Drinking Water Officers' Guide

Consolidated Version

Updated February 2024

Ministry of Health

Drinking Water Officers' Guide

Introduction

Version 1.3 / First Published 2007

Ministry of Health

The Ministry of Health gratefully recognizes the health leadership of First Nations upon whose territories we live and work across the province, and of Métis and Inuit people living in B.C.

Introduction

1. Purpose of this Document

This document has been developed to promote effective, consistent and transparent administration of the *Drinking Water Protection Act* (the "Act") and Drinking Water Protection Regulation (the "Regulation") across British Columbia. It is intended to provide policy and procedural guidance to public health officials who are responsible for the implementation of this Act, recognizing the broad scope of regulatory authority conferred, and the demands placed on the human and financial resources of the regional health authorities in respect of this Act and other public health statutes.

In many respects, this document reflects policies and practices that have been applied by public health officials for years, based on prior legislation and professional expertise. This document seeks to assemble that knowledge and experience for the benefit of all public health officials and members of the general public, and to refine policy and practice to reflect the legislative regime established under the Act. This regime is based upon a multi-barrier approach, which seeks to address threats to drinking water at various stages, including its source, treatment systems, distribution, and at the tap.[1] It is part of an overall strategy set out in the Province's Action Plan for Safe Drinking Water in British Columbia and reflects a comprehensive approach to drinking water protection based on sound risk assessment.

2. Updates in the 2024 Guide

The current 2024 amendment of the *Drinking Water Officers' Guide* is an update to the 2022 version. It provides clarified guidance regarding the *Drinking Water Protection Act.* It also includes minor edits such as updated information regarding the responsibilities of various ministries related to drinking water since the establishment of the Ministry of Water, Land and Resource Stewardship in 2022.

[1] For a discussion of the multi-barrier approach to drinking water protection, see "From Source to Tap: The multi-barrier approach to safe drinking water," May 16, 2002, Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of the Federal-Provincial-Territorial Committee on Environmental and Occupational Health and the Water Quality Task Group of the Canadian Council of Ministers of the Environment (http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/tap-source-robinet/index-eng.php)

3. Application to health authorities

This Guide, including amendments made from time to time, was established by the Minister of Health on the 28th of March 2007, as a "guideline" under section 4 of the Act. Section 4 states:

> (1) The minister may establish
> (a) guidelines that must be considered, and
> (b) directives that must be followed
> by drinking water officers and other officials in exercising powers and performing duties or functions under this Act and the *Public Health Act* in relation to drinking water.
> (2) The Provincial health officer must monitor compliance of drinking water officers with guidelines and directives established under this section.

Drinking water officials must consider this Guide in the exercise of their duties and discretion. They are, however, able to depart from the Guide in any case where sound reason exists to do so (as discussed further below).

The appendices referred to in this document contain a number of sample forms, letters and similar documents that are not "guidelines" approved by the minister. These are included for convenience and reference only. Drinking water officials may use such sample materials contained in the appendices if and as they see fit, or they may use other materials, provided those are developed having due regard to the portions of the Guide to which the appendices relate.

4. Relationship to the Act and Regulation

While approved as a guideline under section 4 of the Act, this Guide does not have the force of law. If there is ever a conflict between this Guide and the Act, the Regulation or the principles of administrative fairness, this Guide is superseded by the latter authorities to the extent of any such conflict.

This document is only intended as a policy guide to inform the exercise of statutory discretion. Decision makers are expected to consider this document and to apply it as a general rule, but if application of this Guide is not considered appropriate to particular facts or circumstances, the provisions of this Guide should not be applied. The only exception relates to "directives" which may be issued by the minister, as "directives" must be followed. At present, there are no directives.

5. Overview of the Guide

The *Drinking Water Officers' Guide* is organized in three sections:

- Part A – Legislative Requirements
- Part B – Best Practices and Technical Assistance
- Part C – Appendices

5.1. Part A – Legislative requirements

Part A of this Guide is devoted to providing guidance around the legislative requirements in the Act and the Regulation. It will break down each section of the Act and Regulation and provide an interpretation of those sections that will assist drinking water officers throughout the province to remain consistent in their application of the legislation. In addition, Part A will provide an interpretation of the drinking water legislation as it relates to other legislation in British Columbia.

5.2. Part B – Best practices and technical assistance

Part B contains a series of documents designed to provide further assistance with the technical aspects of applying the drinking water legislation. For example, the legislation does not provide a detailed breakdown of treatment expectations; therefore, this document outlines treatment objectives based on the *Guidelines for Canadian Drinking Water Quality* (Health Canada).

Part B also contains a number of best practice documents. These documents were developed to provide drinking water officers with procedural guidance in the application of various administrative tasks such as finding small water systems or dealing with a request to investigate a drinking water threat. Each document in Part B is available for separate download on the Ministry of Health website, allowing for easier distribution of pertinent information. The full Guide is also available as a single consolidated PDF.

5.3. Part C – Appendices

Various forms and documents are referenced throughout this Guide, with examples provided in the appendices. For example, there are samples of the following:

- Emergency Response and Contingency Plan
- Boil Water Notice
- Hazard Abatement and Prevention Notice

These are sample documents intended to provide the reader with an example of information that might be contained within each document. Health authorities may wish to use these forms, or to replace them with standard forms for use within their authority.

6. Process for Guide Revision

Any questions or suggestions concerning this Guide, or proposed revisions, should be submitted to:

Attention:
Health Protection Branch
Ministry of Health
PO Box 9646
STN PROV GOV
Victoria B.C. V8W 3C8
PH: (250) 952-1469
FAX: (250) 952-1713
EMAIL: HP-PHW@gov.bc.ca

Proposed revisions will be considered by the Drinking Water Leadership Council (discussed in Part A) on a regular basis. This Guide may be amended from time to time, subject to approval by the Minister.

The latest version of this document will be kept by the Secretariat of the Drinking Water Leadership Council and posted on the Ministry of Health website.

Drinking Water Officers' Guide: Part A

Legislative Requirements

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Ministry of Health

Table of Contents

Chapter 1: Roles and Responsibilities

There are a number of persons or agencies involved with or interested in the administration of the Act. These entities, and their respective roles and responsibilities regarding drinking water protection, are set out below.

1.1 Health authorities

The five regional health authorities established under the *Health Authorities Act* are responsible for the implementation of most aspects of the *Drinking Water Protection Act* (DWPA). In particular, the regional health authorities employ the drinking water officers who are the statutory officials that hold responsibility for most of the powers and functions under the Act.[1] The health authorities also employ other officials to whom the powers of drinking water officers may be delegated. This may include, for example, medical health officers, public health inspectors, environmental health officers and public health engineers.

1.2 Drinking water officers and delegates

Most of the discretionary decision-making power in the Act is provided to drinking water officers. Drinking water officers are appointed under section 3 of the Act. There may be one or more drinking water officers in each health authority.

Drinking waters officers can, in writing, delegate any or all of their powers to other persons under section 3(4).[2] Unlike some other acts, there is no provision in the Act that allows for delegation "on terms and conditions."

Powers of drinking water officers may be delegated to officials employed as medical health officers, public health inspectors, environmental health officers, public health engineers and other officials. Delegation of specific powers may also be made to officials from other ministries and other individuals.

Before delegating powers under the Act, drinking water officers should be satisfied that the person to whom the delegation is provided has the appropriate skills, training and judgment to exercise the powers of drinking water officers in relation to the matters being delegated. They should also ensure that the person being delegated authority is provided with a copy of this guide.

A sample form of delegation is set out in appendix 1.

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[1] A few powers and functions are held by the minister and the provincial health officer, as discussed later, but these do not relate to the day-to-day administration of the act.

[2] The ability to delegate does not apply to the issuance of construction permits, although drinking water officers can designate public health engineers to do this. This is discussed further below.

Any person who has been delegated the authority of a drinking water officer should be able to provide proof of that delegation if requested to do so.

1.2.1 Relationship between appointed and delegated drinking water officer functions

A person who has been delegated the powers of a drinking water officer holds those powers in the very same way as the person who delegated those powers. In other words, the delegated official has the same powers as a drinking water officer in respect of the matters delegated and is as much a statutory official as the drinking water officer themselves.[3]

Accordingly, references to the powers and functions of a drinking water officer in this guide should be taken to include any person who has been delegated the relevant powers of a drinking water officer, unless expressly noted otherwise.

Only persons who have been named or appointed as a drinking water officer should use that title to describe themselves. Persons who have been delegated the powers of a drinking water officer should not use that title, but be aware that they hold the relevant powers of a drinking water officer under the Act in any case where it is necessary to exercise those powers.

1.2.2 Relationship to other officials and managers within a health authority

Because the health authorities employ drinking water officers, they are responsible for their overall management, performance monitoring, and similar matters. Health authorities are also responsible for providing overall operational policy guidance to drinking water officers and their delegates. However, drinking water officers and their delegates cannot be directed by any officials within the health authority in the exercise of their statutory discretion in particular cases. Similarly, their decisions cannot be modified by other officials (except as provided for under section 39.1, discussed later). Drinking water officers are, however, encouraged to consult with medical health officers and other officials when appropriate, as discussed further throughout this guide.

Where a drinking water officer has delegated authority to another person, the drinking water officer does not have the ability to direct the delegate in the exercise of discretion in that particular case. The delegated official may consult with the drinking water officer, but the decision as to how to proceed must be made by the delegated official (unless the drinking water officer themselves assumes full responsibility for the file).

In some cases, exercise of discretion by drinking water officers or delegates may have implications for the health authority (e.g., a decision to take direct action to address a threat to drinking water and

[3] One exception is that a person who has been delegated the powers of a drinking water officer does not have the ability to further delegate those powers to other persons. In other words, delegation can only be undertaken by a person who is actually appointed as a drinking water officer under section 3 of the Act.

then seek cost recovery from the owner if possible). Drinking water officers and their delegates should discuss such matters with the appropriate senior manager[4] of the health authority. In addition, there are a number of other specific circumstances for which this guide recommends such consultation. In all cases where consultation with a senior manager occurs, the final authority for the exercise of statutory authority rests with the drinking water officer or delegate.

1.2.3 Relationship to officials from other agencies or authorities

It may be appropriate for a drinking water officer to consult with officials from other agencies, organizations and governments in the discharge of responsibilities of the drinking water officer under the *Drinking Water Protection Act*. The requirements and limitations respecting such consultations are discussed in various sections of this guide as it relates to specific issues.

Drinking water officers may be consulted by other officials in the exercise of statutory decision-making under other acts, for example as "referrals," or "requests for comments." Where these practices occur, drinking water officers must clearly respect the distinction between comment or review functions and the exercise of statutory responsibilities under the *Drinking Water Protection Act*. They must ensure that any comments they provide to other agencies would not be seen as fettering or biasing their decision under the *Drinking Water Protection Act* in relation to matters that may come before the drinking water officer in due course.

1.3 Issuing officials

Under the Act, construction permits and operating permits may be issued by "issuing officials". The Act and regulations specify who can be an issuing official for each type of permit, and this is discussed in more detail below. In sum, construction permits will generally be issued by public health engineers, and operating permits will be issued by drinking water officers or their delegates, and these two types of issuing officials should work together to coordinate their respective roles and responsibilities.

1.4 Minister of Health

The Minister of Health is responsible to the government and the Legislature for the overall administration of the Act and Regulation. This includes a general role in overseeing the implementation and administration of the Act by the regional health authorities.

The minister also has a number of specific statutory powers and functions under the Act. These include:

- Power to appoint drinking water officers (section 3(2))
- Power to issue guidelines and directives (section 4)

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[4] This Guide will make reference to the generic title of "senior manager" throughout. Organizational structure of health authorities differs across regions and the "senior manager" may have a different title depending on the health authority.

- Requirement to advise Cabinet of problems that cannot be remedied to the satisfaction of the provincial health officer (section 4.2(2))
- Ability to establish advisory committees (section 5)
- Ability to prescribe areas where other statutory decision makers must consult drinking water officers (if Cabinet enables this by Regulation) (section 30)
- Ability to designate an area for development of a drinking water protection plan, establish a process for those plans, and perform various related functions (Part 5)

Ministry officials also provide informal coordination and support functions to the health authorities, but have no formal oversight or operational role as it relates to health authorities and drinking water officers.

More generally, the Ministry has entered into agreements that set out the objectives and expectations for the provision of health services by regional health authorities. The Ministry also provides funding to the health authorities for matters that include, but are not limited to, public health programs such as drinking water protection.

1.5 Provincial health officer

1.5.1 Advisory and reporting functions

Part 6, Division 2 of the *Public Health Act* provides:

64 The provincial health officer is the senior public health official for British Columbia.

66 (1) The provincial health officer must monitor the health of the population of British Columbia and advise, in an independent manner, the minister and public officials

(a) on public health issues, including health promotion and health protection,

(b) on the need for legislation, policies and practices respecting those issues, and

(c) on any matter arising from the exercise of the provincial health officer's powers or performance of their duties under this or any other enactment.

(2) If the provincial health officer believes it would be in the public interest to make a report to the public on a matter described in subsection (1), the provincial health officer must make the report to the extent and in the manner that the provincial health officer believes will best serve the public interest.

(3) The provincial health officer must report to the minister at least once each year on

(a) the health of the population of British Columbia, and

(b) the extent to which population health targets established by the government, if any, have been achieved, and may include recommendations relevant to health promotion and health protection.

(4) The minister must lay each report received under subsection (3) before the Legislative Assembly as soon as it is reasonably practical.

The provincial health officer's general advisory function under this section extends to matters falling under the *Drinking Water Protection Act*.

1.5.2 Supervisions and direction to medical health officers

The provincial health officer plays a formal role in the supervision of actions by medical health officers across the province. Specifically, Part 6, Division 2 of the *Public Health Act* states:

67 (1) The provincial health officer may exercise a power or perform a duty of a medical health officer under this or any other enactment, if the provincial health officer

(a) reasonably believes that it is in the public interest to do so because

(i) the matter extends beyond the authority of one or more medical health officers and coordinated action is needed, or

(ii) the actions of a medical health officer have not been adequate or appropriate in the circumstances, and

(b) provides notice to each medical health officer who would otherwise have authority to act.

(2) During an emergency under Part 5 *[Emergency Powers]*, the provincial health officer may exercise a power or perform a duty of a health officer under this or any other enactment, and, for this purpose, subsection (1) does not apply.

(3) If the provincial health officer acts under subsection (1), the provincial health officer may order a health authority to assist the provincial health officer, and the health authority must ensure that its employees and appointees comply with the order.

(4) For the purposes of exercising a power or performing a duty under this or any other enactment, the provincial health officer may exercise a power of inspection that a health officer may exercise under this Act, and, for this purpose, Division 1 *[Inspections]* of Part 4 applies.

68 (1) The provincial health officer may establish standards of practice for medical health officers in relation to the exercise of their powers and the performance of their duties under this or any other enactment.

(2) Without limiting subsection (1), a standard may include a requirement to make a report or take an action in addition to a requirement of this or any other enactment.

(3) The provincial health officer must

(a) monitor the performance of medical health officers for compliance with established standards, and

(b) conduct performance reviews of medical health officers in accordance with an order of the minister made under section 63 *[power to establish directives and standards]*.

(4) The provincial health officer

(a) must disclose the results of a performance review to the medical health officer and the medical health officer's employer, and

(b) may disclose the results of a performance review to the minister and the Lieutenant Governor in Council.

The provincial health officer does not have authority to direct the actions of drinking water officers or the medical health officers under the *Drinking Water Protection Act*. The one exception is the case in which a water supplier requests a review of a decision under the *Drinking Water Protection Act*:

39.1 (4) If a review is requested,

(a) the review is to be conducted by the provincial health officer or a medical health officer designated by the provincial health officer,

(b) the review is to be a review based on the record,

(c) the person conducting the review may require the applicant to give notice of the review in accordance with the person's directions, and

(d) the person conducting the review may

(i) confirm, vary or reverse the initial decision, or

(ii) refer the matter back to the drinking water officer, with or without directions.

For more information about this situation, go to Part 5, section 5.1.2 of this guide.

1.5.3 Specific functions under the Act

The provincial health officer also has several specific powers and functions under the *Drinking Water Protection Act*. These include:

- Advises minister on qualifications of drinking water officers (3(3))
- Must monitor drinking water officer compliance with ministerial guidelines and directives. (section 4(2))
- Prepares annual report respecting activities under the Act (section 4.1)

- Must advise minister of government action or inaction that significantly impedes protection of public health regarding drinking water (section 4.2)
- If a problem under section 4.2 cannot be resolved to the satisfaction of the provincial health officer then the minister must take it to Cabinet.
- Role in initiating drinking water protection plans (section 31)
- Advises minister in the establishment of advisory committees (section 5)

The office of the provincial health officer also employs a person in a position of "Provincial Drinking Water Officer". This position does not hold any statutory functions under the Act, but is intended to facilitate consultation, cooperation and leadership among the interested parties, particularly as it relates to the role of the provincial health officer, and to support the provincial health officer in fulfilling his mandate under the Act.

1.6 Drinking Water Leadership Council

Recognizing that the health authorities, the Ministry, and the provincial health officer all play important roles in the administration of the *Drinking Water Protection Act*, the Drinking Water Leadership Council has been established to coordinate discussions and foster cooperation among these agencies.

The Drinking Water Leadership Council may include representation from other government ministries that have authority for various regulatory regimes affecting drinking water.

1.7 Advisory Committees

Under section 5 of the Act, the minister can establish technical advisory committees to consider matters referred to it by the minister. The Ministry draws upon the technical knowledge and expertise of various officials and organizations through informal committee consultations.

1.8 Laboratories

Water suppliers are required to have their bacteriological water monitoring analyses undertaken by laboratories approved by the provincial health officer. These can be found on the website of the Provincial Health Services Authority (PHSA). Testing for other parameters (chemical and physical) can be undertaken at any appropriate laboratory. Although there is no legal requirement in the Act or Regulation for any approval or certification of laboratories in respect of these parameters, some labs are voluntarily certified by the Canadian Association for Laboratory Certification in respect of specific testing. See www.cala.ca.

1.9 Environmental Operator's Certification Program

Certain types of water suppliers must meet the qualification requirements set out in section 12 of the Regulation, which refers to classification and certification by the Environmental Operator's Certification Program (EOCP).

The EOCP is a society, established under the *Society Act*. It classifies drinking water and waste water treatment facilities, and collection and distribution systems. The EOCP facility classification determines the level of the senior operator required for operating the facility and the EOCP certifies operators to meet classification requirements. It does not have any regulatory powers and cannot impose legally binding requirements on any party. However, classification of facilities and operator certification by the EOCP are required to meet the requirements of section 12 of the Regulation (as applicable). The EOCP does not offer operator courses, but provides accreditation of courses and training programs to assist in obtaining certification under the EOCP. Those programs are delivered by other organizations (see 1.10 of this guide for more information).

For more information about requirements regarding operator training and accreditation see section 3.2.6.1 of this guide. For information related specifically to small water systems, see section 3.2.6.2 of this guide. The EOCP provides more detailed information on its web site at https://eocp.ca/.

1.10 Operator Trainers

Several organizations and individuals offer EOCP accredited courses and programs. The EOCP established an online training registry to help connect operator trainers with people seeking training in nearby communities. The registry is designed to encourage those who have valuable skills to register as trainers, and allow those seeking to learn about specific skills find training closer to where they work and live. This will make it easier to earn continuing education units towards EOCP certification, and save money in travel.

For more information contact the EOCP at https://eocp.ca/.

Chapter 2: Scope of the Act

2.1 Who and what is covered?

One of the fundamental questions to arise in administration of the Act is, "Which persons or types of systems are covered by the Act and Regulation"? There is no single and simple answer to this, as there may be a number of persons responsible under the Act in relation to a water supply system, and there are various provisions that may impose different obligations on parties, even if they are not water suppliers.[5] It is therefore always necessary to carefully review potentially relevant sections of the Act, and all related definitions, before deciding whether the Act imposes obligations on a person or in respect of a particular system.

Most of the provisions of the Act deal with "water suppliers" and "water supply systems." To understand what these terms mean, it is necessary to consider a number of related definitions. These are set out below. Where a term that is used in a definition is itself defined by the Act or Regulation, this is noted by way of underlining, and the definition of the term is, in turn, discussed further below.

