the backflow preventer.

For your use and information, a list of licensed testers is enclosed.

Should you require additional information concerning the foregoing, please contact the Municipality's Cross Connection and Backflow Prevention Officer at the above address or by calling . . . .

Yours truly,

Cross Connection and

Backflow Prevention Officer

SAMPLE WORK ORDER		Equipment Work Order	
Report Date	09/09/2004 02:00 PM	Submitted By	Page 1

Work Order #	208599	Activity	66055T	VALVE CHECK ELECTRIC		
Equipment ID	0000066055		Description	VALVE GLOBE LLP1-1 DISCHARGE		
Site	FAC xxxxxx		Description	xxxxxx		
Subunit Of	0000067016					
Area			Sub-area	LL	IN PLANT LOW LIFT PUMPING	
District			Loc			
Loc Qualifier	xxxx IN MAIN LOW LIFT PUMP #1		DISCHARGE VALVE			
Equipment Type	VALVE	ALL VALVES EXCEPT COLL & DIST.	Manufacturer	Gold	GOLDEN ANDERSON OF CANADA LTD.	
Building	LL	LOW LIFT BUILDING	Building Level	G	Ground Level	
Service Status	IN	IN SERVICE (INCL. STANDBY)	Expected Life	25		
Avg Monthly Usage	720.00		Total Usage	0.00		
Model #	945820-2049		Warranty Expires		MTBF	0
Serial #			Purchase Date	01/01/1995	Purchase	0.00
Budget #						
Asset Comments						
CO# 94-5820, SHOP# 941771, FIG# X147300DP, REF# 125						
Initiated By			Initiated Date	27/10/2000	Scheduled	01/11/2000 08:00
Assigned To			Service #		Due	
Authorization	FORE	FOREPERSON				
Budget #	5400452	REPA & MAINT—PLANT MECHIN. & EQUIP				
Crew						
Maint Type	Mech	MECHNANICAL MAINTENANCE				
Priority						
Problem						
Project				Out of Service	❑	
Source	FORE	FOREMAN/WOMAN		Potential Service Request	❑	
Last Activity	66055T	VALVE CHECK ELECTRIC		Last Activity Completed	27/11/2005	
Work Order Comments						
Serviced valves and controls						
ActDefn Comments						
OPERATION & MAINTENANCE MANUAL VOLUME 3, PART 3, MECHANICAL PROJECT #5-0002-02, CONTRACT #1						

(Cont'd)

SAMPLE WORK ORDER (cont'd) **Equipment Work Order**

Report Date	09/09/2004 02:00 PM	Submitted By	Page 1

Task	66055T	VALVE GLOBE LL			
Job Class	Crew Type	Description		Pay Type	Hrs Worked
MECH		MAINTENANCE MECHANIC			
Part #	Description			Qty Req'd	Qty Used
CROCLOTH	CROCUS CLOTH			1.00	
	Stock Area		Stock Loc		
VASELINE	VASELINE OR LUBE "A" (WATERPROOF GREASE)			1.00	
	Stock Area		Stock Loc		
Safety Message	Description				
12	WEAR HEARING PROTECTION				
RIGGPP	USE PROPER RIGGING PROCEDURES				
SLIP	SLIPPING HAZARD				
Tool	Description			Qty Required	Qty Used
RIGG	RIGGING EQUIPMENT			1.00	

SAMPLE WORK ORDER		Equipment Work Order	
Report Date	09/09/2004 02:00 PM	Submitted By	Page 2