Water Supplier

an owner of a water supply system (See Act s. 1)

Owner

Includes[6]:

(a) a person who is

(i) responsible for the ongoing operation of the water supply system or

(ii) in charge of managing that operation, and

if

(i) parts of the water supply system are owned by different persons, or

(ii) all or parts of the system is jointly owned by different persons,

all of those persons

Water Supply System

A domestic water system, other than:

(a) a domestic system that serves only one single-family residence[7]

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[5] For example, under section 23 of the Act, all persons are prohibited from contaminating drinking water or tampering with water supply systems, and under section 25 hazard abatement orders can be made against persons other than water suppliers in appropriate cases.

[6] See Act, section 1. The term owner is defined to "include" these persons but is not necessarily limited to them. Part Four, section 3.1of this Guide provides additional information and guidance for cases where it is not readily apparent who the owner of a system is.

(b) equipment, works or facilities prescribed by regulation as being excluded (as noted below in Domestic Water System)

(See Act, section 1)

Domestic Water System

A system by which water is provided or offered[8] for domestic purposes, including:

(a) works used to obtain intake water,

(b) equipment, works and facilities used for treatment, diversion, storage, pumping, transmission and distribution,

(c) any other equipment, works or facilities prescribed by regulation has been included[9]

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[7] The term "single-family residence" is not defined in the Act. It may be interpreted as any residence that constitutes a single structure where:

- bedrooms are rented out and tenant(s) share common spaces with the owner;
- the *Residential Tenancy Act* applies (see s. 5.3.1 of this Guide regarding applicability of the Health Hazards Regulation);
- the structure contains a secondary suite in addition to the primary suite;
- the residence is an owner-occupied bed and breakfast with up to three rooms for rent; or
- the residence is rented out as a vacation home.

Duplexes/multiplexes and residences with additional detached structures such as guest houses, mobile homes and labourer accommodations would fall outside the term "single-family residence." Shared interest properties (e.g., owned by a co-operative, society, corporation or strata) and bed and breakfasts with four or more rooms for rent would also fall outside the definition of "single-family residence." Community care facilities would fall outside the term "single-family residence" as well. However, this is subject to section 20 of the *Community Care and Assisted Living Act*, which states:

(1) This section applies to a community care facility
  (a) for which a licence has been issued,
  (b) is being, or is to be, used
    (i) as a day care for no more than 8 persons in care, or
    (ii) as a residence for no more than 10 persons, not more than 6 of whom are persons in care
  (c) from which, in the event of a fire, persons in care can safely exit unaided or be removed by its staff, and
  (d) that complies with all enactments of British Columbia and the municipality where the community care facility is located that relate to fire and health respecting a single family dwelling house
(2) A provision in an enactment of British Columbia, other than this Act, or of a municipality, does not apply to the community care facility described in subsection (1) if that provision would
  (a) limit the number of persons in care who may be accepted or accommodated at the community care facility
  (b) limit the types of care that may be provided to persons in care at the community care facility, or
  (c) apply to the community care facility only because
    (i) it is not being used as a single family dwelling house, or
    (ii) it operates as a community care facility, a charitable enterprise or a commercial venture.

(Even if a system is deemed to serve a "single-family residence" by virtue of section 20 of the *Community Care and Assisted Living Act* (and thus not a "water supply system" under the *Drinking Water Protection* Act) it would still be subject to any other applicable public health laws.)

[8] In deciding whether water is "provided or offered" it is necessary to consider all the circumstances of a particular case. A person who makes water available for domestic use, but purports to not be doing so may still fall within this definition. Each case will have to be considered on its own facts, having regard to the plain meaning of these terms and the underlying intent of the act. If questions arise in this regard, it may be appropriate to seek legal advice.

(d) a tank truck, vehicle water tank or other prescribed means of transporting drinking water, whether or not there are any related works or facilities, and

(e) the intake water and the water in the system

(See Act, section 1)

The following are excluded from the definition of "domestic water system" in the Act:

(a) equipment, works and facilities constructed, operated or maintained

(i) under a licence, as defined in the *Water Sustainability Act*, for conservation, power or storage purposes,

(ii) under a permit issued under the *Water Sustainability Act*, [10]

(iii) for bottled water production or distribution, [11] or

(iv) for drinking water dispensing machines; [12]

(b) a reservoir relating to a licence or permit referred to in paragraph (a);

(c) a building system[13]

(d) a system within a system[14].

(see Regulation, section 3)

Domestic Purposes

the use of water for

(a) human consumption, food preparation or sanitation,

(b) household purposes not covered by paragraph (a), or

(c) other prescribed purposes[15,16]

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[9] None at present.

[10] Permits are issued under the *Water Sustainability Act* to construct, maintain or operate works on Crown land. This exemption from the definition of "water supply system" applies only to such equipment, works and facilities. This is different than systems that are licensed under the *Water Sustainability Act* to obtain water from a particular source. Systems that draw water from a source licensed under the *Water Sustainability Act* are not exempt from the definition of "water supply system".

[11] These systems may still be subject to the *Food Safety Act*, as well as applicable federal laws.

[12] These systems may still be subject to the *Food Safety Act*, as well as applicable federal laws.

[13] The term "building system" is defined in section 1 of the Regulation to mean "a system, within a building, to which the British Columbia Plumbing Code applies, that receives water from a water supply system operating under a valid operating permit under the act."

[14] This term is defined in section 1 of the Regulation to mean "a water supply system that, in the opinion of a drinking water officer or issuing official,
(a) redistributes water from a water supply system operating under a valid operating permit under the Act, and
(b) does not require further treatment processes, additional infrastructure or ongoing maintenance to prevent a drinking water health hazard. "
Further guidance on systems in systems is provided in section 5.5.1 of this Guide

Given these interrelated and very specific definitions, it is important to carefully consider each of these provisions in assessing whether or not a person or system is subject to the provisions of the Act.

A person will not be considered to fall within or outside the Act simply by virtue of their status under other legislation (e.g. holders of water licences under the *Water Sustainability Act*, or water utilities under the *Water Utility Act*). However, these may be relevant factors in assessing whether they are owners of a water supply system.

There is no specific limitation on the type of entities that can be water suppliers. They might include individuals, partnerships, corporations, societies, improvement districts, utilities, water users communities, local government or any other entity that falls within the above noted definitions.

It will be apparent that the determination of whether a person is an "owner" may be a complex question that varies on the circumstances of individual cases, and that it may have important consequences. Consequently, legal counsel should be consulted in cases where staff are unclear who should be considered "owners" of a water supply system.

2.1.1 Application of the Act to other persons

Although most of the provisions of the Act relate primarily to water suppliers, the Act's scope is broader. For example, many of the remedial actions discussed in Chapter 4, section 4.3 of this guide, such as the power to issue hazard abatement and prevention orders, are not limited to orders made to water suppliers. Similarly, section 23 of the Act contains broad prohibitions against contaminating drinking water or tampering with a water system, and these provisions are not limited to water suppliers.[17] Drinking water officers must ensure that they are aware of and fully consider all of the options available under the Act to address drinking water problems.

2.2 What is a water supplier required to do?

The following comments provide a basic summary of the obligations imposed on water suppliers by the Act and Regulation. References are made to the relevant sections of the Act and Regulation, and these sections should be consulted to determine the specific nature and extent of obligations imposed.

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[15] Systems supplying water (potable or non-potable) solely for use in toilets would generally fall within the definition of a "domestic water system." Such systems are generally still subject to the requirements of the act unless section 3.1. of the regulation applies. Section 3.1 of the regulation provides an exemption to the potability requirement under section 6 of the act. A domestic water system exempted from section 6 of the act is still subject to all other sections of the act, including sections 7 and 8 pertaining to construction and operating permits.
[16] Guidance on the determination of whether water for class D&E slaughter facilities is used for domestic purposes can be found in Part B: *Water Systems For Class D & E Slaughter Establishments And Other Unregulated Uses* of this Guide.
[17] According to subsection 3, these prohibitions do not apply to activities that are authorized or required by or under any other enactment or the person is otherwise acting with lawful authority. In such circumstances, a person cannot be charged for an offence. However, all other aspects of the *Drinking Water Protection Act* continue to apply to problems even if they arise from activities authorized under another act. This includes the power to issue hazard prevention and abatement orders under section 25.

In some cases, the relevant sections of the Act impose requirements only on "prescribed" water supply systems, meaning those specified as such in the Regulation. The Regulation provides (in section 4) that all water supply systems are prescribed as being covered by the requirements of sections 8, 10 11 and 22(1)(b) of the Act, and all systems except "small systems"[18] are prescribed for the purposes of section 9 of the Act.

Potable water

All water suppliers must supply water which is potable and meets any requirements set out in the operating permit or regulations. "Potable" is defined in section 1 to mean

(a) meets the standards prescribed by regulations, and

(b) is safe to drink and fit for domestic purposes without further treatment

The Regulation also requires all surface water to be "disinfected"[19]. Unlike the former Safe Drinking Water Regulation under the old *Health Act*, there is no discretion to exempt water suppliers from this requirement. (See Act, section 1 and 6, Regulation, section 5)

Exception: A system is not required to meet the potability requirements if the system does not provide water for human consumption or food preparation[20,21] and is not connected to a system that does. "Small systems" are not required to meet the potability requirement if each recipient of water from the system has a Point-of-Entry or Point-of-Use treatment system[22] that makes the water potable.

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[18] Section 1 of the Regulation defines "small system" to mean all water supply systems that serve up to 500 individuals during any 24-hour period.

[19] The term "disinfect" is not defined in the Act or Regulation. It is referred to in section 5(2) of the Regulation.
A drinking water officer may impose specified disinfection requirements as terms and conditions of an operating permit, as discussed below in Part 3, section 2.6. However, even in the absence of any such terms and conditions, the requirement to disinfect surface water applies to all water suppliers.
For reference sources concerning the term "disinfect", see the US Environmental Protection Agency EPA website at http://epa.gov

[20] Guidance on the determination of whether water for class D&E slaughter facilities is used for domestic purposes can be found in Part B: Water Systems For Class D & E Slaughter Establishments And Other Unregulated Uses of this guide.

[21] The term "human consumption" is not defined in the Act. It must be given its plain meaning and applied to the facts of each case. In general, this would likely mean water that is used for purposes of ingestion (drinking, ice, cooking etc.) and would not include water used solely for washing and bathing (although there may be some cases where this is less clear, such as washing facilities to be used by toddlers). Similarly, the term "food preparation" is not defined in the Act. It must also be given its plain meaning and applied to the facts of each case. In general, water used for washing food before consumption, or for adding to food for the purposes of consumption, would be considered water used for "food preparation". If drinking water officials have any question concerning the application of these terms to the facts of a particular case, they should consult legal counsel.

[22] Neither the Act nor the Regulation define what is a "Point-of-Entry " or "Point-of-Use" treatment system. For the purposes of this guide, a Point-of-Entry (POE) treatment device is taken to mean a treatment device applied to the drinking water entering a house or building for the purpose of making the water distributed throughout the house or building potable. A Point-of-Use (POU) treatment is taken to mean a treatment device applied to a single tap for the purpose of making the water distributed by that tap as potable when it leaves the tap. (For this reason, a kettle that may be used to boil water would not be considered a Point-of-Use device, even if boiling water can address certain threats to drinking water.) See Part B:

In each of these circumstances, the water supplier must ensure that the location of non-potable discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized. (See Act section 1 and 6 and Regulation section 1 and 3.1)

Construction permits

Persons may only construct a water supply system if they obtain a construction permit in advance. (See Act section 7 and Regulation section 6)

Exception: for "small systems" the requirement for a construction permit may be waived (with or without conditions) by an issuing official. (See Regulation section 6(3)(c))

Operating permits

Water suppliers must not operate a water supply system without an operating permit and must comply with the terms and conditions of the permit. (See Act section 8 and Regulation section 7)

Operator Training

Persons must not operate a water supply system unless they meet the operator training and certification requirements set out in the regulation. (See Act section 9, Regulation section 12)

Exception: "small systems" are not required to meet any operator training and certification requirements unless their operating permit so specifies. (See Regulation section 4(2))

Emergency response and contingency plans

Water suppliers must have written emergency response and contingency plans[23] (See Act section 10, Regulation section 13)

Monitoring

Water suppliers must engage in sample monitoring as required by the regulations, operating permit and directions of a drinking water officer (See Act section 11, Regulation section 8). This includes monitoring for total coliform and, effective April 1, 2006, *Escherichia coli*.

Laboratory reports

Laboratories must immediately report to water suppliers, the drinking water officer and the medical health officer if test results respecting E-coli and fecal coliform do not meet specified standards. Laboratories must also advise drinking water officers of other information if the drinking water officer so requests. Water suppliers must immediately advise the drinking water officer that they have been notified by the labs in such cases. (See Act section 12, Regulation section 9)

Notifying drinking water officer of threats

Obligations of the Water Suppliers of Drinking Water Treatment Systems that have Point of Use/Point of Entry Devices of this Guide for more information about this exception.

[23] Samples and guides respecting Emergency Response and Contingency Plans for small systems are set out in appendix 2.

Water suppliers must immediately notify the drinking water officer of other threats to drinking water if they become aware of them. (See Act, section 13)

Public notice of threats

Water suppliers must provide public notice of threats to drinking water if requested by a drinking water officer. (See Act section 14, Regulation section 10)

Also, if a laboratory advises that an immediate reporting requirement exists, or the supplier is otherwise aware of a potential drinking water health hazard, and the drinking water officer cannot be immediately contacted, the water supplier must notify the users of the water supply system immediately, in accordance with emergency response and contingency plans. In this case, no request or order from a drinking water officer is required. (See Act section 14, Regulation section 10)

Publication of other information

Water suppliers are required to make various other types of information public in accordance with the regulations and requirements of the drinking water officer. This includes information regarding emergency response plans and contingency plans[24], an annual report of monitoring, and information concerning assessments. (See Act section 15, Regulation section 11).

Flood-proofing of wells

Owners and operators of wells must flood proof them if required by the regulations.[25]

(See Act section 16, Regulation section 14)

Assessments

Water suppliers must conduct water source and system assessments of water supply systems, if required by the regulations or a drinking water officer (See Act, section 19).

Assessment Response Plans

In response to an assessment, the drinking water officer may make changes to the terms and conditions of the operating permit as well as order the water supplier to prepare an assessment response plan. The purpose of an assessment response plan is to identify the measures that may reasonably be taken to address identified threats (e.g., cross connection) to the drinking water that is provided by the water supply system (see Act section 22).

Drinking Water Protection Plan

If directed by a drinking water officer, a water supplier is required to participate in the development of a drinking water protection plan. (See Act section 33(1)(a)).

[24] A sample form of an Emergency Response and Contingency Plan is set out in0 Appendix 2 (Part C) of this Guide.
[25] Applies only to wells identified through an assessment as being at risk of flooding.

Other

In various other circumstances, drinking water officers have the ability to make requests or orders and impose requirements on water suppliers under the Act. Water suppliers must comply with those requests, orders and requirements.

2.2.1 Best practice tools and reference documents for water suppliers

Although there are specific legal obligations set out in the Act, Regulation, permits and other orders or requests of drinking water officers, these instruments will not provide specific direction in respect of every matter that a water supplier may encounter in the day-to-day operations of a water supply system. However, a number of best practices and technical assistance documents have been developed or identified that may assist water suppliers in this regard. These are set out in Part B of this guide. Drinking water officers are encouraged to bring the documents in Part B to the attention of water suppliers and other interested persons, with the caveat that they are not legally binding and, in the event of inconsistency between those documents and the Act, Regulation, permits, or any direction of the drinking water officer, the documents in Part B must give way to the legally binding requirements.

Chapter 3: Construction and Operating Permits

3.1 Construction permits

Section 7(1) of the Act requires a person to obtain a construction permit for the construction, installation, alteration or extension of:

a water supply system, or

(b) works, facilities or equipment that are intended to be a water supply system or part of a water supply system.

The requirement for construction permits is not limited to new systems. Any time a construction permit is requested – whether for the construction or installation of a new system, or the extension or alteration of an existing system – all the requirements of section 7 apply.

3.1.1 The issuing official

Section 6(1) of the Regulation specifies the following persons are issuing officials for the purposes of construction permits:

(a) a drinking water officer who is a professional engineer, or who is working under the direction of a professional engineer;

(b) a professional engineer who has been approved by a drinking water officer

It is only these people who can issue construction permits or, in the case of a small system, waive the requirement for one.

If a health authority wishes to ensure that only persons appointed as drinking water officers (and not their delegates) have the power to approve engineers for this purpose, then any delegation of drinking water officer powers should specifically exclude the power to approve engineers under section 6(1)(b) of the Regulation.

Professional engineers who have been designated as issuing officials must not consider applications for construction permits in respect of systems that they themselves have designed or would install.

3.1.2 Construction Permit Waivers for small systems

Under section 6(3)(c) of the Regulation, an issuing official may waive the requirement for a construction permit in the case of a small system. In deciding whether to waive the requirement for a construction permit, the issuing official should consider whether and to what extent a construction permit is necessary to address potential threat to public health. This should include consideration of all relevant information including:

- The nature and complexity of the proposed system

- The source of water that will be used by the system, and the potential for risks to arise in relation to it that would require addressing with specialized equipment or construction practices
- The likelihood that the applicant is prepared to accommodate suggestions or requests of the issuing official in the absence of any formal legal requirement for approval of a construction permit
- The knowledge and experience of the people undertaking the construction
- In the case of systems using Point-of-Entry or Point-of-Use treatment, whether the issuing official believes it is necessary to impose conditions respecting construction, design or equipment to provide reasonable confidence that the POE / POU devices will be able to provide potable water, and where such conditions could not likely be addressed through an operating permit.

The issuing official responsible for issuing the construction permit is often not the drinking water officer responsible for issuing the operating permit or conducting field inspections. For such circumstances, the issuing official responsible for issuing the construction permit should consider consulting with their operating permit counterpart to obtain their views on the request for a waiver. Should the information obtained from the issuing official responsible for issuing the operating permit have the potential to negatively impact the person's waiver request, it should be shared with the applicant for comment before a decision is made about whether to issue a waiver.

In general, if an applicant is prepared to construct a relatively simple system and there are no significant reasons why a construction permit is required, then it may be appropriate to provide a waiver. However, this is a matter that is solely within the discretion of the issuing official, who must exercise discretion on a case by case basis. There is no reason to provide or deny an applicant a waiver solely because of how another person's waiver request was decided.

Even in cases where the waiver request is denied, the issuing official has considerable discretion to determine the form of application and supporting information required to obtain a construction permit. This discretion can be used to make the construction permit application process as efficient and practical as possible (as discussed below).

3.1.3 Submission of applications

Applications for construction permits must be made to the issuing official "in a form satisfactory to the issuing official" (Regulation section 6(2)). Appendix 4 sets out an operating permit cover letter and appendix 5, a standard form operating permit. Health Authorities may wish to use these forms, or to replace them with standard forms for use within their authority.

Issuing officials have discretion to permit other forms of applications where they consider that appropriate. For example, if a person has prepared relevant construction information and drawings as part of an application for a water utility, that information could be used in support of an application for construction permit if and to the extent an issuing official considers appropriate.

Similarly, the scope and detail required in drawings or plans submitted as part of a construction permit might also appropriately vary depending on the nature, size and complexity of a proposed system. Applicants should therefore be encouraged to discuss these matters with the issuing official before submitting their application. This will ensure that issuing official receive the information they consider necessary in the circumstances, without requiring the applicant to incur unnecessary effort or expense.

Where a person applies for a construction permit after construction has already commenced, the principles set out in Chapter 4, section 4.3.13.3 of the guide should be applied.

3.1.4 Confirming a responsible person

Before issuing a construction permit, the issuing official should ensure that an owner has been identified as being responsible for the water supply system (See Act, section 7(4)). The person responsible for the ongoing operation may or may not be the same as the person who is identified on the application as the "owner", and there may be more than one "owner" of a system, as that term is defined in section 1 of the Act. For example, if a municipality is applying for a construction permit, the permit may be requested in the name of the municipality, but the person responsible for the ongoing operation of the system may be the senior operator with direct responsible charge.

Generally, the responsible person should be one who will have the authority and resources to manage the system; they may also operate the system on a general basis. The information required in this regard may vary, depending on whether the owner will be a natural person, a company, a society, etc. Some common situations, and the information that may be appropriate to request in relation to each, are set out below.

Applications by or on behalf of individuals

- Clarification of the person who proposes to be the principal responsible person, as well as the name of all other persons who will be "owners" as defined in section 1 of the Act

Applications by or on behalf of local governments

- Confirmation of the authority of the person making the application on behalf of the local government

Applications by or on behalf of partnerships

- Copies of any certificates or registration statements filed by the partnership with the Corporate Registry (BC Registry Services), and any acknowledgements by the Corporate Registry.
- Confirmation of the authority of the person making the application on behalf of the partnership

Applications by or on behalf of corporations established under the *BC Business Corporations Act*[26] or the *Canada Business Corporations Act*,

[26] The B.C. *Business Corporations Act* replaced the *Company Act* in 2004. The B.C. *Company Act* was repealed at the same time.

- Copy of the company's certificate of incorporation
- Confirmation of authority by the corporation to make application for permit on its behalf

Applications by or on behalf of societies established under the *Society Act*

- Copy of society's certificate of incorporation
- Confirmation of authority by the society to make application for permit on its behalf

Applications by or on behalf of water users communities established under section 51 of the *Water Users' Communities Act*

- The incorporation records of the water users' community,
- The name of the manager, the committee of management, and all members of the water users' community

The person designated as having primary responsibility for the ongoing operation of the system may not be the only "owner" of the system. The term "owner" is defined broadly in section 1 of the Act to "include" specified persons; it is not limited to them. As such, issuing officials should be careful to ensure that no assurances are made that limit which persons may be considered an "owner".

If the issuing official is not satisfied that the applicant has identified an owner of the water system that will be responsible for the ongoing operation of the system, the issuing official should refuse to issue the permit, as contemplated by section 7(4) of the Act.

3.1.5 Consultation with other officials

Although the Act requires separate permits for construction and operation of the water supply system, the issues addressed by them are related. Consequently, before a construction permit is issued, the issuing official responsible for issuing the construction permit should commence a relationship of close consultation with the person who will be responsible for considering an application for an operating permit in respect of that system. This relationship of close consultation should continue throughout the construction permitting process and into the operating permitting process. This may be particularly helpful in cases where the person seeking the construction permit proposes to use a water source for which no other operating permits presently exist. The issuing official should also consult, where applicable, with any other health authority staff that has been responsible for inspecting the system to date.

The issuing official should also consider consulting with the drinking water officer and the medical health officer in respect of health issues, particularly in respect of the proposed water source.

An issuing official may refer a construction permit application to other agencies that may have an interest in the matter. For example, the issuing official may wish to consult with:

- The Ministry of Transportation and Infrastructure approving officers, given their responsibility for subdivision approvals in rural areas and the approving officers' information in respect of servicing issues.
- The Ministry of Water, Land and Resource Stewardship, given their responsibilities for:

  - Licensing of surface water under the *Water Sustainability Act*,
  - Groundwater management and well protection under the *Water Sustainability Act* and Groundwater Protection Regulation (including Water Management Plans under Part 4 of the *Water Sustainability Act)*
  - Regulation of utilities under the *Water Utility Act*
  - Technical information regarding water source quantity and quality (this may include seeking technical assistance with hydrogeological matters). Two critical issues in B.C. are: (1) wells intersecting artesian aquifers (i.e. flowing conditions) and (2) wells in areas at high risk of saltwater intrusion.
- The Ministry of Environment and Climate Change Strategy, given their responsibility for environmental protection.
- Local governments that may have existing or planned water supply systems that may be impacted by the system for which a construction permit is sought.

Finally, issuing officials may choose to consult with specialists concerning matters that are outside their expertise in certain circumstances. While most specialist consultations will be undertaken by applicants and the results reported as part of the application process, an issuing official is free to consult other specialists directly. This may include experts within government who may be able to provide input free of charge, or, in exceptional cases, other persons. In the latter case, any decision to incur expenditures in this regard should be made only after consultation with the senior manager of the health authority.

Ultimately, there is no requirement that consultations occur with other officials, and this is a matter for the issuing official's discretion. Furthermore, the issuing official is the responsible person for the decision regardless of whether consultation occurs.

Where an issuing official consults with another person in respect of an application, the issuing official must, as a matter of administrative fairness, ensure that any information or comment provided by the other person is shared with the applicant if it has the potential to adversely affect the applicant's interests. In such cases, the applicant must be given an opportunity to respond to the comments or information before any final decision is made.

The issuing official should document the recommendations received, particularly from the person who will be responsible for considering an application for an operating permit in respect of that system, in the final report regardless if the recommendations are taken into consideration for the construction permit.

Issuing officials may also choose to inform other agencies when construction permits have been issued. There is no requirement in the Act that this occur, and this is a matter for the discretion of the issuing official.

3.1.6 Deciding whether to issue a construction permit

3.1.6.1 Information to be considered

In deciding whether to issue a construction permit, the issuing official should consider all relevant information, including:

- All of the information set out in or accompanying the application form
- The results of water quality analyses as required by sections 7(3)(a) or 7(3)(b) of the Act
- Any relevant best practices and technical assistance documents (see Part B of this guide)
- Operational history of the system (if any)
- Existing operating permit conditions (if any)
- Any information relevant to that system that has been obtained from assessments undertaken under section 19 of the Act in relation to systems that share the same water source or have other common conditions.

The issuing official should consult the reference treatment documents, the *Guidelines for Canadian Drinking Water Quality* (and the B.C. specific departures from the GCDWQ as listed in section 3.1.6.2 of this document), the *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia*, the *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia* and the *British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems* (found in Part B of this guide), and local water quality information when considering which water analyses should be required under sections 7(3)(a) or 7(3)(b).

If an issuing official believes that further information is required before deciding whether to issue a construction permit, they should request the additional information from the applicant. This may include, for example, drawings, reports or technical assessments from professional engineers and other professionals. It may also include other water quality analyses that have been requested by the issuing official or the drinking water officer under section 7(3)(b) of the Act.

3.1.6.2 Decision making process

In deciding whether to issue a construction permit, a fundamental consideration for all systems is to determine if the proposed new system or changes to the existing system meet appropriate public health engineering standards for that type of system. Another fundamental consideration for an existing system is to determine if the new construction is an improvement to the system. Regardless if it is new or existing, the water supply system should have sufficient ability to provide appropriate water to the intended user given the end use of the water, source water quality, proposed and/or existing treatment and/or disinfection technology, potential source-to-tap threats the system could encounter and finances (i.e., will the system be sustainable).

Generally, most systems will need to meet the requirement for potable water as set out in section 6 of the Act. This requirement does not apply in relation to:

- Systems that provide water for purposes that do not include human consumption or food preparation and are not connected with systems that do, or
- Small systems for which all recipients have a Point-of-Entry or Point-of-Use treatment system that provided potable water. (See Regulation, section 3.1)

For each of these circumstances, the water supplier must ensure that the location of non-potable discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

Another consideration related to existing systems concerns the decision to allow for continuous improvements towards the desirable end-state rather than requiring all required changes in one construction cycle. The issuing official should consider the financial circumstances of the system and the ability of the water supplier to set out and follow a defined plan to work towards the desirable end-state over time.

Consideration may also be given to protective measures that may be available through legal regimes administered by other agencies, such as backflow prevention programs that may apply under municipal bylaws.

For water treatment requirements, specific factors and points that the issuing official may wish to consider include the following:[27]

<u>New systems</u>

- With respect to water quality analyses, the issuing official should ensure that he/she has adequate data to determine that the proposed treatment is adequate to address public health risks in relation to relevant microbiological and chemical/physical parameters.
- *For microbiological risks:* In deciding what treatment modalities are required to address risk to public health, the issuing official must consider the requirements of section 2 and Schedule A of the Regulation respecting coliform and *E-coli*. In addition, the issuing official should consider requiring that the water system meet the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia and the Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia found in Part B of this guide. These documents provides guidance about the multiple barrier approach, the removal or inactivation of viruses, the removal or inactivation of *Giardia* and *Cryptosporidium* cysts, as well as turbidity objectives, and *E. coli*. In addition, the issuing official should consult the British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems to ensure that water quality is maintained after treatment.
- *For chemical risks:* The issuing official should consider whether to require any of the information described in the document Determining Appropriate Drinking Water Chemical and Physical Monitoring Guidelines found in Part B of this guide, along with any other information considered necessary in relation to that water system. The issuing official should consider

[27] Some of all of these may not be relevant in respect of systems that are exempt from the potable water requirements, pursuant to section 3.1 of the Regulation.

whether, and at what levels, disinfectant residuals are to be present in the distribution system. The issuing official may wish to consider the particulars of the system, Canadian and B.C. best practice documents, and requirements by other Canadian and international drinking water regulators.

- A construction permit may not be issued for a system in which the water originates from surface water, or groundwater that is at risk of containing pathogens, unless the system provides for disinfection (See Regulation, section 5 (2)). The disinfection/treatment should result in water that meets the accepted levels as outlined above. There is no ability for a medical health officer to waive this requirement under the Act and Regulation. This circumstance does not necessarily apply to systems receiving an exemption (under section 3.1 of the regulation) to section 6 of the act, which is the potability requirement.
- Issuing officials may wish to consider whether alternatives exist for the provision of safe drinking water that would be preferable from a public health perspective. This might apply, for example, if a developer proposed to establish a small water system within reasonable proximity to an existing municipal system, and it would be possible to instead connect onto a municipal system with higher levels of treatment and protection. This is only one relevant factor and each situation must be considered on its own merits, having regard to all relevant factors.[28]

<u>Existing systems</u>

- In some cases, an issuing official may decide to issue a construction permit for improvement or extension to an existing system in cases where, if the application were made to construct such a system today, the permit would not be issued.[29] In doing so, the issuing official should:
    a) satisfy themselves that the improvement will decrease the risk associated with the system or, at minimum, not adversely affect the risk and have other operational benefits,
    b) ensure the water supplier and drinking water officer are aware of the aspects of system that would not meet present standards if an application were made to create such a system today,
    c) advise that the approval of the construction permit does not affect the ability of the drinking water officer to impose any terms and conditions on the operating permit, or take any other steps they consider necessary under the Act, to avoid unacceptable risks to public health,
    d) if not the drinking water officer, advise the drinking water officer regarding the issuance of the construction permit

[28] Where the issuing officials considers that it may be appropriate to require a proposed system to become part of another existing system, the issuing official should consult the owner of the existing system to determine the willingness and ability of that water supply system to take on additional users. The issuing official may, in the case of water obtained from surface sources licensed under the *Water Act*, also wish to consult officials responsible for the *Water Act*, and the potential application of section 33 of that Act. It states, "If satisfied that the joint use of works would conserve water or avoid duplication of works, the comptroller may order the joint use and set its terms."
[29] An example may be improvement to provide chlorination to a non-disinfected surface supply. This will provide enhanced protection and is affordable, but it does not deal with *Cryptosporidium* risks and may not adequately deal with *Giardia* risks.

Departures from the *Guidelines for Canadian Drinking Water Quality*

The BC Ministry of Health applies Health Canada's guidelines on a substance by substance basis, ensuring guidelines are appropriate to the B.C. context. The following substances depart from the guidance found in the Guidelines for Canadian Drinking Water Quality due to B.C. specific circumstances:

Selenium

- The B.C. Ministry of Health recommends a Maximum Allowable Concentration (MAC) of selenium in drinking water of 10 µg/L, while Health Canada has a MAC of 50 µg/L.
- British Columbians are exposed to higher levels of selenium in food than those living in other parts of the country. Specifically, infants and children in BC may have greater exposure to selenium and exceed recommended upper limits of exposure to selenium from food alone. Further risk of overexposure of selenium through drinking water is also higher for children because they ingest more water relative to their bodyweight than adults.
- In addition to these concerns, uncertainty surrounding the toxic effects of inorganic selenium from water on human health suggests a precautionary approach be taken.
- The Ministry is concerned that raising the selenium threshold in drinking water may result in additional exposure to selenium.
- Most water systems in BC are well below levels of 10 µg/L, so maintaining this threshold will have minimal impact on water supply systems across the province.

Systems exempted from the requirement to provide potable water

Where applications are made for systems that are exempt from the requirement to provide potable water (as per section 3.1 of the Regulation), the issuing official should consider the factors outlined under the following scenarios:

(a) Systems that do not provide water for human consumption or food preparation and are not connected to water supply systems that do provide water for these domestic purposes.

- The water supplier must ensure that the location of non-potable water discharge and piping are identified by markings that are permanent, distinct and easily recognizable.
- The potential that persons might inadvertently use the water for human consumption or food preparation.
- Steps that can be taken to mitigate the above-noted risk (e.g., posting of signs, monitoring use).
- What constitutes as appropriate labeling for discharge points and piping to prevent inadvertent use of non-potable water for potable purposes
- The nature and extent of public health threat if the proposed system was inadvertently or intentionally used for human consumption or food preparation.

(b) Small systems that provide water only to Point-of-Entry or Point-of-Use systems and have the required permanent and distinct markings.

In addition to the factors noted above in relation to new systems and existing systems generally, issuing officials may wish to consider:

- What constitutes as appropriate marking for discharge points and piping to prevent inadvertent use of non-potable water for potable purposes
- Whether the issuing official considers that such a system presents an unacceptable risk to public health, considering the potential threats that may not be addressed by the POE or POU devices, or considering the risk that the POE or POU devices may fail or not be properly maintained. In particular, the drinking water officer may wish to consider:
    - Whether the POE or POU devices being used have received certification by an accredited third party agency to comply with standards established by an independent and respected national or international standard setting agency,[30] or whether the drinking water officer is aware of other information concerning a particular system that provides a similar degree of confidence in the system;
    - Whether the POE or POU systems have a warning device or other mechanism to alert users if the systems are not functioning properly;
    - Whether the POE or POU system has an automatic shut-off/warning system;
    - Whether the POE and POU system will be installed and operated in accordance with the manufactures suggestions or as directed by the issuing official;
    - In the case of POU systems, the potential for water to be used from access points that do not have a POU device, and to be used in a manner which poses a threat to public health;
- Whether there are other practicable means of providing potable water to the users of the water supply system that would provide significantly greater confidence regarding public health protection (e.g., whether it would be reasonably feasible for a water supplier to install a centralized treatment system that provides protection from a broader range of potential pathogens or contaminants, or for the same pathogens or contaminants but with a significantly higher degree of reliability). In considering this factor it would be appropriate for the issuing official to weigh the marginal benefit to public health protection that would result from utilizing another form of treatment system against the feasibility and practicality of this other form of treatment to the applicant; and,

[30] Examples include the Canadian Standards Association, NSF International, Underwriters laboratories Inc., Quality Auditing Institute International and Association of Plumbing & Mechanical Officers. For further information on standards and certification, see: https://www.canada.ca/en/health-canada/services/environmental-workplace-health/water-quality/drinking-water/products-materials-that-come-into-contact-drinking-water.html

- Where the issuing official has concerns or potential concerns regarding a system that serves POE and POU devices, the degree to which those concerns could be addressed through the imposition of terms and conditions (discussed below).

The points and principles discussed above are set out solely for the assistance of issuing officials in the exercise of their discretion. Subject to those matters addressed by the Act and Regulation, the decision as to whether to issue a construction permit, and the decision to include any terms and conditions, rest with the discretion of the issuing official.

As a general matter, issuing officials may also consider the applicant’s history with drinking water matters, for applications respecting new and existing systems.

3.1.7 Terms and conditions

The types of terms and conditions that an issuing official may include in a construction permit are not specifically set out in the Act. Further, the Act specifically states that the terms and conditions of a construction permit may set requirements and standards that are more stringent than those established by the Regulation (section 8(5)). Where terms and conditions are included, they should be included in the permit itself, or referred to in the permit and appended to it (for example, as a schedule). Comments and directions set out in a cover letter would not likely be considered terms and conditions of a permit unless expressly incorporated into the permit.

In exercising the discretion to include terms and conditions in a permit, the issuing official should consider which terms and conditions are necessary to meet the test for approval of a permit application.

3.1.8 If the issuing official is not satisfied with the permit application

If the issuing official is not satisfied with an application and is not prepared to issue a construction permit based on the information provided to that point, having regard to terms and conditions that could be included, the issuing official should provide the applicant with reasons for the decision. If the issuing official believes that the application could potentially warrant approval if certain amendments are made to the proposed system, the issuing official should advise the applicant accordingly and invite the applicant to consider making the necessary changes and resubmitting the application.

If the issuing official believes a substantial amendment to the application is required, the issuing official should ask the applicant to consider making amendments to the application, rather than simply granting the permit with terms and conditions that would require substantial modification of the proposed construction. However, in cases where the proposed construction is acceptable to the issuing official with only minor proposed modifications, the issuing official may wish to simply issue the permit on the terms and conditions that the construction proceeds in accordance with specified minor modifications, rather than requiring an amendment and resubmission of the application.

3.1.9 Form of permit

Neither the Act nor Regulation specifies the form of a construction permit.

3.1.10 Pre and post- approval inspections

Pre- and post-approval inspections can be undertaken where the issuing official considers it necessary. In making this decision, the issuing official may wish to consult the drinking water officer or other public health official with knowledge of the system or local circumstances.

In most cases it is anticipated that the issuing official will not perform inspections, but rather will make it a term and condition of the construction permit that the system be constructed in accordance with the approved plans. The issuing official may also include a term and condition that the designer or installer of the system certify that it was installed or constructed in accordance with the plans as approved. The issuing official may also, in appropriate cases, wish to require the certification to be provided by a professional engineer.

If an issuing official for a construction permit believes that a system is not constructed in accordance with the plans as approved, they should advise the person who will be responsible for considering the application for an operating permit for that system. Such information should also be provided to the applicant.

3.1.11 Request for changes

Under the Act, an issuing official does not have the ability to vary a construction permit once issued. Therefore, if an applicant requests a substantial change to a construction permit and the issuing official believes that the change is appropriate, a new construction permit must be issued (Act, section 7(6)(c)).

To avoid the need for issuance of a new permit in cases of minor changes to design specifications, the issuing official may wish to include as a term and condition a requirement that the system be must constructed in accordance with the plans as approved, or with any modifications that may be subsequently approved by the issuing official in writing. In this way, the construction permit itself need not be changed to accommodate minor changes in design specifications.

3.1.12 Repairs

In some cases, people may have questions as to whether repair of an existing system requires a construction permit. Given the breadth of the wording in section 7, a construction permit will be required where repairs are undertaken if they result in the alteration or extension of the system. However, if a person is simply undertaking a repair to return a system to the condition for which construction had previously been authorized, then no construction permit would be required. Moreover, under section 6(3)(a) of the Regulation, a person is not required to obtain a construction permit for emergency repairs.

A person undertaking repairs to a system may also require certification under the EOCP program, depending on the class of system and the date on which the relevant requirements of the Regulation apply to it (see Regulation, section 12(3) and (4)). However, even in that case, EOCP certification will not be required if the person conducting the repairs is:

> … a person with specialist knowledge immediately relevant to maintenance or repair of a water supply system provided the maintenance or repair is conducted following procedures approved by a person certified by the Environmental Operators Certification Program (See Regulation, section 12(6)).

This section is intended to allow people with specialized technical knowledge of water treatment and distribution equipment (e.g., a service representative from an equipment manufacturer) to work on the maintenance or repair of that system, without that person being certified by the EOCP program. However, this applies only if the following criteria are met:

- The person must have "specialist knowledge". That term is not defined in the regulations. It should generally be taken to mean knowledge that is not commonly held and which is acquired by some specific form of training or experience.
- The specialist knowledge must be "immediately relevant" to the maintenance or repair. It is not sufficient if a person is a specialist in a particular area, but the maintenance or repair does not relate to that area. Similarly, the person cannot use this exemption to "get a foot in the door" and then conduct maintenance or repairs that do not require specialist knowledge
- The maintenance or repair must be conducted following procedures approved by a person certified by EOCP.

Drinking water officers and issuing officials should encourage water suppliers to call them in advance to discuss any situation in which the water supplier is unclear as to whether a person who plans to conduct maintenance or repairs without being certified themselves by EOCP meets the requirements of section 12(5) of the Regulations.

3.2 Operating permits

Section 8 of the Act prohibits a person from operating a water supply system unless the water supplier holds a valid operating permit. The water supplier must also comply with all terms and conditions of the permit.

The following sections address the process and principles for considering applications for new operating permits, or amendments to existing permits.

3.2.1 The issuing official

Under section 8 of the Act, an operating permit can be issued (or amended) by an "issuing official". According to section 7 of the Regulation, all drinking water officers are issuing officials for the purposes of operating permits.

Operating permits can also be issued by any person to whom a drinking water officer[31] has delegated this power.

3.2.2 Submission of applications

Applications for operating permits must be made to the issuing official "in a form satisfactory to the drinking water officer" (Regulation section 7(1)).