Safety Procedures Message	Description	Activity	Comments
3 YEAR	TRI-ANNUAL MAINTENANCE	66055T	INTRODUCTION: This Preventative Maintenance Procedure has been developed to aid field personnel in the care and maintenance of the specified equipment. However, maintenance personnel are expected to look for and correct defects which are not anticipated in this procedure. This document will not provide all the technical information that may be required, and it may be necessary to refer to the manufacturer's manual for further details. The "As Found" and "As Left" readings, as well as any abnormalities found and any repairs carried out, are to be recorded on the Maintenance Feedback Sheet. RUNNING CHECKS: 1) Check for leakage from the air vent tube. 2) Check for leakage from indicator rod. Check for leakage at the control valves. 3) Check and record gauge pressures at the inlet and outlet side of the valve first with pump off and then with pump running. MAINTENANCE PROCEDURE 1) Remove, inspect and clean the water strainer. 2) Dismantle and inspect internal components of the pressure reducing pilot valves. Check for deterioration of rubber seats and diaphragm.
3 YEAR	TRI-ANNUAL MAINTENANCE	66055T	3) Dismantle, clean and inspect all internal components of the main electric check valve. Follow procedures in the manual. 4) Reassemble main components. 5) Check the valve position micro switches for proper mounting and freedom movement 6) Lubricate the roller and pivot arm of the micro switch. 7) Check security of pivot arm to switch stern. 8) Check condition and proper mounting of vent tube hose. 9) Check all piping and unions for leakage. 10) Inspect and clean the solenoid valves. 11) Inspect and clean the thread and gear of the valve position sensor. 12) Check general condition of electrical wires and return to original position. 13) Exercise all manually operated valves and return to original position. 14) Reassemble all auxiliary components. 15) Rest pressure reducing pilot valves and controls to original specs. 16) Check that the pressure reducing pilot valve screw locknuts are tight.
EEN	ENTRY AND EXIT NOTIFICATION		ENSURE DIRECT SUPERVISOR OR THEIR DESIGNATE HAVE BEEN NOTIFIED OF ENTRY INTO THE SITE. THE FOLLOWING INFORMATION SHOULD PROVIDE APPROXIMATE TIME AND DURATION. ON COMPLETION OF DUTIES NOTIFICATION TO BE GIVEN THAT SITE HAS BEEN VACATED AND SECURED.
JSP	JOB SAFETY PLANNING		TAKE TIME TO IDENTIFY HAZARDS AND PLAN HOW EACH HAZARD WILL BE ELMINATED OR CONTROLLED. WORK PRACTICES MUST BE IN ACCORDANCE ITH THE OCCUPATIONAL HEALTH & SAFETY ACT AND THE PLANT SAFETY MANUAL.
WPROT	WORK PROTECTION		ISOLATE AND DE-ENERGIZE THE EQUIPMENT IN ACCORDANCE WITH THE LOCK-OUT PROCEDURE.

Extra Item				
Change Date	Time	Extra Item	Quantity	Rate

Labour		Choose Crew Type, Crew ID, or Job					
Change Date		Time	Crew ID	Job Class	Employee ID	Pay Type Hours	Worked

SAMPLE WORK ORDER	**Equipment Work Order**		
Report Date	09/09/2004 02:00 PM	Submitted By	Page 3
Work Order #	208599	Activity 66055T	VALVE CHECK ELECTRIC

Vehicle	Choose Crew, Vehicle Type or ID										
Charge Date		Time		Crew		Vehicle Type		Vehicle ID		Total usage	Usage
Comments											
Started						Completed					
Date		Time		By	80039	Date	27/11/2004	Time	12:26	Hours	6:00
Result			Condition					Quantity		Uni of Mass	
Total Usage											
Data Group							Sign-off				

REQUEST FOR SERVICE LAYOUT

REQUEST SHOULD BE AT LEAST 48 HOURS PRIOR TO DIGGING

To be filled in by Municipality:

Date Received: ....Request No.: ....

To be filled in by Applicant:

<table>
<tr><td colspan="10">Location</td></tr>
<tr><td colspan="2">Info. Required by:</td><td>Y</td><td>M</td><td>D</td><td colspan="2">Requested by:</td><td colspan="2">Contact Name:</td><td>Phone No.:</td></tr>
<tr><td colspan="10">Nature of Work</td></tr>
<tr><td colspan="10">Limits of this Stake-Out</td></tr>
<tr><td rowspan="3">Method of Marking</td><td>Stakes</td><td></td><td rowspan="3">Type of Plant</td><td colspan="2">Sewer</td><td></td><td colspan="3" rowspan="3">Remarks / Additional Instructions</td></tr>
<tr><td>Paint</td><td></td><td colspan="2" rowspan="2">Water</td><td rowspan="2"></td></tr>
<tr><td>Other</td><td></td></tr>
<tr><td colspan="10">DEPTH OF PLANT VARIES AND MUST BE DETERMINED BY HAND DIGGING OR VACUUM EXTRACTION</td></tr>
<tr><td colspan="10">Sketch not drawn to scale</td></tr>
<tr><td colspan="10"></td></tr>
<tr><td colspan="10">CAUTION! HAND DIG WITHING 1 METRE OF THE MARKINGS INCUTS OF NO MORE THAN 0.3 m (1 FOOT) IN DEPTH. VACUUM EXTRACTION MAY BE USED AS AN ALTERNATIVE TO HAND DIGGING.</td></tr>
<tr><td colspan="10">The applicant requesting the foregoing information with regard to the location of the plant acknowledges that the same is approximate only and that the applicant and any person undertaking work in or around the plant assumes all risk in connection therewith and any damage done or occasioned to the said plant shall be repaired at the sole cost and expense of the applicant. The applicant acknowledges having reviewed this entire form and the attached CAUTION notes on the following page, and agrees to abide by same. The applicant agrees to review carefully and abide by any and all Special Instructions which may be provided in relation to the request.