3.2.3 Confirming a responsible person and specifying owners

Before issuing an operating permit, the issuing official should ensure that an owner has been identified as being responsible for the water supply system, that the system has been classified by the EOCP and that a senior operator that meets the level of the system classification is employed to operate the system. For circumstances in which the water supply system is owned by two or more persons, the owners should designate one of their numbers for the purposes of receiving and providing information and records as required or authorized under the Act (see Act, section 17(1)). The drinking water officer should designate one of the owners for the purposes of section 17 of the Act (see Act, section 17(2)). Issuing officials may require different types and amounts of information from different applicants, and may require more or less information than is in the standard operating permit application form. In general, the type of information that may be required in this regard, for different types of applicants, is as follows:

<u>Applications by or on behalf of individuals</u>

- Clarification of the person who proposes to be the principal responsible person, as well as the name of all other persons who will be "owners" as defined in section 1 of the Act
- Copies of any agreements between such persons regarding responsibility for, and liability for, the ongoing operation of the system

<u>Applications by or on behalf of local governments</u>

- Confirmation of the authority of the person making the application on behalf of the local government
- Clarification of the person who will hold primary responsibility for the ongoing operation of the system
- Names of other persons who will provide assistance to the person with primary responsibility

<u>Applications by or on behalf of partnerships</u>

- Copies of any certificates or registration statements filed by the partnership with the Corporate Registry (BC Registry Services), and any acknowledgements by the Corporate Registry.
- Confirmation of the authority of the person making the application on behalf of the partnership

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[31] In this context, the term "drinking water officer" refers to a person who has been appointed as a drinking water officer, and not a person to whom the powers of a drinking water office have been delegated. In other words, a person delegated powers is not able to further delegate them to another person.

Applications by or on behalf of corporations established under the BC *Business Corporations Act*[32] or the *Canada Business Corporations Act,*

- Copy of the company's certificate of incorporation
- Confirmation of authority by the corporation to make application for permit on its behalf
- Names of the officer or employee who will hold primary responsibility for the ongoing operation of the system
- Names of other persons who will provide assistance to the person with primary responsibility

Applications by or on behalf of societies established under the *Society Act*

- Copy of society's certificate of incorporation
- Confirmation of authority by the society to make application for permit on its behalf
- Names of the officer or employee who will hold primary responsibility for the ongoing operation of the system
- Names of other persons who will provide assistance to the person with primary responsibility

Applications by or on behalf of water users communities established under section 51 of the *Water Users' Communities Act*

- The incorporation records of the water users' community
- The name of the manager, the committee of management, and all members of the water users' community
- Names of the person who will hold primary responsibility for the ongoing operation of the system
- Names of other persons who will provide assistance to the person with primary responsibility

In cases where the issuing official is aware of other persons who also fall within the definition of "owner" as that term is used in the Act, the issuing official should consider naming the additional owners on the operating permit. However, the issuing official should be careful to note, in the cover letter or otherwise, that the listing of persons as owners on the operating permit does not necessarily mean that other persons might not also be considered "owners" in appropriate circumstances.

3.2.4 Consultation with other officials

When considering applications for operating permits, issuing officials should be in or commence a relationship of close consultation with the person who issued the construction permit and this relationship should continue until the operating permitting process is complete. The issuing official should review comments provided by agencies consulted at the construction permit application stage, and may engage in further consultations with other agencies if the issuing official considers this appropriate. The issuing official should also consider consulting with the drinking water officer and

[32] The B.C. *Business Corporations Act* replaced the B.C. *Company Act* in 2004. The B.C. *Company Act* was repealed at the same time.

the medical health officer in respect of health issues. Such consultation may also be appropriate when considering potential amendments to an existing operation.

Ultimately, there is no requirement that consultations occur with other officials, and this is a matter for the issuing official's discretion. Furthermore, the issuing official is the responsible person for the decision regardless of whether consultation occurs. Any consultation does not fetter the decision-making discretion of the issuing official responsible for issuing the operating permit.

Where an issuing official consults with another person in respect of an application, the issuing official must ensure that any information or comment provided by the other person is shared with the applicant if it has the potential to adversely affect the applicant's interests. In such cases, the applicants must be given an opportunity to respond to the comments or information, before any final decision is made.

The issuing official should document the recommendations received, particularly from the person who issued the construction permit for that system, in the final report regardless if the recommendations are taken into consideration for the operating permit.

Issuing officials may also choose to inform other agencies when operating permits have been issued. Again, there is no requirement in the Act that this occur, and this is a matter for the discretion of the issuing official.

3.2.5 Deciding whether to issue an operating permit

3.2.5.1 Information to be considered

In deciding whether to issue an operating permit, the issuing official should consider all relevant information, including:

- All of the information set out in the standard application form
- The water supply system has an EOCP certified senior operator with the same level of certification as the EOCP classification of the system (Regulation, section 12(2))
- The results of water quality analyses provided in the application for construction permit, as required by sections 7(3)(a) or 7(3)(b) of the Act
- Any relevant best practices and technical assistance documents (see Part B of this guide)
- Whether a construction permit has been issued and any conditions attached to it[33]
- Information provided by the official that issued the construction permit or other agencies that were consulted

[33] If a construction permit has not been issued and construction has occurred, the person will be in violation of section 7 of the Act, unless a waiver has been granted. Where a person is in violation of the construction permit requirements, they should be advised that a construction permit will be required before their application for an operating permit will be considered, and referred to the issuing official responsible for dealing with construction permits. In appropriate cases, the drinking water officer may also consider taking other compliance action, such as issuing a contravention notice under section 26 or pursuing an offence under section 45 of the Act.

- Any information relevant to that system that has been obtained from assessments undertaken under section 19 of the Act in relation to systems that share the same water source or have other common conditions.
- The existence or absence of approvals under other legislation which are necessary for the proper operation of a water supply system. This may include, for example, a water licence under the *Water Sustainability Act*, or, in the case of a water utility under the Water Utility Act, a certificate of public necessity and convenience. Potentially relevant statutes are discussed further below in Chapter 5, section 5.3.[34]
- Requests to use groundwater from a flowing artesian well should consider the adequacy of measures used to control flowing conditions as outlined in section 52 of the *Water Sustainability Act* (consult Ministry of Water, Land and Resource Stewardship staff.)
- Requests to use groundwater in coastal areas of B.C. should consider whether or not the well or wells being proposed for use can be operated without risk of causing intrusion of saline water as outlined in Section 58 (2) (a) of the *Water Sustainability Act* (consult Ministry of Water, Land and Resource Stewardship staff).[35]

If an issuing official believes that further information is required before a decision can be made whether to issue an operating permit, they should request that additional information from the applicant. This may include a request for reports or technical assessments from professional engineers and other professionals.

3.2.5.2 Decision making process

In deciding whether to issue an operating permit for a new water system, consideration should be given to the matters discussed in section 3.1 of this guide (in relation to construction permit applications). Namely, the primary consideration should be whether the proposed system, if operated in accordance with the terms and conditions of the permit, will have sufficient ability to provide safe drinking water to the intended user, having regard to potential threats that the system may face. In particular, the system should:

- Have staff that meet any certification requirements applicable to that class of system (see Regulation, section 12)
- Be capable of operating on an ongoing basis without significant threat of failure or contamination of water in the system
- Meet the treatment standards expectations as per section 3.1.6 of this guide
- Comply with the recommended monitoring and reporting guidelines
- Have adequate cross connection procedures
- Comply with other operating best practice guidelines

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[34] Although there is no specific requirement that issuing officials confirm compliance with other legislation, this is a relevant factor that they may consider. If the issuing official is aware that the applicant does not have the necessary approvals under another act, they may decline to issue the operating permit, or issue it subject to the condition that it becomes effective only when all necessary approvals have been obtained under other applicable laws.

[35] See this page for information: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/information-for-well-drillers-well-pump-installers/well-drilling-advisories

- Address any other identified concerns that the issuing official considers to pose a threat to the water supply system in the circumstances

Issuing officials may wish to take into consideration a risk assessment of the particular water system when reviewing the timeline proposed by the water supplier to achieve the accepted treatment levels and other operational targets. Elements of that risk assessment could include:

- Quality of the source water
- Level of treatment, including secondary treatment, as per British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems, currently provided
- Number of users of the water supply system
- Number of users from vulnerable populations.[36]
- History of water-borne diseases
- Historical water quality
- Whether the water is for purposes or provided in circumstances that are exempt from the potability requirements of the Act
- Population demographics and trends
- Community socioeconomic status
- Financial assets and potential for infrastructure grants
- Other relevant operating information.

For some parameters (e.g., lead or trihalomethanes (THMs)) it may be appropriate to consider factors such as the whether the water will be consumed on an ongoing or intermittent basis, or special vulnerabilities of persons likely to consume the water.

The timelines for achieving treatment and other system outcomes should be shortened in the face of increased risk to public health. The issuing official should not issue an operating permit unless they are satisfied that all unacceptable risks to public health will be addressed by the proposed system.

<u>Systems exempted from the requirement to provide potable water</u>

Where applications are made for systems that are exempt from the requirement to provide potable water (as per section 3.1 of the Regulation), the issuing official should consider factors outlined under the following scenarios:

(a) Systems that do not provide water for human consumption or food preparation and are not connected to water supply systems that do provide water for these domestic purposes.

- The water supplier must ensure that the location of non-potable water discharge and piping are identified by markings that are permanent, distinct and easily recognizable.

[36] Vulnerable populations within this context generally include children, elderly and people experiencing compromised immune systems due to circumstances such as HIV infection, diabetes, transplant medications and chemotherapy. This list is not exhaustive – the drinking water officer may need to use discretion in determining people that may be at increased risk to infections caused by water-borne diseases.

- The potential that persons might inadvertently use the water for human consumption or food preparation.
- Steps that can be taken to mitigate the above noted risk (e.g., posting of signs and monitoring use).
- The nature and extent of the public health threat if the proposed system was inadvertently or intentionally used for human consumption or food preparation.
- The type of warning mechanisms or signs to advise the users and what constitutes as appropriate labeling for discharge points and piping to prevent inadvertent use of non-potable water for potable purposes.

(b) Small systems that provide water only to Point-of-Entry or Point-of-Use systems and have the required permanent and distinct markings.

In addition to the general factors noted earlier in this section, the drinking water officer may also wish to consider:

- What constitutes as appropriate markings for discharge points and piping to prevent inadvertent use of non-potable water for consumption or food preparation. Whether overall such a system presents an unacceptable risk to public health, considering the potential threats that would not be addressed by the POE or POU devices, or considering the risk that the POE or POU devices may fail or not be properly maintained. In particular, the drinking water officer may wish to consider:
  - The steps that the water supplier is prepared to take, and has the ability to take, on an ongoing basis to ensure the proper operation, maintenance and monitoring of POE and POU devices supplied by the water supply system;
  - The emergency response plan the operator has and how that may address threats to public health that may arise that the POE / POU systems may be incapable of effectively treating;
  - Whether a pilot study may be appropriate to help address any uncertainties that exist with respect to the efficacy of the system, whether the applicant is prepared to conduct such a pilot study, and the results of the pilot study where conducted;[37]
  - The steps that the operator has taken and is prepared to take to provide or otherwise ensure ongoing education and training of POE and POU device users;
  - In the case of POU systems, the potential for water to be used from access points that do not have a POU device, and used in a manner which poses a threat to public health;

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[37] Where a pilot study is conducted, the system must comply with any applicable provisions of the act and regulations (including the requirement for an operating permit where applicable). In such cases the drinking water officer may consider issuing an operating permit for a specified period of time, and with terms and conditions they consider necessary, to provide reasonable safeguards for public health while the pilot study is being undertaken.

- Where an issuing official has exempted the applicant from the need for a construction permit, any of the factors that would have otherwise been considered at the stage of a construction permit application (see section 3.1.5.2 above); and,
- Where the issuing official has concerns or potential concerns regarding a system that uses POE or POU devices, the degree to which those concerns could be addressed through the imposition of terms and conditions (discussed below).

As a general matter, issuing officials may also consider the applicants history with drinking water matters, for applications respecting new and existing systems.

3.2.6 Terms and conditions

The types of terms and conditions that an issuing official may attach to an operating permit are broad. They include, but are not limited to, terms and conditions respecting:

- Treatment requirements (which may include dates by which they must be implemented)
- Equipment, works, facilities and operating requirements (including compliance with the construction permit)
- Qualifications, training or certification of the persons operating, maintaining or repairing the water supply system
- Monitoring of the drinking water source and water in the water supply system, including specifying a minimum bacteriological sampling frequency
- Standards applicable to the water in the water supply system (e.g., setting a minimum free chlorine residual level)
- Reporting and publication of monitoring results or other information respecting the water supply system. (Act, section 8(3))[38]
- Well protection and source protection
- Developing a cross connection control plan
- Setting the frequency for reviewing and updating the Emergency Response and Contingency Plan (see Appendix 2 / Part C of this Guide for a template)
- Maintenance and servicing of Point-of-Entry and Point-of-Use systems[39]

Also, the Act specifically provides that terms and conditions of an operating permit may be more stringent than the requirements and standards set by the Act or Regulation (Act section 8(5)). Generally, the standards set out in terms and conditions may not be less stringent than those set out in the Act and regulations. However, there are two exceptions:

1. Section 12(5) of the Regulation allows the operating permit to set a different date on which the operator certification provisions apply. When deciding whether or not to set less stringent standards respecting EOCP certification, the drinking water office or delegate should consider

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[38] In this regard, consideration should be given to require publication of all sampling undertaken, not merely sampling undertaken at the frequency required by the regulations.
[39] These could be attached either to the operating permit of a water supply system that supplies water to point of use or point of entry systems, or to the operating permits respecting point of entry and point of use systems themselves if they are used in circumstances that render them a water supply system under the act and thus in need of their own operating permit.

whether there are sounds reasons for applying an alternate date (e.g., lack of availability of courses in the region), and they should be satisfied that modifying the requirements will not pose an unacceptable risk to public health in respect of that particular system. This does not constitute a "waiver" from the certification requirements, but allows suppliers some extra time, and an opportunity to provide a strategy for obtaining training and experience necessary to achieve certification.

2. Section 8(3) of the Regulation allows for sampling frequencies to be less stringent than those set out in schedule B. In deciding whether to set lower frequencies, consideration should be given to all relevant factors including:
   - The water source (including whether it is surface water or groundwater at risk of influence by surface water)
   - The history of the system
   - Any special vulnerabilities of the intended users
   - Experience of other systems using the same or related water sources
   - Whether the water is being provided to Point-of-Entry or Point-of-Use treatment systems
   - Other monitoring that is being undertaken by the water supplier (such as chlorine residuals, other disinfection effectiveness monitoring, turbidity, particle counts, etc.)

More generally, in exercising the discretion to attach terms and conditions to a permit, the issuing official should consider which terms and conditions are necessary to ensure that all significant threats to public health are addressed.

In general, terms and conditions should not duplicate requirements in the Act and Regulation unless there is some difference in the applied standard. Moreover, issuing officials should ensure that water suppliers are aware that they are required to meet the requirements set out in the Act, the Regulation and the operating permit, and that not all requirements are set out in the permit. Issuing officials may, in the cover letter accompanying the permit, wish to draw the permit holder's attention to other obligations that exist by virtue of the Act and Regulation, but it must be made clear that the permit holder is responsible for ensuring compliance with all applicable requirements, whether or not they are listed in the permit and cover letter.

A sample cover letter for an operating permit is set out in appendix 4.

3.2.6.1 Requirements regarding operator training and certification

Operator training and certification requirements are set out in section 12 of the Regulation. It provides specific certification requirements (through the Environmental Operator's Certification Program or EOCP) for persons who operate systems classified by the EOCP as level 1, 2, 3 or 4.

Generally, these are systems other than "small systems."[40] Persons who operate, maintain or repair such systems must be appropriately certified by the EOCP. EOCP certification involves four elements:

1. System Classification

   The water supplier (owner) must submit an application and fee to the EOCP for review and consideration of a facility classification and number.

2. Operator Training

   A water system operator may be trained on the job, participate in classroom instruction, combined classroom and hand-on training, or distance educational training. Courses are not offered by EOCP, but EOCP maintains a registry of courses that can be applied towards EOCP certification.

3. Operator Experience

   Operator must have specified types and amounts of practical experience to be eligible to write a certification examination

4. Operators Certification

   Upon completion of the operator training, the EOCP certification exam may be taken. Although no specific training is a requirement to write a certification exam, EOCP often schedules exams in conjunction with training activities for the convenience of Operators, especially those in remote locations.

Section 12(2) of the Regulation provides that operators of systems classified as classes 1, 2 and 3 require certification as of January 1, 2006. However, section 12(5) of the Regulation provides that an operating permit may establish a later date on which these rules apply to a water supply system. Drinking water officers should consider exercising their discretion to delay the operator certification requirements of the Regulation only in cases where they are satisfied that:

(a) It would be impracticable for the water supplier comply within the timeframe specified in the Regulation,
(b) The water supplier can demonstrate, to the satisfaction of the drinking water officer, that there would be minimal risk to public health by the delay in obtaining the certification required under the EOCP program, having regard to the circumstances of that water supply system and any potential threats to it, and
(c) The water supplier has a strategy to provide the requisite degree of training and experience within a reasonable period of time.

[40] An introduction to EOCP is available in section 1.9 of this guide. For more detailed information on the EOCP classification system, see http://eocp.ca/facilities/facility-classification.

The drinking water officer should consider contacting the EOCP prior to making discretionary decisions with respect to operator certification in order to receive aid with evaluating any information received from the water supplier.

3.2.6.2 Terms and conditions respecting operator qualification for small systems

Although section 12 of the Regulation does not directly impose any operator qualification requirements for small systems, section 12(4) does provide that an operating permit may require a person to be certified by EOCP to operate, maintain or repair a small system. The decision of whether to impose such a term and condition is one for the drinking water officer to make, in their discretion. Generally, the requirement for operator certification should be imposed (through operating permit terms and conditions) on small systems in cases where the drinking water officer considers that there is something about the system in question or that the persons operating it requires a higher standard of formal training than would be normal for a small system. This might include, for example:

- Systems which have a history of problems due to operator error or omission
- Systems which are particularly vulnerable to errors or omissions in operation
- Systems which may present significant public health risk even though they are a small system (for example, systems serving vulnerable users such as a small rural hospital).

Drinking water officials can impose terms and conditions related to operator training and knowledge, short of requiring formal certification by EOCP. This could include, for example, requiring an operator to read specified materials, complete a basic water safety course such as Watersafe,[41] etc. The terms and conditions could also include requiring the water supplier to prepare an operations guide for the system,[42] or having the system inspected from time to by a person who is qualified by EOCP for small systems.

While reasonable efforts should be made to ensure some degree of consistency in the approach taken on these matters, there is no requirement that each system be treated exactly the same in this regard. To the contrary, the exercise of discretion on a case-by-case basis will require some differences in treatment of systems and this is to be expected under the terms of the Regulation.

3.2.7 If the issuing official is not satisfied with the permit application

If the issuing official is not satisfied with an application and is not prepared to issue an operating permit based on the information provided to date, having regard to terms and conditions that could be included, the issuing official should provide the applicant with reasons for the decision. If the issuing official believes that the application could potentially be approved if certain amendments were made to the application, then the issuing official should advise the applicant accordingly and invite the applicant to consider making the necessary changes and resubmitting the application.

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[41] http://www.watersafebc.ca
[42] The BCWWA website provides information that may assist in the preparation of operational guides. (See www.bcwwa.org)

3.2.8 Form of permit

Neither the Act nor Regulation specifies the form of an operating permit. A standard form permit is, however, set out in appendix 5 for consideration.

3.2.9 Changes

Where an owner seeks an amendment to an operating permit, the owner should be asked to make the request in writing, detailing how the circumstances of the water supply system have changed in such a way that they believe would warrant the amendment to the operating permit.

Where changes to the terms and conditions are proposed on the initiative of a drinking water officer, those changes can only be made after consultation with the water supplier and consideration of any comments the water supplier may provide in respect of the proposed changes (see Act, section 8 (4)). There is no requirement that this consultation occur in writing. In general, in the interest of time and efficiency, it may be sufficient to consult verbally with persons in respect of changes to which they are unlikely to have any objection. If, however, the person is likely to, or has indicated they do, object to a proposed change, the rationale for the proposed change should be provided in writing, and the person's response should similarly be requested in writing. There is no requirement that the permit holder consent to the proposed amendments, but their views must be considered before any final decision is made.

Although operating permits can be changed, it is not possible to change the name on an operating permit to effectively transfer it to another person. Rather, section 7(2) of the Act expressly provides that operating permits are not transferable.

Chapter 4: Ongoing Functions of Drinking Water Officers

4.1 Routine monitoring, inspections, investigations and reports

There are a variety of ways in which drinking water officers may obtain information regarding potential problems with water supply systems. These include:

- Notice of immediate reporting circumstances by laboratories (Act, section 12)[43]
- Report of threat to drinking water by water suppliers (Act, section 13)
- Report of threats where reporting is required under other acts (Act, section 24)
- Complaints or requests for investigations by users of the system
- Information generated through assessments (Act, section 19)
- Routine inspections, auditing and follow-up by the drinking water officers, Environmental Health Officers and Public Health Inspectors.

In addition, there is a potential for regulations to be developed that would require officials from other agencies to report concerns to drinking water officers when they become aware of them (Act, section 24(2)). However, no such regulations have been developed to date.

To ensure that drinking water officers are able to receive information in circumstances where it is to be provided to them, they should ensure that approved laboratories and water suppliers are provided with their contact information. Each health authority may wish to develop specific practices in this regard that suit its own circumstances. In general, this should ensure that the drinking water officer can be contacted immediately, and that there is no potential for information to sit for unacceptable periods of time on voice message systems or otherwise.

Health authorities are encouraged to consider designating a single, 24-hour on call number which could be provided as the contact number for all such circumstances. The health authority should ensure that any such number is staffed by a person who, in turn, is able to immediately contact the drinking water officer or another appropriate official.

4.1.1 Routine monitoring and inspections

4.1.1.1 Authority

Drinking water officers have the authority to conduct inspections under section 40 of the Act. This section in turn gives them all of the powers of a medical health officer under Division 1 of Part 4 of the *Public Health Act*.

4.1.1.2 When inspection may be made under the *Public Health Act*

23 Subject to section 25 *[entering to inspect]*, a health officer may stop a person or vehicle, enter a vehicle or place and inspect a vehicle or place for any of the following reasons:

[43] Similar notice must also be provided to the medical health officer. See section 12(1)(c).

(a) for the purposes of determining whether

(i) the person is an infected person,

(ii) the person has custody or control of a person who is an infected person, or of a thing that is an infected thing,

(iii) the vehicle or place is an infected thing, or has an infected thing in it or on it,

(iv) a health hazard exists or likely exists in or on the vehicle or place, or in relation to the activities of the person, or

(v) a provision of this Act or a regulation made under it, a term or condition of a licence or permit issued under this Act or an order made under this Act may have been, is being or is likely about to be contravened;

(b) if the person, vehicle or place is described in a report made under Division 3 [*Reporting Disease, Health Hazards and Other Matters*] of Part 2;

(c) to determine whether

(i) a licence or permit should be issued, or an order should be made, under this Act, or

(ii) a term or condition of a licence or permit issued under this Act, or an order made under this Act, should be varied or rescinded;

(d) to monitor or confirm compliance with

(i) a provision of this Act or a regulation made under it, or

(ii) a term or condition of a licence or permit issued under this Act, or an order made under this Act;

(e) if a health officer has the power to monitor or confirm compliance with a provision of another enactment, to monitor or confirm compliance with that provision;

(f) for any purpose for which an inspection by a health officer is expressly authorized under this or any other enactment;

(g) for a prescribed purpose.

4.1.1.3 Inspection powers under the *Public Health Act*

24 (1) A health officer may do one or more of the following for the purposes of an inspection:

(a) be accompanied or assisted by a person who has special, expert or professional knowledge of a matter relevant to the inspection;

(b) require a person to produce relevant records or things in the person's possession or control;

(c) inspect, copy or remove relevant records or things;

(d) require a person to stop engaging in an activity, or stop the operation of a thing;

(e) require a person to demonstrate a relevant skill, or operate a thing or carry out a procedure as directed by the health officer;

(f) make records in respect of a person, place or thing;

(g) take samples and perform analyses and tests, including tests in which a sample is destroyed;

(h) require that a place or thing not be altered or disturbed for a reasonable period of time;

(i) question a person whom the health officer reasonably believes to have relevant information;

(j) attend a relevant training program;

(k) make an order necessary for the purpose of exercising a power of inspection.

(2) If a health officer removes records or things under subsection (1) (c), the health officer must

(a) provide a receipt for the records or things to the person from whom they were taken, and

(b) subject to a power under this or any other enactment to order a thing destroyed, promptly return the records or things

(i) when they have served the purposes for which they were taken, or

(ii) if an action or a proceeding is taken under this or any other enactment as a result of an inspection, and the records or things are relevant to the action or proceeding, no later than 3 months after the conclusion of the action or proceeding.

(3) For the purposes of an order made under subsection (1) (k), the person who is subject to the order must comply with it.

4.1.1.4 Entering to inspect under the *Public Health Act*

25 (1) A health officer may conduct an inspection at any reasonable hour.

(2) Before entering a vehicle or place, a health officer must

(a) take reasonable steps to notify the owner or occupier of the place of the date and time that the health officer will be entering, and

(b) if the place is a private dwelling, obtain either the consent of the owner or occupier or a warrant to enter.

(3) Despite subsection (2) (a), a health officer may conduct an inspection without providing notice if

(a) providing notice would not be reasonably possible or practical in the circumstances, or

(b) in the case of a regulated activity, providing notice would frustrate the purposes of the inspection.

These inspections powers may be particularly important in relation to Point-of-Entry and Point- of-Use treatment systems, as these might not[44] be subject to the general rules regarding monitoring of water under section 11 of the Act, or the requirement to hold an operating permit under section 8.

Drinking water officers should be familiar with all of these provisions and be prepared to use them where circumstances so require.

The inspection powers apply generally and, unlike some other provisions of the Act, they do not apply only to "water supply systems." Inspection powers can be used in relation to systems serving a single-family residence (see section 2.1 of this Guide for situations where this applies).

4.1.1.5 Frequency of inspections

The decision as to how frequently to conduct routine inspections is one that must be made by drinking water officers, based on risk assessment (see section 5, below) and all relevant factors. This may include consideration of matters such as the number of systems within their responsibility, distance and accessibility to sites, history of compliance or noncompliance, threats that have been identified in relation to the system or its area and overall workload demands. There is no specific requirement in the Act that all systems be inspected, and there is no specific requirement regarding the timing and frequency of inspections when they do occur. However, drinking water officers are encouraged to develop and document an inspection policy appropriate to the nature and circumstances of the systems within their area of responsibility. Such policies should be developed in consultation with management of each health authority.

Where inspections are conducted, the drinking water officer should:

- Assess the system's compliance with the Act, Regulation and terms and conditions of construction and operating permits
- Review the emergency response and contingency plan (and refer the water supplier to supporting development tools where appropriate)[45]
- Review monitoring and other records (including operational logs, results of confirmation of adequacy of treatment, chlorine residual levels),
- Determine if there are any identifiable threats to the drinking water source
- Identify any deficiencies in comparison with normal waterworks standards
- Review cross connection control program

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[44] The question of whether a system that uses point-of-entry or point-of-use treatment is a "water supply system" to which the various substantive requirements of the Act and Regulations apply is one that must be considered on the facts of each case, having regard to the definition of "water supply system".

[45] For emergency response plans, see the Ministry of Health documents entitled Emergency Response and Contingency Planning for Small Water Systems and Guide to Emergency Response and Contingency Plans for Water Supply Systems. A sample of an emergency response plan template can be found in Appendix 2 (Part C) of this Guide.

- Review the risk-assessment rating for the water supply system (see section 4.5)
- Review the status of the water supplier's continuous improvement plan (if any)
- Consider whether an assessment under section 19 is required.[46]

For each inspection, the drinking water officer should complete an Inspection Form/Hazard Rating form. The specific type of form may vary by region to reflect the needs and circumstances of each health authority.

4.1.2 Investigations

An investigation differs from inspection in that an inspection is undertaken solely for the purposes of monitoring and assessing compliance and to identify threats. An investigation, by contrast, occurs when an official has some reason to believe that a form of noncompliance exists. An investigation is used to determine whether and to what extent this is the case, and to assemble evidence necessary to take remedial or enforcement action as appropriate.

While it may be difficult in some cases to draw a distinct line between inspection and investigation activity, where a drinking water officer believes that their activities might be reasonably characterized as being an investigation, the officer should:

- Notify the subject of the investigation that the drinking water officer has some reason to believe there may be a concern with respect to noncompliance (unless the provision of that information at the time would materially impair the ability to investigate)
- Take notes of all discussions and observations
- Where evidence is taken, ensure that the drinking water officer will, if necessary, be able to testify as to the integrity of the evidence from the time it was obtained to the time it may be presented in court (i.e. "the chain of continuity").

Assembling evidence as part of an investigation does not necessarily mean that formal compliance action will be undertaken, and in many cases the concerns can be remedied through information, discussion and education of the water supplier. However, the foregoing principles should be followed in any event, to help avoid challenges to the drinking water officer's actions if informal means do not resolve the matter and more formal compliance action is required.

4.1.2.1 Requests for investigations

The Act, under section 29, sets out a process for dealing with requests for investigations. It states:

> (1) If a person considers that there is a threat to their drinking water, the person may request the drinking water officer to investigate the matter.

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[46] For more information about completing a source-to-tap screen or assessment go to http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators.

(2) A request under subsection (1) must be in writing and must include specifics of the facts that the person considers constitute the threat.

(3) On receiving a request under subsection (1), the drinking water officer must review the request and consider whether an investigation is warranted.

(4) As applicable,

(a) if the drinking water officer decides against undertaking an investigation, the officer must advise the requesting person of this, and

(b) if the drinking water officer undertakes an investigation, the drinking water office must advise the requesting person of the results of the investigation.

Under section 29 of the DWPA, any person has a right to request an investigation by a drinking water officer if they consider there is a threat to their drinking water. The drinking water officer is obligated to consider this request and should be able to make a decision whether to initiate an investigation based on the submission of information outlined in Part B: Requests For Investigation Of A Drinking Water Threat Under The Drinking Water Protection Act of this guide.

Drinking water officers' should also proactively inform persons concerned with their drinking water, that they have a right to request an investigation under section 29 if they feel that the water is threatened and can bring forward specifics of the facts that constitute the threat.

Section 29 requires requests for an investigation to be in writing. If a request is made verbally to a drinking water officer, the drinking water officer should inform the person the request is required to be in writing.

Information provided by an applicant in relation to the questionnaire referred to in Part B: Requests For Investigation Of A Drinking Water Threat Under The Drinking Water Protection Act should provide sufficient evidence for a drinking water officer to make a determination as to whether to initiate an investigation into the matter. The purpose of an investigation is to gather information to determine whether and to what extent a threat exists. It is not incumbent on the person requesting the investigation to definitively prove to the drinking water officer that the threat exists.

If it can be reasonably demonstrated, based on the preponderance of responses in the questionnaire, that a threat to drinking water may exist, this is a sufficient basis on which to initiate an investigation.

In deciding whether or not to conduct an investigation, drinking water officers must consider all relevant factors. This may include, but is not limited to, considering:

- Whether the request for investigation includes credible information to suggest a threat may exist
- Any information that the drinking water officer has on file in respect of the water supply systems and prior dealings with the water supply system or owner

- The degree of potential harm that could occur if a threat complained of does exist or comes into existence
- The history of the drinking water officer's dealings with the person requesting the investigation[47]
- The extent the matter has already been reviewed (e.g., through other complaints or at the initiative of the drinking water officer)
- The extent to which the matter is being or will be investigated by another agency with related authority (e.g., Ministry of Water, Land and Resource Stewardship staff responsible for administering the Groundwater Protection Regulation under the *Water Sustainability Act* or Ministry of Environment and Climate Change Strategy staff responsible for administering the *Environmental Management Act*)[48]

If the drinking water officer decides not to conduct an investigation, they must provide a basic explanation as to why the decision was made. Drinking water officers should provide this to the person requesting the investigation in writing.

If an investigation is conducted, the drinking water officer must advise the person who requested the investigation of the results of the investigation. The drinking water officer should specify their findings regarding whether any threat was found, and what, if any, follow-up action will be taken. The amount of information and detail provided will vary depending upon the facts of the case, and other factors including, but not limited to, the significance of the threat with respect to human health, the complexity of the investigation, the availability of supporting data and the potential impact on the population at risk from the threat. The drinking water officer's response should provide enough information to allow the recipient to understand the drinking water officer's conclusions and the basis upon which they were drawn. Drinking water officers should also provide this information in writing.

4.1.3 Privacy rights and warrants

Section 8 of the Canadian Charter of Rights and Freedoms states:

> Every person has the right to be secure against unreasonable search and seizure.

There is a significant body of case law defining what constitutes a "search" or "seizure" for the purposes of section 8 of the *Charter*, and when a search or seizure will be considered "unreasonable." These will depend on various factors, including whether the person in question has a reasonable expectation of privacy in the place or thing being searched or seized and the nature of the inspection or enforcement activity being undertaken.

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[47] In some cases, the person requesting the investigation may be the water supplier

[48] The fact that there may be overlapping authority or activity being undertaken by another agency does not mean that the drinking water officer lacks authority or may disregard responsibility in relation to a matter. Such situations should be carefully assessed in accordance with the principles for cooperation with other agencies, discussed below in Chapter 5, sections 5.3 and 5.4 of this Guide.

The *Drinking Water Protection Act* or the *Public Health Act* does not allow a drinking water officer to enter a private dwelling place, unless the occupant consents or a warrant has first been obtained from court. It is important to respect this limitation, as a failure to do so could compromise an investigation. Such failure may also constitute a violation of section 8 of the *Charter* and could result in a court awarding remedies against the health authority.

If a drinking water officer believes that it is necessary to enter a private dwelling and consent cannot be obtained, or it is not appropriate to request entry under the circumstances, a warrant should be sought. To obtain a warrant, an application must be made to a justice under section 41 of the Act. It states:

> If satisfied by evidence on oath or affirmation that access on or into property is necessary for the purposes of this Act, a justice may issue a warrant authorizing a person named in the warrant to enter on or into property and conduct an inspection, undertake hazard abatement or prevention activities or take other action as authorized by the warrant.

Legal counsel should be consulted regarding the form and process for applying for a warrant, as the Act does not prescribe the forms to be used.

Once a warrant is issued, it must be executed against the party to whom it is directed. When executing a warrant, the following principles and practices should be applied:

- The drinking water officer executing the warrant should be accompanied by at least one other person
- If the drinking water officer executing the warrant has any reason to believe that the property owner or occupant will not cooperate with the warrant, the drinking water officer should speak in advance with the local police or RCMP and request that a peace officer accompany the drinking water officer in the execution of the warrant
- Upon arrival at the property, the drinking water officer executing the warrant must attempt to advise the occupants of the property of the warrant. The drinking water officer should bring an additional copy of the warrant to leave for the occupant of the property
- If there is no one at the property that is able to allow physical access, the drinking water officer should attempt to execute the warrant at another time, unless there is some imminent danger to human health that would result from any delay in executing the warrant
- If there is a danger to human health that requires immediate attention and there is nobody at the property that is willing or able to provide the drinking water officer with access based on the warrant, entry to the property should be obtained with the assistance of a peace officer.

Warrants can also be obtained under the authority of the *Offence Act* and the *Public Health Act*. However, the relevant legal standards and process may differ somewhat from a warrant requested under the *Drinking Water Protection Act*. If a drinking water officer believes that the ability to obtain a warrant under section 41 of the *Drinking Water Protection Act* is not appropriate, they should discuss the matter with legal counsel before seeking a warrant under these other acts.

4.1.4 Reports that must be made by water suppliers and laboratories

Water suppliers are required to report various matters to a drinking water officer. This includes reports of monitoring under section 11 of the Act and any applicable operating permit requirements, reports made pursuant to emergency response plans (Act, section 10), and reporting of threats to drinking water (Act, section 13). Drinking water officers should consider all such information in assessing risks and deciding whether any further action is required under the act in relation to the relevant water supply system.

Reports may also be made by laboratories under section 12 of the Act where immediate reporting standards are not met.

To facilitate timely and effective reporting by laboratories, some health authorities have established protocols including a single number for the laboratories to call to discharge their obligations respecting reporting to the drinking water officer and medical health officer under section 12(3).

4.1.5 Reports that must be made by other officials

Section 24 of the Act allows the Lieutenant Governor in Council (Cabinet) to make regulations that would require specified public servants and public officials to report to a drinking water officer "any situation they observe, or of which they become aware that they consider may be a threat to drinking water".

No regulations have been developed in this regard to date. However, drinking water officers are encouraged to establish working relationships with other statutory decision makers, and to request other officials to provide information about threats to drinking water on a voluntary basis wherever possible. If a drinking water officer believes that it is not sufficient to rely on voluntary cooperation by other agencies in this regard, then they should discuss the matter with their Senior Manager. The Senior Manager may wish to refer the matter for consideration by the Drinking Water Leadership Council, which may consider making recommendations to government respecting the development of regulations to compel such reporting.

4.2 Obtaining further information

When a potential concern regarding drinking water is identified through routine monitoring, inspections or investigation, the drinking water officer must consider whether additional information is required to determine an appropriate response. There are several ways in which additional information can be obtained.

4.2.1 Additional monitoring, testing and laboratory reporting

Section 8(6) of the Act allows the drinking water officer to order a water supplier to undertake additional monitoring or testing, if the drinking water officer considers that further information is necessary to determine whether the water supplied by the system meets the requirements of section 6 [potable water] or the requirements and standards established by the Regulation and operating permit. Further technical guidance on additional monitoring and testing can be found in Part B of this guide.

Additional monitoring and reporting requirements can be imposed without amending the operating permit itself. Where such an order is made, no particular form is required. However,

- The order should be made in writing,
- It should specify that the order is being made under the authority of section 8(6) of the Act,
- It should specify the precise type and frequency of monitoring or testing required, and
- It should specify the manner in which the results must be reported to the drinking water officer and, if directed by the drinking water officer, the public as well.

Further, section 8(5) of the Regulation allows a drinking water officer to request laboratories to provide the drinking water officer, the water supplier, or both, with listings of all water samples sent by the water supplier, and the results of testing for total coliform and *Escherichia coli*. Drinking water officers may exercise this power simply by contacting the laboratory in question.

Where potential concerns exist in relation to Point-of-Entry or Point-of-Use systems, drinking water officers have the following options available in terms of obtaining additional information:

- Request the end user to monitor voluntarily
- Require the water supplier who provides water to the Point-of-Entry or Point-of-Use systems to monitor the water, either

  (a) Before the water enters the Point-of-Entry or Point-of-Use systems, or

  (b) After those systems provided that the person using the Point-of-Entry or Point-of-Use system is prepared to provide the water supplier with access for sampling purposes

- Order a person causing or contributing to a health hazard to provide information and undertake tests under section 25(3)(a) and (b) of the Act (provided the drinking water officer has reason to believe a health hazard exists or is imminent as per section 25(1)).

4.2.2 Assessments

Under Part 3 of the Act, a drinking water officer can require a water supplier to complete a water source and system assessment. The drinking water officer can order a water supplier to prepare an assessment if

> the drinking water officer has reason to believe that an assessment is necessary to properly identify and assess threats to drinking water in relation to the water supply system (section 19(1)(a)).

The term "threat" is defined in section 1 of the Act to mean:

> in relation to drinking water, a condition or thing, or circumstances that may lead to a condition or thing, that may result in drinking water provided by a domestic water system not being potable water

In deciding whether an assessment should be ordered, it is important to recognize that the purpose of an assessment is, according to section 18(2):

> .... to identify, inventory and assess:
>
> (a) the drinking water source for the water supply system, including land use and other activities and conditions that may affect that source,
>
> (b) the water supply system, including treatment and operation,
>
> (c) monitoring requirements for the drinking water source and water supply system, and
>
> (d) threats to drinking water that is provided by the system.

Circumstances in which an assessment might be appropriate include, but are not limited to, situations where there has been:

- A history of malfunctions or threats to drinking water from the water supply system
- A history of boil water orders / advisories
- A history of threats to drinking water in the area
- Significant changes in the quality of water in a water supply system
- Problems experienced by water suppliers in similar circumstances
- Impacts or potential impacts to the quality of the water source (e.g., nearby development or resource extraction)
- More than the prescribed number of years have passed since the previous assessment [there is nothing in the Regulation at present]

In deciding whether an assessment is necessary, the drinking water officer may wish to consult with the medical health officer, and should also consult the water supplier. However, it is not necessary to obtain the consent of a water supplier before ordering an assessment.