ACCEPTED BY: ....TITLE: ....
Locator’s Signature: ....TITLE: ....</td></tr>
</table>

CAUTION

STAKE-OUT INFORMATION IS BASED ON EXISTING PLANT DRAWINGS/LAYOUT INFORMATION WHICH HAS NOT BEEN PREPARED BY (THE MUNICIPALITY). (THE MUNICIPALITY) TAKES NO RESPONSIBILITY FOR THE INACCURACY OF SUCH DRAWINGS/LAYOUT INFORMATION.

STAKES OR MARKINGS MAY DISAPPEAR OR BE DISPLACED. IF ANY DELAYS SHOULD OCCUR IN ACTING ON THE LOCATE INFORMATION AS GIVEN OR SHOULD SKETCH AND MARKINGS NOT COINCIDE, A NEW STAKE-OUT MUST BE OBTAINED.

THIS STAKE-OUT IS BASED ON INFORMATION GIVEN AT THE TIME. ANY CHANGES TO LOCATION OR NATURE OF WORK REQUIRES A NEW STAKE-OUT.

SPECIAL INSTRUCTIONS

1) Notify (Municipal) staff when the excavation is going to start.
2) If the excavation results in any damage to the plant, all work within the excavation shall cease and (the Municipality) must be contacted immediately.

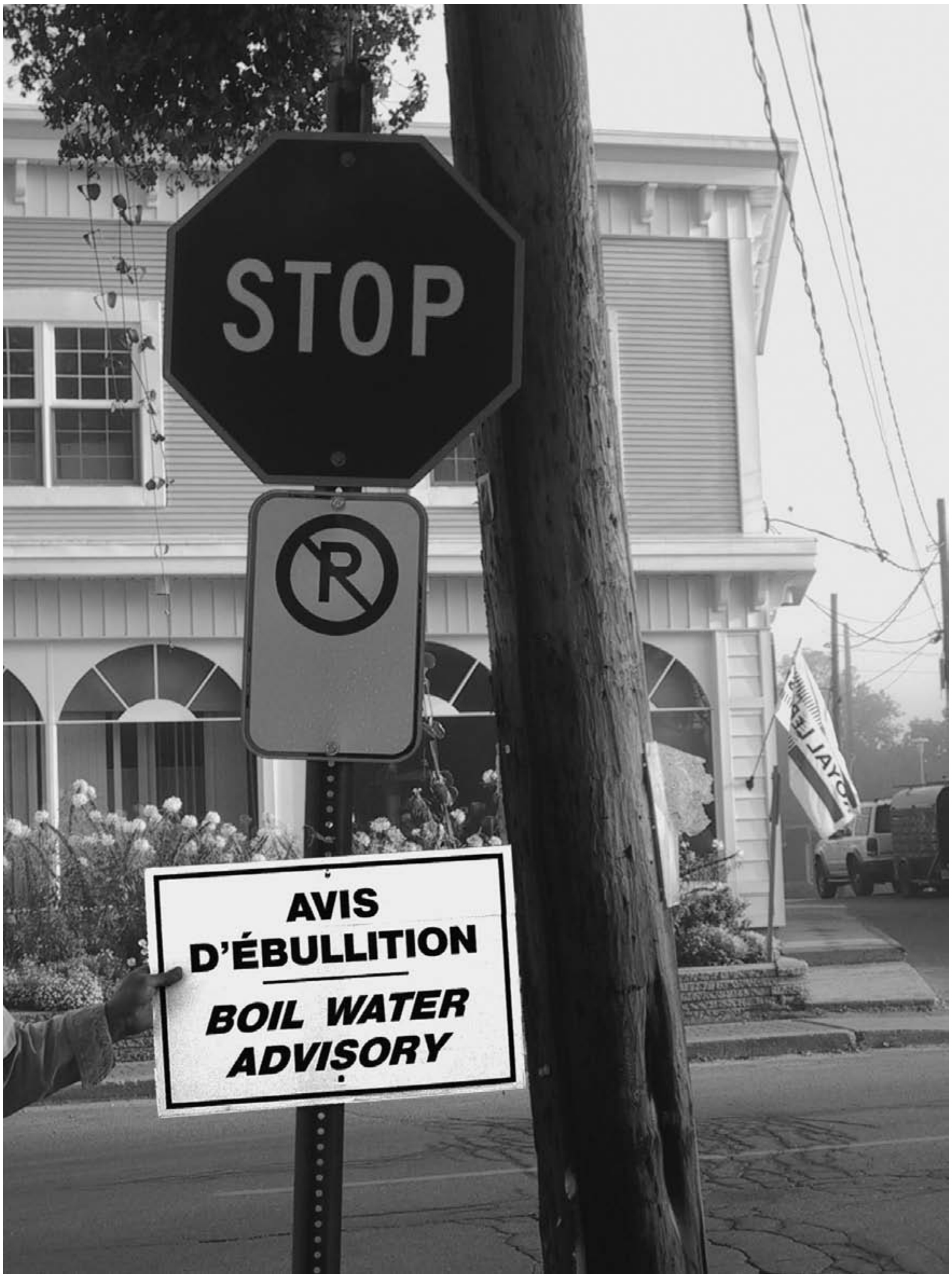
   Municipal contact/telephone number:

   ____
3) The applicant (and contractor if the applicant does not carry out the excavation) shall carry sufficient liability insurance to cover any damages which may result due to the excavation.
4) (Municipality) to (add additional instructions as required)

Appendix E: “Boil Advisory” Sign, Notice,

Figure E–1
“Boil Advisory” Sign

Figure E–1 : “Boil Advisory” Sign



E. "Boil Advisory" Sign, Notice, and Volunteer List

HUDSON EMERGENCY MEASURES TELEPHONE CHAIN

SAMPLE EMERGENCY MESSAGES

BOIL WATER ADVISORY

Hello, my name is _____________, and I am calling on behalf of the Hudson Emergency Telephone Chain. We are calling to advise you that the Town of Hudson has just issued a boil water advisory. This means that you should be boiling your water for a minimum of ____ minutes before using it for consumption. We will be calling you back once this advisory has been lifted. Thank you.

OTHER POSSIBLE EMERGENCIES

Hello, my name is ____________, and I am calling on behalf of the Hudson Emergency Telephone Chain. We are calling to advise you that there is a __________________________ emergency presently in progress.

POSSIBLE EMERGENCIES:

- FIRE
- EVACUATION
- FLOOD
- HAZARDOUS MATERIAL EMERGENCY
- BOMB THREAT

POSSIBLE STATEMENTS:

- PLEASE STAY OFF THE FOLLOWING STREETS FOR THE NEXT_______HOURS.
- A SHELTER HAS BEEN OPENED AT THE FOLLOWING LOCATION.
- IF YOU ARE IN IMMEDIATE DANGER PLEASE CONTACT __________________.

HUDSON EMERGENCY TELEPHONE CHAIN

DISTRICT ....

TEAM CAPTAIN

Name:

Address:

Telephone #: | E-Mail Address:

VOLUNTEER 1 | BACKUP

VOLUNTEER 1	BACKUP
Name	Name:
Address:	Address:
Telephone #:	Telephone #:
E-Mail Address:	E-Mail Address:

VOLUNTEER 2 | BACKUP

VOLUNTEER 2	BACKUP
Name:	Name:
Address:	Address:
Telephone #:	Telephone #:
E-Mail Address:	E-Mail Address:

VOLUNTEER 3 | BACKUP

VOLUNTEER 3	BACKUP
Name:	Name:
Address:	Address:
Telephone #:	Telephone #:
E-Mail Address:	E-Mail Address:

VOLUNTEER 4 | BACKUP

VOLUNTEER 4	BACKUP
Name:	Name:
Address:	Address:
Telephone #:	Telephone #:
E-Mail Address:	E-Mail Address:

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