The drinking water officer can order two or more water suppliers to prepare a joint assessment if they use the same drinking water source or related sources (Act section 19(2)).

4.2.2.1 Process for assessments

Neither the Act nor the Regulation set out the specific process by which an assessment must be completed. Consequently, the process, preparation, form, content, area of coverage and time for completing an assessment must be done in accordance with the directions of the drinking water officer. In determining which directions to give, the drinking water officer must consult the medical health officer, and may establish a technical advisory committee (Act, section 20).

As guidance to drinking water officers and water suppliers in relation to assessments, the Ministry of Environment and Climate Change Strategy and the Ministry of Health developed three assessment tools for consideration. These are the Drinking Water Source-to-Tap Screening Tool (appendix 6), the Water Supply System Assessment (appendix 7) and the Comprehensive Drinking Water Source-to-Tap

Assessment Guideline (appendix 8).[49] These documents were on the basis of extensive consultation with water suppliers, industry and interested government agencies, and have been the subject of peer review and comment. Drinking water officers are encouraged to use these tools when they believe an assessment is required. There is no legal requirement that the drinking water officer require suppliers to use these specific tools, and if the drinking water officer believes that some other form of assessment is required, the drinking water officer should modify or replace these tools with the process and requirements the drinking water officer considers appropriate in the circumstances.

Where a drinking water officer orders a water supplier to complete an assessment, the drinking water officer must write a letter to the water supplier explaining that they are required to complete the assessment pursuant to section 19 of the Act. The letter must also indicate the process, form, content and area of coverage for the assessment. Where the tools referenced above are used, some of this information will be apparent from the tool itself, but it is the responsibility of the drinking water officer to ensure that the correspondence provides the information necessary for the water supplier to reasonably understand the requirements. The letter must also indicate the date by which the results of the assessment must be provided to the drinking water officer, and what form of public notice of the assessment is required (see section 21 of the Act).

As a matter of administrative fairness, the drinking water officer must provide the water supplier with an opportunity to make their views known before the decision to order an assessment (including the process for the assessment, form, scope of coverage, time frames etc.) is finalized. Although this consultation may occur though discussions, drinking water officers should also consider sending written correspondence to this effect. Appendix 9 sets out a sample letter for this purpose.

Finally, drinking water officers may consult with water suppliers regarding potential threats and remedial actions, without necessarily ordering a formal assessment under section 19. This may be particularly important for smaller systems with limited financial resources. In such cases, the Drinking Water Source-to-Tap Screening Tool (appendix 6), the Water Supply System Assessment (appendix 7) and the Comprehensive Drinking Water Source-to-Tap Assessment Guideline (appendix 8) can still be used.

Similarly, water suppliers may also be interested in undertaking assessments on their own initiative, and in such cases drinking water officers should consider providing the water suppliers with copies of, or references to, the Drinking Water Source-to-Tap Screening Tool, the Water System Assessment and the Comprehensive Drinking Water Source-to-Tap Assessment Guideline .

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[49] The Screening Tool is a simple questionnaire that suppliers can complete themselves. The Comprehensive Assessment Guideline is intended for professionals who are investigating more complex risks to water supply systems. The Water System Assessment fills a gap between the Screening Tool and the Comprehensive Assessment Guideline. The intention is to offer an alternative that will allow for developing an action plan to reduce risks to and in a water system, without the added cost and time commitment of a comprehensive assessment.

4.2.2.2 Assessment follow-up

The drinking water officer should review each assessment to determine whether it has identified threats to the drinking water provided by the water supply system. If no such threats are identified, no further action is required.

If threats to the drinking water provided by the water supply system are identified, the drinking water officer should consider whether any changes to the terms and conditions of an operating permit are required, or whether an assessment response plan should be prepared (Act, section 22). Section 22(4) of the Act notes that the drinking water officer can require an assessment response plan to include provisions respecting any or all of the following:

(a) Public education and other means of encouraging drinking water source protection;

(b) Guides to best management and conservation practices;

(c) Infrastructure improvements;

(d) Cooperative planning and voluntary programs;

(e) Input respecting local authority zoning and other land use Regulation.

When ordering an assessment response plan, the drinking water officer should ask that the plan set out proposed responses to the threats identified by the assessment. In addition, section 15 of the Regulation requires that all assessment response plans include provisions to identify, eliminate and prevent cross-connections with non-potable water sources.

An assessment response plan must be submitted to the drinking water officer, who should review it relative to the threats identified in the assessment. If the drinking water officer is not satisfied the assessment response plan will address the threats, she or he can order the water supplier to review and revise it in accordance with the directions of the drinking water officer.

In every case where an assessment has been completed, the information obtained by the assessment (and the steps to be taken under an assessment response plan, if any) must be included in the appropriate physical file and electronic data storage systems.

4.3 Preventative and remedial action

Under the Act, there is wide range of preventative or remedial actions that can be taken by drinking water officers where a concern is identified. It is important that drinking water officers consider this full range of options and determine which may be appropriate in any particular circumstances. The specific options available, and general considerations of the circumstances in which they may be appropriate, are set out in the sections below.

There are other preventative and remedial actions that may be ordered or undertaken under other legislation that may have a positive impact on drinking water (See Chapter 5, section 5.3). Although drinking water officers will not have authority under those other acts (with a few exceptions to the

Water Sustainability Act, discussed in Chapter 5, section 5.3), they should be aware of and consult other agencies in cases when they consider that appropriate.

4.3.1 Amending an operating permit

This option should be used when the drinking water officer believes it is important to change the legal requirements imposed upon a particular water supplier. Amendments can help ensure that the water supplier knows exactly what is required of them, and to help ensure that water suppliers understand that taking the action specified is essential to meeting their legal obligations. Amending terms and conditions of an operating permit may also make enforcement action easier in the future, if necessary, as it may be easier to prove a violation of the specific term and condition of an operating permit, rather than some other potential violations of the Act that are more generally described (or example, the requirement to provide potable water that is "safe to drinking and fit for domestic purposes without further treatment.").

Any amendment of an operating permit must occur in accordance with section 8(4) of the Act, which requires prior consultation with the water supplier. In any such consultations, the drinking water officer must allow the water supplier to state their views as to whether amendments are required. Further, the drinking water officer may wish to discuss and solicit ideas from the water supplier as to the most efficient and effective means of addressing the drinking water officer's concerns if there are a variety of possible ways to do so. The drinking water officer should not avoid amending an operating permit in a manner they considers necessary simply because the water supplier may be unwilling to comply, or have difficulty with complying with the amended permit.

4.3.2 Order to review and update emergency response and contingency plan

This option might be appropriate to consider in cases where there is no immediate concern about a drinking water health hazard[50], but there is some concern about the ability of the operator to respond appropriately in emergency situations.

Even if a drinking water officer believes that a review and update of an emergency response and contingency plan is required, it may not be necessary to issue a formal order under the Act in all cases. [51] In practice, it may be sufficient for the drinking water officer to simply discuss the matter with the water supplier and allow the supplier an opportunity to amend the plan.

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[50] The term "drinking water health hazard" is defined in section 1 of the Act to mean:
(a) a condition or thing in relation to drinking water that does or is likely to
(i) endanger the public health, or
(ii) prevent or hinder the prevention or suppression of disease,
(b) a prescribed condition or thing, or
(c) a prescribed condition or thing that fails to meet a prescribed standard;

[51] A sample Emergency Response and Contingency Plan can be found in Appendix 2 (Part C) of this Guide.

If, however, the drinking water officer believes the water supplier is not likely to review and update the plan voluntarily, the drinking water officer should consider making a formal order under the Act. There is no specific form by which an order must be made, but it should be made in writing and should specifically indicate that it is an order under section 10(2) of the Act.

4.3.3 Order for public notice of threats to drinking water

Under section 14 of the Act, the drinking water officer can request or order a water supplier to give public notice, in the manner approved by the drinking water officer, if:

- The drinking water officer has received a report from a laboratory indicating that an immediate reporting standard is not being met (as per section 12)
- The drinking water officer has received a report from a water supplier concerning threats to drinking water (as per section 13), or
- The drinking water officer considers there is, was or may be a threat to the drinking water provided by the water supply system

The term "threat" is defined very broadly in the Act to mean:

> In relation to drinking water, a condition or thing, or circumstances that may lead to a condition or thing that may result in drinking water provided by a domestic water system not being potable water.

Drinking water officers should engage in dialogue about "public notice" provisions prior to the need for an order (e.g., at a time when no public notice is required). The water supplier is obligated to protect public health from threats to the drinking water (see Act, section 14(2)). The dialogue should seek consensus on the circumstances requiring public notice as well as the manner by which the public notice shall be issued. This dialogue should strive to result in the water supplier issuing a public notice without the need for a drinking water officer to make an order.

The power to order public notice also exists under the hazard abatement and prevention orders section of the Act (section 25(3)(f)). However, the powers under section 25 differ from the powers under section 14 in two important ways:

- An order under section 14 may be issued in the circumstances where the drinking water officer believes there is, was or may be a "threat". By contrast, an order under section 25 can only be made where a drinking water health hazard exists, or there is a significant risk of an imminent drinking water health hazard.
- An order under section 25 is subject to a request for review and reconsideration under section 39.1 of the Act, whereas an order under section 14 is not subject to section 39.1.

4.3.3.1 What is the threshold necessary to request or order public notice?

Generally, public notice of some form may be appropriate when:

- Monitoring indicates:
    - There is detectable fecal coliform or *E-coli* per 100 ml (see Regulation, schedule A)

  - The detectable total coliform levels exceed those permitted under the Regulation for sample frequency (see Regulation, schedule B)
  - Testing has indicated the presence of some other bacteria, viruses or parasites that has a potential to cause health concerns and which may be addressed by boiling the water (such as *Cryptosporidium, Giardia, Campylobacter, Shigella*).
  - A turbidity event is likely to impede a system's capacity to disinfect, or the source of turbidity is related to an event that is likely to introduce pathogenic microorganisms into the water. (see Part B: Decision Tree for Responding to a Turbidity Event in Unfiltered Drinking Water of this guide)
- There is evidence of disease in the community and drinking water is suspected as the source of infection.
- An event has occurred that compromises the treatment and distribution systems, or which compromises the water source that is not reasonably expected to be addressed by the treatment system. These situations could include introduction of substances into water sources, breaks in water pipes, cross connections or natural disasters.
- A water supply system is using untreated surface water or groundwater that is at risk of containing pathogens, contrary to section 5 of the Regulation.

This list is not exhaustive and there may be other circumstances in which drinking water officers consider public notice appropriate. [52]

When making decisions about requiring public notice of a threat to drinking water, drinking water officers must always be guided solely by consideration of public health protection. Expense, inconvenience, or other concern of a water supplier or water users is not a sufficient reason to avoid issuing public notice if the drinking water officer considers that necessary to ensure protection of public health. However, drinking water officers should ensure that where they believe the public notice is required, they are able to provide a rationale for this determination.

The drinking water officer should strive for consensus on the need for the order and the specific language of the order with the water supplier. The drinking water officer should provide the water supplier with an opportunity to make their views known and considered where possible, provided that no significant delay occurs on this account that could prejudice public health protection. In addition to meeting the tests of administrative fairness, this approach will, in most cases, result in better relations with the water supplier, and will ensure that public health requirements are dealt with in a manner that addresses the water supplier's interests and concerns to the extent possible in the circumstances.

Drinking water officers should consider consulting with the medical health officer before requiring public notice, unless such consultations cannot be completed immediately and any delay would cause unacceptable risks to public health.

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[52] For additional reference materials on issuing boil water notices, see the Health Canada document, *Guidance for Issuing and Rescinding Boil Water Advisories in Canadian Drinking Water Supplies*, found at https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-issuing-rescinding-boil-water-advisories-canadian-drinking-water-supplies.html.

4.3.3.2 Internal communication systems to ensure timely action

All drinking water officers should have an appropriate contact system in place to ensure they can be contacted and take action under section 14 in a timely manner as appropriate. This should include identification of alternate persons who may act in a particular area when the drinking water officer is unavailable.

4.3.3.3 Request or order

Section 14 of the Act provides that the drinking water officer can "request" or "order" that a water supplier provide public notice in certain circumstances.

In general, a request may be appropriate in circumstances where the water supplier is in support of the public notice and is prepared to do so without any formal order. Where the drinking water officer is not sufficiently certain that a water supplier will comply with a request, an order should be used. A failure to comply with an "order" constitutes an offence under section 45(1) of the Act.

A sample form Order Respecting Public Notice is set out in appendix 10. A sample form Request Respecting Public Notice is set out in appendix 11.

Finally, notices may be issued by water suppliers on their own initiative whenever they deem that appropriate, even if a drinking water officer has not requested or ordered that to occur. Water suppliers are required to provide public notice without any request or order by the drinking water office if the water supplier has received a report that an immediate reporting standard is not met or they consider that there may be a drinking water health hazard in relation to the drinking water and they are not able to immediately contact a drinking water officer (Act, section 14(2)).

4.3.3.4 Type of notice

In the past, public health officials have implemented some form of boil water advisory when testing indicated the presence of fecal coliform or E-coli. However, some concerns have been expressed about this practice, including the following:

- Different regions used different, and at times inconsistent, terminology (e.g. boil water advisories, boil water notices, water use advisories) so the public had difficulty understanding the specific meaning and consequences of such notice
- A zero tolerance policy was adopted that resulted in boil water advisories or notices being issued in circumstances where some questioned the need for that step to be taken
- Boil advisories or notices are not in any event sufficient to address threats that are not neutralized by boiling

Given these concerns, and the fact that section 14 of the Act (and section 25, discussed below) provides broad discretion to drinking water officers regarding the type of public notice required, drinking water officers should consider use of the following range of public notice options, and should require whichever is appropriate to the facts of a particular case. If the drinking water officer believes some other form of notice should be used, they should request or order this, but should be able to rationalize the decision to require some form of notice other than those set out below.

Water Quality Advisory

A "Water Quality Advisory" should be used where a drinking water officer determines there is some level of risk associated with water use, but the circumstances do not warrant a "Boil Water Notice" or "Do Not Use Water Notice", discussed below. A Water Quality Advisory should specify the nature of the risk presented, steps that the water supplier is taking or is required to take to address them, and steps that water users may take in the meanwhile to minimize the risk associated with that water.

Boil Water Notice

A "Boil Water Notice" should be used when a drinking water officer determines that there is a risk associated with consumption of water, and that risk can be adequately addressed by boiling the water in accordance with the notice, prior to human consumption. The notice should contain specific instruction regarding boiling requirements, and the steps that the water supplier is taking or is required to take to address the risks that exist other than through use of the boil water notice.

A sample form of Boil Water Notice and the information to be included in it is set out in appendix 12.

Do Not Use Water Notice

A "Do Not Use Water Notice" should be used when a drinking water officer identifies there is a risk associated with consumption of water, and that risk cannot be adequately addressed by boiling the water or issuing a Water Quality Advisory. This might include, for example, circumstances in which unacceptable levels of nitrates or lead are detected in the water, or where there is concern that a water system may have been subject to vandalism, accidents (such as chemical spills) or natural events such as mudslides or earthquakes. In some cases, it may be appropriate for the notice to specify those specific types of water use that are not acceptable (e.g. in some circumstances it may be acceptable to use water for showering, but nor for human consumption.)

A sample form of Do Not Use Water Notice and the information to be included in it is set out in appendix 13.

Guidance for determining appropriate form of notice

In deciding which form of notice to require, the drinking water officer must conduct a risk assessment. This should be undertaken in consultation with the medical health officer and other public health officials the drinking water officer considers appropriate. It should involve consideration of all relevant matters. This may include, but is not limited to, matters such as:

- The degree to which it has been determined that a health hazard does exist in relation to the water (e.g., has only one of numerous samples indicated a low presence of fecal coliform, or presence of *E. coli*, is presence found in multiple samples, or is the presence at a high level even if only one sample?)

- The severity of harm that may result from consumption of the water in question
- The degree to which each type of notice would serve to address the threat
- Past history of the water source and water supply system in question
- Recent operational factors

Some of the specific issues typically considered by officials that may fall within the above noted principles include:

Background

- ❑ Type of water system
- ❑ Type of treatment
- ❑ Integrity of water supply system
- ❑ Size of system - number of connections
- ❑ Population served - type

Operational Information

- ❑ Certified operators
- ❑ Operations history
- ❑ Cross connection control
- ❑ Age of infrastructure
- ❑ Water conservation requirements
- ❑ Fire flow requirements
- ❑ Potential to isolate parts of water system
- ❑ Time involved for complete changeover of water
- ❑ Significant deterioration in source water quality
- ❑ Equipment malfunction during treatment or distribution
- ❑ Situations where operation of the system would compromise public health

Monitoring Information

- ❑ Known or suspected communicable disease outbreak in community
- ❑ Recent raw water quality events
- ❑ Monitoring records
- ❑ Chlorine residual records
- ❑ Turbidity records
- ❑ Public health inspector /drinking water officer inspection
- ❑ Public health engineer inspection
- ❑ Inadequate disinfection or disinfection residuals
- ❑ Unacceptable microbiological quality
- ❑ Unacceptable turbidities or particle counts

Sampling Information

- ❑ Sample location
- ❑ Sampling procedures and changes
- ❑ Sample shipping
- ❑ Re-sampling time element

- ❑ Lab certification
- ❑ Confidence in lab results
- ❑ Number of samples taken/available
- ❑ New Sampler

Seasonal Information

- ❑ Weather conditions
- ❑ Drought conditions

4.3.3.5 Process for ensuring compliance with a public notification order

Given the importance of public notice to the protection of public health, drinking water officials should develop and document a plan for ensuring implementation of all public notification orders issued under sections 14 or 25. The specific measures that will be appropriate may vary with individual cases, depending on the nature of the risk, the vulnerability of the population at issue and other relevant factors. As such, it is ultimately for the drinking water official to decide what steps are appropriate. In making this decision, drinking water officials should consider the following possible steps, as well as any others they may consider appropriate:

- Contacting people within the affected community to determine if they have received notification
- Visiting the affected community at the earliest opportunity (and in any case no more than 48 hours after the order is issued) unless timely physical attendance is impracticable. In the latter case, other means should be explored to obtain the type of information that would have normally been obtained from personal attendance (such as requesting a local government official to attend and advise the drinking water officer of the results).

Drinking water officials should document all steps taken to ensure compliance with a public notification order.

Where non-compliance with a public notification order is found, the drinking water officer should take other remedial compliance action in accordance with this guide. The drinking water officer should also consider alternate means to ensure public notification occurs in a timely manner, such as posting information on the health authority's website, alerting local governments and media or providing information directly to affected persons.

4.3.3.6 Rescinding public notification orders

In assessing whether a public notification order should be rescinded, the drinking water officer should consider, in consultation with the medical health officer and other public health officials as appropriate:

- Whether the problem or threat has been fully identified
- Whether the problem or threat has been resolved

- Whether the relevant microbiological quality, turbidity, particle counts or disinfectant residual of the treated water in at least two consecutive sets of samples has returned to an acceptable level;
- Whether sufficient water changeover or flushing has occurred in the distribution system to eliminate any remaining contaminated water.[53]

When the drinking water officer determines that a public notification order may be rescinded, the drinking water officer should communicate that decision to the water supplier.

To minimize any potential for misunderstanding about whether and when an order has been rescinded, drinking water officers should ensure that all parties are aware that the order will remain in force unless and until it is rescinded in writing. A statement to this effect should be included in the original order.

4.3.4 Order flood proofing of well

Section 16(1) of the Act and section 14 of the Regulation provide that wells that supply water to a drinking water supply system must be flood proofed if they are identified in an assessment (under section 19) as being at risk of flooding. In some cases, other wells may also have the potential to affect the water supply system in question. Drinking water officers can also require flood proofing of those other wells (see section 16 (2)).

In addition to the drinking water officer's ability to order flood-proofing of wells under section 16 of the *Drinking Water Protection Act*, the well protection provisions of the *Water Sustainability Act* and Groundwater Protection Regulation may also be relevant (see Chapter 5, section 5.3 of this guide).

4.3.5 Hazard abatement and prevention orders

These powers are found in section 25 of the Act. It contains a broad range of orders that can be made when the drinking water officer has reason to believe that a drinking water health hazard exists, or there is a significant risk of an imminent drinking water health hazard (section 25(1)).

Such orders can be made against any person who falls within the terms of section 25(2), and must be served on the person (see section 25(4) and 46 regarding service). Orders can be served by the means described in section 3 of the Public Health Inspections and Orders Regulation under the *Public Health Act* (including registered mail and email, so long as the section 3 requirements are met). Section 80(1) of the *Public Health Act* states that if health officers are given powers under another enactment, this Act and its regulations apply to the exercise of those powers. Therefore, they may rely upon the Public Health Inspections and Orders Regulation to serve orders made under the DWPA.

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[53] For additional reference materials on rescinding boil water notices, see the Health Canada document, *Guidance for Issuing and Rescinding Boil Water Advisories in Canadian Drinking Water Supplies*, found https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-issuing-rescinding-boil-water-advisories-canadian-drinking-water-supplies.html.

Hazard abatement and prevention orders can, in urgent situations, be issued orally, to be followed in writing as soon as possible thereafter (section 25(7)).

Although there are no specific requirements in the Act to provide prior notice to a person before a hazard abatement or prevention order is issued, this should be done in any case where it can be done without significant threat to public health. In cases where a delay would cause significant risks to public health, the order should be made immediately, but the person should, immediately thereafter, be given an opportunity to present their views as to whether the order is required, and whether the specific requirements of the order are appropriate in the circumstances.

The range of remedies that can be ordered is set out in section 25(3).

If the person to whom the order is addressed fails to take the action required, then the drinking water officer can, under section 27, take further steps to ensure it occurs. This is discussed further below in section 4.3.8.

A sample of a hazard abatement and prevention order is set out in appendix 14.

(Note: Section 25(5) and (8) – (10) contain other provisions respecting contravention Orders that might potentially be relevant in some cases, and must be considered any time an Order is issued.)

Violations of orders under section 25 can be made the subject of a violation ticket. As such, enforcement action can be taken without the need to prepare a report to Crown Counsel and without the need for any approval by Crown Counsel to pursue charges in court.

4.3.6 Orders under the Public Health Act

Section 2(2) of the *Drinking Water Protection Act* states:

> Nothing in this Act affects the powers, duties and functions of a medical health officer under the *Public Health Act* or any other enactment

Consequently, any of the powers that a public health official holds under the *Public Health Act* continue in respect of drinking water matters, if the relevant provisions of the *Public Health Act* are applicable to the facts of the case.

One of the most significant parts to consider in this regard is Division 4 of Part 4 of the *Public Health Act*:

4.3.6.1 When orders respecting health hazards and contraventions may be made

30 (1) A health officer may issue an order under this Division only if the health officer reasonably believes that

(a) a health hazard exists,

(b) a condition, a thing or an activity presents a significant risk of causing a health hazard,

(c) a person has contravened a provision of the Act or a regulation made under it, or

(d) a person has contravened a term or condition of a licence or permit held by the person under this Act.

(2) For greater certainty, subsection (1) (a) to (c) applies even if the person subject to the order is complying with all terms and conditions of a licence, a permit, an approval or another authorization issued under this or any other enactment.

4.3.6.2 General powers respecting health hazards and contraventions

31 (1) If the circumstances described in section 30 *[when orders respecting health hazards and contraventions may be made]* apply, a health officer may order a person to do anything that the health officer reasonably believes is necessary for any of the following purposes:

(a) to determine whether a health hazard exists;

(b) to prevent or stop a health hazard, or mitigate the harm or prevent further harm from a health hazard;

(c) to bring the person into compliance with the Act or a regulation made under it;

(d) to bring the person into compliance with a term or condition of a licence or permit held by that person under this Act.

(2) A health officer may issue an order under subsection (1) to any of the following persons:

(a) a person whose action or omission

(i) is causing or has caused a health hazard, or

(ii) is not in compliance with the Act or a regulation made under it, or a term or condition of the person's licence or permit;

(b) a person who has custody or control of a thing, or control of a condition, that

(i) is a health hazard or is causing or has caused a health hazard, or

(ii) is not in compliance with the Act or a regulation made under it, or a term or condition of the person's licence or permit;

(c) the owner or occupier of a place where

(i) a health hazard is located, or

(ii) an activity is occurring that is not in compliance with the Act or a regulation made under it, or a term or condition of the licence or permit of the person doing the activity.

4.3.6.3 Specific powers respecting health hazards and contraventions

32 (1) An order may be made under this section only

(a) if the circumstances described in section 30 *[when orders respecting health hazards and contraventions may be made]* apply, and

(b) for the purposes set out in section 31 (1) *[general powers respecting health hazards and contraventions]*.

(2) Without limiting section 31, a health officer may order a person to do one or more of the following:

(a) have a thing examined, disinfected, decontaminated, altered or destroyed, including

(i) by a specified person, or under the supervision or instructions of a specified person,

(ii) moving the thing to a specified place, and

(iii) taking samples of the thing, or permitting samples of the thing to be taken;

(b) in respect of a place,

(i) leave the place,

(ii) not enter the place,

(iii) do specific work, including removing or altering things found in the place, and altering or locking the place to restrict or prevent entry to the place,

(iv) neither deal with a thing in or on the place nor dispose of a thing from the place, or deal with or dispose of the thing only in accordance with a specified procedure, and

(v) if the person has control of the place, assist in evacuating the place or examining persons found in the place, or taking preventive measures in respect of the place or persons found in the place;

(c) stop operating, or not operate, a thing;

(d) keep a thing in a specified place or in accordance with a specified procedure;

(e) prevent persons from accessing a thing;

(f) not dispose of, alter or destroy a thing, or dispose of, alter or destroy a thing only in accordance with a specified procedure;

(g) provide to the health officer or a specified person information, records, samples or other matters relevant to a thing's possible infection with an infectious agent or contamination with a hazardous agent, including information respecting persons who may have been exposed to an infectious agent or hazardous agent by the thing;

(h) wear a type of clothing or personal protective equipment, or change, remove or alter clothing or personal protective equipment, to protect the health and safety of persons;

(i) use a type of equipment or implement a process, or remove equipment or alter equipment or processes, to protect the health and safety of persons;

(j) provide evidence of complying with the order, including

(i) getting a certificate of compliance from a medical practitioner, nurse practitioner or specified person, and

(ii) providing to a health officer any relevant record;

(k) take a prescribed action.

(3) If a health officer orders a thing to be destroyed, the health officer must give the person having custody or control of the thing reasonable time to request reconsideration and review of the order under sections 43 and 44 unless

(a) the person consents in writing to the destruction of the thing, or

(b) Part 5 *[Emergency Powers]* applies.

4.3.6.4 Ordering others to comply and entering to take action

33 (1) If a health officer is not satisfied that a person is adequately complying with, or has adequately complied with, an order, the health officer may

(a) if the person is the owner of the place in respect of which the original order was issued, order an occupier of the place to comply with the original order,

(b) if the person is an occupier of the place in respect of which the original order was issued, order the owner of the place to comply with the original order, or

(c) take action to prevent or remove, or mitigate the harmful effects of, the health hazard that is the subject of the original order, including authorizing a person to carry out work on behalf of the health officer.

(2) Subject to subsection (3), a health officer who has issued an order, or a person acting on behalf of the health officer, may enter on or into a place that is subject to the order for the purpose of taking an action under subsection (1) (c).

(3) Section 25 [entering to inspect] applies to entry under subsection (2) as if the health officer, or the person acting on behalf of the health officer, were making an inspection of the place.

4.3.6.5 Duties to comply with orders

> **42** (1) A person named or described in an order made under this Part (Part 4) must comply with the order.

4.3.6.6 Violations of orders under Part 4 of the *Public Health Act*

Violations of orders under Part 4 of the *Public Health Act* can be made the subject of a violation ticket. As such, enforcement action can be taken without the need to prepare a report to Crown Counsel, or the need for any approval by Crown Counsel to pursue charges in court.

4.3.7 Direct action by drinking water officer

In some cases, the test for issuing a hazard abatement and prevention order may be met, but there is no person against whom an order under section 25 can appropriately be made. In these circumstances, section 28 of the *Drinking Water Protection Act* specifically authorizes the drinking water officer to take actions to address the health hazard or to authorize a water supplier or other person to do this. This section is very similar to the power to order remedial action under section 27 of the Act (see section 4.3.8 of this guide), but actions under section 28 can be taken immediately, without the requirement of first determining that a person named in an order is in default.

Where action is taken under section 28 of the Act, the cost recovery provisions of sections 27(3) and (4) of the Act apply. However, given that the powers of this section are to be used only when the drinking water officer is not aware of a person against whom a hazard abatement and prevention order can be made, there may be little practical ability to seek cost recovery in these circumstances.

Drinking water officers should consult with their senior manager and the appropriate spending authority within the health authority before expending funds through direct action under section 28.

4.3.8 Action in default

Section 27 of the *Drinking Water Protection Act* provides that, if a person does not comply with a hazard abatement and prevention order (or a contravention order, as discussed below), the drinking water officer may advise the person that if they fail to take the action required, the drinking water officer can direct someone else to enter onto the property to do the work.

Where notice is given under section 27, before further steps are taken to remedy the matter, the drinking water officer should give the person reasonable time to respond. The amount of time that will be considered reasonable will depend on the circumstances and the nature of the threat posed, and is a matter for the drinking water officer's discretion.

Notice under section 27 should be given in writing wherever possible. If, however, it would cause unacceptable delay and risks to public health to provide notice in writing, then verbal notice should be given, with written notice to follow as soon as possible thereafter. A sample letter advising of that steps may be taken under section 27 is set out in appendix 18.

When a person becomes aware of the potential consequences to them under section 27, they may be more inclined to take the remedial action required. If, however, the person still refuses to take the action required, then the drinking water officer can authorize a person to go onto the property and do the work (section 27(3)). The Act does not specify who such a person may be, and it could be either a person employed by the health authority, or a third party.

Although subsection 3 allows the person who has done the work to claim the costs against the person to whom the order was made, in practice, it is not likely that a third party contractor will be prepared to undertake the work solely on the basis of the right to claim against the party that has refused to take the action required. In such cases, section 27 may only provide a practical remedy if the health authority is prepared to directly undertake the work, or to fund the third party contractor, and then seek costs against the person to whom the order was made.

Drinking water officers should discuss with their senior manager situations that may warrant action under section 27. Drinking water officers must also consult with the appropriate spending authority within the health authority before expending funds under section 27.

4.3.9 Cost recovery by health authority

If the health authority takes or funds action under section 27 of the Drinking Water , its ability to recover costs is not limited to recovery through court proceedings. Rather, subsection 4 provides that the costs and expenses may be recovered in accordance with section 35 of the *Public Health Act:*

4.3.9.1 Recovery of costs by health authorities

35 (1) If a health officer or health authority does work or contracts for work to be done under section 33 (1) (c) *[ordering others to comply and entering to take action]*, the health officer or health authority may recover reasonable costs from the person who was subject to the original order by filing a certificate in the prescribed form in the Supreme Court.

(2) A certificate must be filed within 2 years of the work being done.

(3) A certificate must be signed by the health officer or the corporate executive officer of the health authority or their delegate, and must include all the following information:

(a) the details of the original order, including the date it was issued;

(b) the total amount owing;

(c) the name of the person who was subject to the original order;

(d) the date the costs were incurred, and the manner in which they were incurred.

(4) Subject to the regulations, a certificate has the same effect, and proceedings may be taken on it, as if it were a judgment of the Supreme Court for the recovery of a debt in the amount stated against the person who was subject to the original order.

(5) A certificate is

(a) admissible in any proceedings to recover the certified debt without proof of the signature or official position of the person appearing to have signed the certificate, and

(b) proof of the certified facts.

(6) A copy of the filed certificate must be served in the prescribed manner on the person who was subject to the original order.

(7) A person who has been served with a copy of the filed certificate under subsection (6) may, within 30 days of being served, request the Supreme Court to review, in accordance with the regulations, the amount owing.

(8) After reviewing the amount owing, the Supreme Court may rescind or modify the certificate if satisfied that the amount owing is not reasonable.

Cost recovery under section 27 of the Act is an option that is not frequently required or used. If a drinking water officer believes it may be appropriate to explore use of this option in a particular case, they should discuss the matter with the senior manager before taking any action in this regard.

4.3.10 Orders respecting contraventions

Section 26 of the Act sets out circumstances in which a drinking water officer can make an order directing a person to comply with the Act or regulations. It can be made if the drinking water officer has reason to believe that the person is in contravention of the Act or regulations. The section also sets out process for issuing such an order.

A contravention of the Act is an offense even in the absence of a contravention order. However, contravention orders further clarify and confirm the nature of an alleged contravention, and the specific action that the drinking water officer requires for the person to come into compliance with the Act and regulations. As such, they can be important tools for ensuring a person understands the gravity of a matter and for securing compliance. They may also assist in establishing an appropriate record for cases where further compliance action, including prosecution, is required. However, a contravention order does not itself institute any form of charge and court proceeding. Such proceedings may be initiated through a report to Crown Counsel and related decision by Crown Counsel to pursue charges for an offence. Violations of orders under section 26 can be made the subject of a violation ticket. As such, enforcement action can be taken without the need to prepare a report to Crown Counsel, and without the need for any approval by Crown Counsel to pursue charges in court.

A contravention order, like a hazard abatement and prevention order, can be made the subject of the "action in default" provisions of section 27, discussed in section 4.3.8 of the guide, if the person to whom it is addressed does not undertake the action required.

A sample form contravention order is set out in appendix 16.

4.3.11 Drinking water protection plans

In circumstances where monitoring or assessment results indicate a potential threat to drinking water that may result in a drinking water health hazard, and no other practicable measures are available under the Act to address or prevent the drinking water health hazard, a drinking water protection plan may be initiated under part 5 of the Act.

The decision whether to initiate a drinking water protection plan is one for the minister to make, upon recommendation of the provincial health officer (section 31 of the Act). Although the drinking water officer does not have authority to initiate a drinking water protection plan on their initiative, section 31(3) provides that the provincial health officer must consider whether to make a recommendation to the minister to initiate a drinking water protection plan if requested to do so by a drinking water officer.

Drinking water officers must consider all other options available under the Act before requesting the provincial health officer to consider recommending a drinking water protection plan. A drinking water officer should, however, make such a request in circumstances where they consider it appropriate. Drinking water officers should, particularly, be familiar with the types of matters that can be considered in a drinking water protection plan (see section 32), as well as the steps that can be taken to implement a drinking water protection plan once developed (see sections 35 – 38). These are significant powers that can be used to address complex and multifaceted drinking water protection problems as necessary.

There is no ability under the Act to allow people other than drinking water officers to request the provincial health officer to recommend that a plan be developed. However, section 31(4) provides that a local authority or water supplier can request a drinking water officer to make a request to the provincial health officer. If the drinking water officer is asked by a local authority or water supplier to do so, the drinking water officer must consider the request and should provide reasons as to whether or not a request will be made to the provincial health officer. If the request is made by a person other than a local authority or a water supplier, the person should be advised of the limits of section 31 (4) and advised that they should pursue the matter with the local authority and/or water supplier.

4.3.12 Reports of problems relating to provincial government action

Section 4.2 of the Act contains a unique provision respecting accountability for government action. Specifically, it provides that the provincial health officer must report to the minister on any situation that, in the opinion of the provincial health officer, significantly impedes the protection of public health in relation to drinking water and which arises in relation to the actions or inactions of government or government agencies. "Impeding protection of public health" means a situation where a policy or practice interferes with or threatens the ability of water supplier to deliver potable water, or interferes with or threatens a drinking water officer's ability to prevent a drinking water health hazard.

If a drinking water officer is aware of any situation that impedes the protection of public health which arises in relation to the actions or inactions of government or government agencies, that has not been resolved, the drinking water officer should discuss the situation with the senior manager and the medical health officer, who may wish to advise the provincial health officer accordingly. The following information should be identified to the PHO for consideration:

- Identify and document the public health concern resulting from impediment
- Identify what policy or decision is creating the impediment
- Identify steps that have been taken to resolve the impediment, who has been engaged, and why a resolution has not been successful

The provincial health officer will review the information submitted and make a decision on whether to move the issue forward under Section 4.2. Situations brought to the attention of the provincial health officer may include specific isolated problems as well as ongoing systemic problems.

As the senior public health official, the provincial health officer holds the discretionary authority to assess what constitutes a significant impediment. That said, the following information provides guidance on the types of situations that may significantly impede the protection of public health in relation to drinking water and arises in relation to actions or inaction of one or more ministries, government corporations or other agents of the government. Such situations include but are not limited to:

- Government policies, guidelines, legislation and/or statutory decisions that
  - Hamper a drinking water officers' ability to uphold the DWPA and take action to prevent a health hazard related to drinking water from occurring
  - Impede an investigation or assessment under the DWPA
  - Impede water supply system owners and/or operators from being able to meet legislative requirements under the DWPA
  - Conflict with the DWPA or its regulation
- Statutory decisions and/or authorizations under an enactment that in the opinion of a DWO create or may lead to the creation of a health hazard relating to drinking water
- Failures of a government agency to:
  - Inform a drinking water officer and/or water supplier of a situation or activities creating a health hazard relating to drinking water or that has the potential to create a health hazard relating to drinking water.
  - Follow and/or enforce policies, guidelines, objectives, or legislation that protects drinking water.

4.3.13 Problem systems

4.3.13.1 Systems where ownership responsibilities are not clear or no apparent owner exists

One of the most challenging situations facing drinking water regulators is systems for which no apparent owner exists, and for which some form of action or improvement to the system is required to address threats to drinking water. In addressing these situations, it is important to remember that the definition of an "owner" of a water supply system in section 1 of the Act is broad, and it is not exhaustive. This means that there may be some people who, in specific circumstances, might be considered an "owner" under the Act, even if they might not be considered an owner in the common use of that term.

If a drinking water officer is uncertain as to who is an "owner" of the system as that term is defined in section 1 of the Act, the drinking water officers should contact the users of the system, asking them for information in this regard. This may be done verbally, or in writing. Where this is done in writing, drinking water officers may wish to consider using the sample letter set out in appendix 17.

If the drinking water officer identifies a person that the drinking water officer believes may fall within the definition of owner in the Act, but the person is not aware of this or is unwilling to acknowledge this responsibility, the drinking water officers should advise the person, indicating the tentative position of the drinking water officer in this regard, and asking the person to provide their views in respect of the matter. This may be done verbally, or in writing. Where this is done in writing, drinking water officers may wish to consider using the sample letter set out in appendix 18.

In any case where a drinking water officer is not able to determine any owner in relation to a system, they should discuss the matter with the senior manager. The purpose of such consultations would be to confirm that there is no "owner" for the purposes of the Act and, if there is no legal "owner," to consider possible options and strategies for addressing public health threats in relation to that system.

While owners are the persons ultimately responsible for ensuring a system complies with the Act, this does not mean that remedial action under the Act can only be directed at owners. Rather, the hazard abatement and prevention orders under section 25 can, in appropriate cases, be directed at persons other than owners (discussed in section 4.3.5 of the Guide).

4.3.13.2 Systems for which the owner is unable or unwilling to address the concerns

In situations where an owner is identified, but the owner is unable or unwilling to take the remedial action required, the drinking water officer should draw to the owner's attention to their obligations under the Act, as well as the potential actions that can be taken in relation to them. Generally, this information should be provided in writing. It should be provided not for the purposes of in any way threatening the owner, but to ensure that they are fully aware of their obligations. The person should also be advised that the drinking water officer is not willing or able to simply avoid taking action on the basis that there may be negative financial consequences for various parties.

Providing this information in writing to water suppliers may help those persons better understand the nature and extent of their obligations, and the consequences of failure to comply. Equally importantly, it may also assist water suppliers in engaging in discussions with the users of the system, with the view towards finding an acceptable means of addressing and funding the concerns with the water system.

While drinking water officers must not assume responsibility for solving all problems associated with water systems and the funding of them, the drinking water officers may consider providing basic referrals and information if that would be of assistance to people in certain situations. For example, this may include:

- Referring owners and water users to the local government to consider if there is a potential for the system to be taken over by the local government, with funding to be amortized over the long term through mechanisms such as the establishment of a local service area under Part 7, Division 5 of the *Community Charter*, or other such options
- Referring the owners and water users to the Ministry of Municipal Affairs to determine whether there is any potential for the water system to apply for financial assistance under the Canada / BC infrastructure program, if the systems were to be taken over by a local government
- Providing basic information about possible types of water systems and treatment systems, and recommending consultation with vendors of water supply / treatment systems, or professional engineers (without recommending particular vendors or suppliers)

4.3.13.3 Systems for which no operating or construction permit has ever been issued

Construction or operation of a water supply system without an applicable permit may constitute a violation of the Act[54] and should be addressed in accordance with the Health Authority's compliance policy.

The appropriate response under the compliance policy will depend on various factors such as the degree of threat to public health, history of the conduct of the water supplier, and the willingness of the water supplier to bring the system into compliance with the Act and Regulation.

Options for response may include:

- Informal discussions and education
- Contravention order (see section 4.3.10 of this Part)
- Charge for an offence (see section 4.4.1 of this Part)

[54] Whether there is a violation of the requirement for a construction permit may depend on when the system was constructed, and whether a waiver has been issued.

- In the case of failure to obtain construction permits, consideration of terms and conditions on operating permits to address any outstanding concerns that may exist as a result of the failure to obtain the construction permit.

In addition, in cases where the lack of compliance results in a threat to public health, the drinking water officer should consider the actions discussed in sections 4.3.3 (public notice of threats), 4.3.5 (hazard abatement and prevention), 4.3.7 (direct action by drinking water officer), 4.3.8 (action in default) and 4.3.9 (cost-recovery) of this Chapter of this guide.

In any case where a drinking water officer is dealing with a system that came into or is in existence without the necessary construction or operating permits, the drinking water office must make clear that the system is considered to be in violation of the Act. Additionally, it should be made known that in determining an appropriate response and working to bring the system into compliance, the drinking water office is not in any way accepting or sanctioning the non-compliance for any period of time.[55]

If any legal questions arise regarding the status or appropriate means for dealing with such systems, the drinking water office should consider consulting legal counsel, in accordance with the Health Authority's policies in that regard.

4.3.13.4 Problem systems which involve Point-of-Entry or Point-of-Use treatment

Water supply systems that supply water to Point-of-Entry and Point-of-Use treatment systems are exempt from the requirements of section 6 of the Act (potable water) provided the Point-of-Entry or Point-of-Use systems make the water potable (see Regulation section 3.1(a)). However, these water systems do remain subject to other provisions of the act.[56] As such, questions may arise concerning the relationship between the water supplier and the end users of Point-of-Entry / Point-of-Use systems in cases where problems arise. The following principles may assist drinking water officers in determining an appropriate course of action in such cases:

- Even where the exemption from section 6 of the Act applies, the water supplier is still covered by other applicable sections of the Act. This includes the requirement to hold an operating permit (section 8), and the requirement to monitor (section 7);
- If the water supplier is providing water to Point-of-Entry or Point-of-Use systems that do not provide potable water, the water supplier may lose the exemption from section 6 of the Act because they are no longer providing water to a Point-of-Entry or Point-of-Use device "that makes the water potable." It is necessary to avail oneself of the exemption in section 3.1(a) of the Regulation, and that in certain cases, the water supplier could be subject to a contravention order in this regard, or some other remedial order. The decision whether to issue such an

[55] For help in finding unregulated systems, see Part B: *Strategies, Tools and Procedures That Health Authorities May Use to Find And Regulate Small Systems* for more detail.
[56] See Part B: *Obligations of the Water Suppliers of Drinking Water Treatment Systems that have Point of Use/Point of Entry Devices* for more details.

order is one to be made by the drinking water officer using their discretion. This may involve consideration of issues such as whether, or to what degree the lack of potability at the end point relates to actions or inactions of the water supplier as opposed to the end user, and whether other steps are being or could be taken to address any public health threats (such as installation of a centralized treatment system); and,

- Where the water being used through a Point-of-Entry or Point-of-Use system may present a health hazard, the drinking water officer has all the powers available under sections 25, 27 and 28 and related orders can be made against the water supplier and /or the end user(s) as appropriate to the facts of any particular case. This is ultimately a matter for the drinking water officer's discretion.

4.3.14 Systems with significant source protection issues

The multi-barrier approach to drinking water protection begins at the water source, and this can raise complex questions regarding the relationship between the Act and Regulation and other legislation, including potentially complex and controversial issues associated with competing land use decisions. This is particularly for situations in which limiting activities to protect a water source would benefit a water supplier and users of a water supply system, but might have adverse consequences for other parties.

The Act recognizes the important but complex relationship between source protection and the safe and effective operation of water supply systems and, while it does not wholly displace responsibilities held by officials under other legislative regimes, it includes a number of provisions that must be considered by drinking water officers where source protection presents challenges in respect of a water supply system. Many of these provisions are discussed in other sections of this guide, but for ease of reference, the following are some of the options or steps that drinking water officers should consider and pursue as appropriate when source protection issues exist.

- Ordering that a water source assessment be completed under section 19 of the Act, particularly given that section 18(2)(a) indicates that one purpose of an assessment is to identify, inventory and assess the drinking water source for the water supply system, including land use and other conditions and activities that may affect that source. (See Chapter 4, section 4.2.2 of this guide)
- Designation by regulation of other officials that must report to the drinking water officer anything that may be a threat to drinking water under section 24(2) of the Act. (See Chapter 4, section 4.1 of this guide)
- Designation by regulation (by area or generally) of decisions under other acts that can only be made after consultation with drinking water officer, local authorities and water suppliers. (See Act, section 30)[57]

[57] No such regulations have been developed to date. If drinking water officers are aware of situations that may warrant development of regulations in this regard, they should consult the senior manager so that recommendations may be made to the Ministry as appropriate.

- Under Part 5 of the Act, order the establishment of a drinking water protection plan, which can result in a wide range of potential outcomes including restricting the exercise of statutory decisions under other acts.
- Recommending that provincial health officer make a report to the minister about problems respecting provincial government action. (See Chapter 1, section 1.5 of this guide)

These provisions complement, but do not replace, informal consultation among agencies and individuals involved in drinking water protection issues.

Other ministries and agencies may also have statutory responsibilities that are relevant to addressing source protection issues. Some of these are discussed below in Chapter 5, sections 5.3 and 5.4 of this guide. Drinking water officers should consider these and consult with other interested ministries and agencies in cases where source protection issues may be of interest to them.

4.4 Dealing with non-compliance

Compliance activities are generally considered to fall into a continuum that includes education, warnings, requiring remedial action, and enforcement. Regulators frequently develop compliance policies and strategies based on the compliance continuum such as a "graduated enforcement" approach. In exercising the authorities discussed in this section, officials should consider and apply any general compliance policies and strategies that have been developed by the applicable health authority or the province in respect of public health matters.

4.4.1 Charge for offence

All violations of the Act, Regulation, permits, orders and directions of a drinking water officer constitute an offense under section 45(1) of the Act. It is also a violation of the Act to provide false or misleading information, or to hinder, obstruct, impede, or otherwise interfere with a drinking water officer, delegate or issuing official in the performance of their duties or the exercise of their powers (section 44).

Persons convicted of an offense are liable to a fine of up to $200,000, or imprisonment for up to 12 months, or both. In addition, where an offense is a continuing offense, the maximum fine of $200,000 can be applied to each day the offense is continued.

Charging a person for an offense is, in most cases, the last option that a drinking water officer would consider as part of the spectrum of compliance options. However, it is important that drinking water officers consider and pursue prosecution for an offense in appropriate cases.

Where a drinking water officer believes it may be appropriate to charge a person with an offense, they should discuss the matter with legal counsel. The drinking water officer must ensure that the case is fully investigated, that appropriate evidence is assembled, and that a report is made to crown counsel in an appropriate form. Information regarding the appropriate form of report may be obtained by speaking with Crown Counsel, or with the health authority's legal counsel.

If a person is convicted of an offense under the Act, there are a wide range of additional things that a court may order in relation to the offense beyond the fine and imprisonment. Specifically, section 45(3) of the Act states that section 107 of the *Public Health Act* applies in relation to an offense under this Act. Section 107 of the *Public Health Act* allows a court to impose a range of orders to ensure remedial action and prevent future non-compliance. It states:

107 (1) To give effect to the purposes of sentencing as set out in section 106 [purposes of sentencing], a sentencing judge may order a person convicted of an offence under this Act to do one or more of the following:

(a) do a thing, or not do a thing, as set out in a joint submission under section 105 *[determining sentence]*;

(b) take any action the court considers appropriate to remedy or avoid a health hazard or health impediment caused by the commission of the offence;

(c) pay a person an amount of money as compensation, in whole or in part, for the cost of a remedial or preventive action taken by or on behalf of the person as a result of the commission of the offence;

(d) perform community service for a period of up to 3 years;

(e) not do any act or engage in any activity that may, in the opinion of the court, result in the continuation or repetition of the offence or the commission of a similar offence under this Act;

(f) comply with any conditions that the court considers appropriate for preventing the person from continuing or repeating the offence or committing a similar offence under this Act;

(g) submit to the minister or a health officer information respecting the activities of the person that the court considers appropriate in the circumstances, for a period of up to 3 years;

(h) if the person is a corporation, designate a senior official within the corporation as the person responsible for monitoring compliance with the Act or the regulations made under it, or the terms or conditions of a licence or permit held by the corporation under this Act;

(i) develop guidelines or standards in respect of a matter, implement a process, or do another thing, for the purposes of preventing the person from continuing or repeating the offence, or committing a similar offence;

(j) make available, either free of charge or for a fee, to another person or class of persons guidelines or standards developed under paragraph (i), in any manner and under any conditions the court considers appropriate, for up to 3 years from the date by which the guidelines or standards must be developed;

(k) publish, in any manner the court considers appropriate, the facts relating to the commission of the offence and any other information the court considers appropriate;

(l) post a bond for an amount of money the court considers appropriate for the purpose of ensuring compliance with a prohibition, direction or requirement under this section;

(m) submit to inspections, submit samples or analyses, or do any other thing necessary to permit a health officer or other person specified by the court to monitor compliance, for a period of up to 3 years, with an order made under this section.

(2) For the purposes of subsection (1) (j), the court may set or limit the amount of the fee, or put conditions on the charging of the fee.

Drinking water officers should keep the provisions of section 107of the *Public Health Act* in mind when deciding whether it is appropriate to seek to charge a person for an offense under the Act.

4.4.1.1 Limitation period

Section 45(6) of the Act provides that, if a person is to be charged with an offense, this must be done within two years after the facts on which the charge is based first came to the knowledge of a drinking water officer.

Also drinking water officials should be aware that, at least in some cases, unnecessary delay in pursuing a charge can have negative impacts on the ability to have that charge prosecuted (even if the charge is brought within 2 years). Therefore, where drinking water officers conclude that prosecution may be appropriate, they should provide a report to Crown Counsel as soon as all the necessary information has been obtained.

If drinking water officers have any question regarding the application of the two year limitation, or questions about what may constitute unreasonable delay on the facts of particular cases, they should consult legal counsel.

4.4.2 Violation tickets

Several drinking water-related offences under the *Drinking Water Protection Act* and *Public Health Act* have been designated as offenses for which a ticket can be issued under the *Offence Act* and the Violation Ticket Administration and Fines Regulation. The following is a listing of these offences and their related fines.

Provision	Contravention	Fine	Victim Surcharge Levy	Ticketed Amount
Drinking Water Protection Act				
section 7 (2) (a)	Construct water supply system without permit	$500	$75	$575
section 7 (2) (a)	Construct works, facilities or equipment without permit	$500	$75	$575
section 7 (2) (b)	Construct water supply system contrary to terms of permit or regulations	$500	$75	$575
section 7 (2) (b)	Construct works, facilities or equipment contrary to terms of permit or regulations	$500	$75	$575
section 8 (1) (a)	Operate water supply system without permit	$500	$75	$575
section 8 (1) (b)	Operate water supply system contrary to terms of permit	$500	$75	$575
section 8 (1) (c)	Operate water supply system in violation of regulations	$500	$75	$575
section 9 (1) (a)	Operate, maintain or repair water supply system without being qualified	$300	$45	$345
section 9 (1) (b)	Operate, maintain or repair water supply system without supervision of qualified person	$300	$45	$345
section 11	Fail to comply with water monitoring requirements established by permit or regulations	$500	$75	$575
section 14	Fail to comply with order to provide public notice of a drinking water threat	$500	$75	$575
section 23 (1)	Contaminate drinking water	$500	$75	$575
section 23 (2)	Tamper with water supply system	$500	$75	$575
section 25	Fail to comply with hazard abatement or prevention order	$500	$75	$575
section 26	Fail to comply with an order respecting a contravention	$500	$75	$575
***Drinking Water Protection Act* – Drinking Water Protection Regulation, B.C. Reg. 200/2003**				
section 5 (2) (a)	Fail to disinfect drinking water originating from surface water	$300	$45	$345

Provision	Contravention	Fine	Victim Surcharge Levy	Ticketed Amount
section 5 (2) (b)	Fail to disinfect drinking water originating from groundwater at risk of containing pathogens	$300	$45	$345
section 8 (2)	Fail to monitor for total coliform bacteria or *Escherichia coli*	$500	$75	$575
Public Health Act				
section 99 (1) (k)	Fail to comply with an order issued under Part 4	$300	$45	$345
section 99 (4) (a)	Provide false or misleading information	$100	$15	$115
section 99 (4) (b)	Interfere with or obstruct an official	$100	$15	$115
Public Health Act **– Health Hazards Regulation, B.C. Reg. 216/2011**				
section 7	Fail to provide sufficient potable drinking water	$100	$15	$115
Public Health Act **– Public Health Act Transitional Regulation, B.C. Reg. 51/2009**				
section 15	Fail to notify of a discharge	$200	$30	$230

Nothing in the *Drinking Water Protection Act* affects the application of the *Public Health Act*, and there may be some circumstances in which facts that give rise to an offense under the *Drinking Water Protection Act* could also constitute an offense under the *Public Health Act* or its regulations. This includes failure to report spills under section 15 of the Public Health Act Transitional Regulation, and failure to comply with health hazard abatement orders under section 42 of the *Public Health Act* (discussed in section 4.3.6 of this guide). As such, a ticket under the *Public Health Act* can be issued in appropriate cases, even if the violation of the *Public Health Act* occurs in relation to drinking water matters.

4.4.3 Court order to require compliance

In addition to the ability to prosecute a person for an offense, a health authority can make an application to court to seek an "injunction." This requires the person to stop contravening the Act, regulations or order, or take action as directed by the court for the purpose of achieving compliance or remedying or preventing a drinking water health hazard (section 42).

The importance of an injunction under this section is that, if a person fails to comply, they are not only in noncompliance with the Act, but they would also be in contempt of court.

An order to require compliance under section 42 of the Act does not necessarily require the same evidentiary standards or legal burdens of proof that may be required when prosecuting a person for an offense under the Act.

Where a drinking water officer believes an application to court under section 42 would be appropriate, they should discuss the matter with the senior manager and legal counsel as appropriate.

4.5 General policy for prioritizing compliance activity based on health risks

Given the large number of water systems that are subject to the Act, and the fact that resources for drinking water officers and their delegates is limited, oversight and compliance activity should be prioritized to ensure that resources are allocated based on a principled and risk-based policy if necessary.

Drinking water officers are encouraged to establish a prioritization policy that meets these basic principles, having regard to the circumstances of the health authority in which they are operating. This policy should categorize systems as being of low, medium or high priority for the purposes of drinking water officer activity. It should be based on the professional judgment of the drinking water officer and should, in general, consider factors that include, but are not limited to:

- Risk that the system is not providing or will not provide potable water
- Likelihood and impact, consequence or severity of the threat posed
- Number of persons using the system (i.e. number of users/ connections)
- Population demographics (i.e. vulnerable population groups like schools and care facilities)
- Past history of compliance, threat identification and voluntary remedial action
- System complexity

A sample of a basic tool for assessing the hazard rating of a water system can be found in appendix 19.

The prioritization of systems should be regularly reviewed and revised as necessary, particularly at any time that a drinking water officer obtains new information about a system that may affect its priority rating.

Once prioritizations have been assigned, compliance activities should be undertaken in accordance with the policy framework set out below.

4.5.1 Low priority systems

Where water systems are considered to be low risk in terms of possible threats to human health, these systems should be considered low priority. While drinking water officers should take steps to ensure compliance with these systems to the extent possible, it is important to consider how these systems should be prioritized relative to others. More specifically, where drinking water officers cannot be reasonably expected to take routine monitoring and compliance action in relation to such systems without compromising regulatory efforts in respect of medium and high-risk systems (discussed below), these low priority files should be noted as such. Files should be maintained and information should be added to the file as it becomes available. If any information comes to the attention of the drinking water officer to suggest that such a file is no longer appropriately considered low priority, that information must be considered and the file managed accordingly.

Although low priority files may not be the principal focus of drinking water officer's activity where resource limitations present challenges, the obligation of water suppliers to comply fully with the Act remains. It is therefore important that drinking water officers not do or say anything to the operators of such systems to indicate that less than full compliance with the Act is acceptable.[58] Rather, if the drinking water officer believes that it is appropriate to provide some relief or relaxation from the standards of the Act and Regulation in relation to such low risk systems, the drinking water officer should do so by exercising the authority available under the Act. For example, this could include amending the terms and conditions of an operating permit regarding the date on which the operator qualification provisions become applicable, or modifying frequency of sampling required.

4.5.2 Medium priority systems

Where water systems are considered to propose moderate risk to public health, these should be considered medium priority. They should be subject to regular and systematic review and inspection, to the extent time and resources permit. Drinking water officers should draw to the attention of the water supplier any concerns that exist regarding potential threats to public health and compliance with the Act, and should indicate the actions that might be taken if the concerns are not addressed. Drinking water officers should also exercise their discretion in deciding whether to take further actions in respect of systems that are considered medium priority, having regard to available resources and other higher priority risks. If a system that has been considered to be medium priority is subject to a change in circumstances such that the drinking water officer believes there is a significant threat or potential threat to public health, the system should be considered a high priority system, and dealt with as discussed below.

4.5.3 High priority systems

In any case where a drinking water officer is aware of a system that poses a high risk to public health, that system should be considered to be high priority. Drinking water officers should consider the full range of remedial actions that may be required or taken in relation to such a system, and should take steps to ensure that the appropriate action is taken. If a drinking water officer is not able, due to time or resource constraints, to attend to high priority systems within a time frame that the drinking water officer considers reasonable having regard to the risk presented, the drinking water officer should advise the senior manager and the medical health officer immediately.

[58] This is important because it could lessen a water supplier's commitment to compliance with the Act and Regulation, and also because it could have potentially negative implications for enforcement action if that is necessary at some point, as the water supplier might potentially argue the defense of "officially induced error."

Drinking water officers should maintain a system of tracking the prioritization of files, and should provide regular updates to the senior manager regarding overall caseload and risk prioritization. This will ensure that the health authority executive is fully informed of the status of files, and can make appropriate resource allocation decisions within the overall public health protection functions of the health authority.

Health authority officials should consider consulting the Ministry of Health and other Health Authorities in the development of risk assessment tools and supporting data systems. This is a matter that can be discussed through the Drinking Water Leadership Council forum.

Chapter 5: Other Considerations

5.1 Reconsideration and review of decisions

Under the Act, there is no way for persons who are dissatisfied with a decision of the drinking water officer or issuing official to appeal that decision.

The Act does, however, provide for limited rights of reconsideration and review, in section 39.1. Specifically, a person who is affected by a decision[59] can request a review or reconsideration only in relation to the following types of decisions of a drinking water officer:

(a) section 19 *[drinking water officer authority in relation to assessments]*;

(b) section 25 *[hazard abatement and prevention orders]*;

(c) section 26 *[orders respecting contraventions]*;

(d) section 31 (4) *[request respecting plan initiation]*;

(e) a decision resulting from a reconsideration under subsection (3) of this section.

If a drinking water officer is asked to make one of these orders but elects not to, this should be considered a "decision" for the purposes of determining a person's right to request a review or reconsideration.

Reconsideration and review are two different matters. It is important that the difference be clearly communicated to persons who may inquire about such options.

5.1.1 Reconsideration

A request for reconsideration can be made at any time after a decision is made. Where a request for reconsideration is made, the person must indicate new evidence that they believe would justify the drinking water officer changing, reversing or varying a prior decision.

"New evidence" means evidence that was not provided to or considered by the drinking water officer when the original decision was made. Although there is no specific requirement that a person use a designated form when requesting reconsideration, people should be encouraged to use the standard form set out in appendix 20. If, however, a person simply writes a letter that provides the basic information necessary to consider a request for reconsideration, then that request should be considered and the person should not be required to complete the standard form.

[59] The Act does not specify who is "affected by a decision." If a drinking water officer has a question as to whether a person requesting a review or reconsideration meets this test, they should discuss the matter with legal counsel.

In deciding whether to confirm, vary or reverse the initial decision, the drinking water officer should assess whether there is new evidence which, if it had been available when the decision was made, would have caused them to make a different decision.

Reconsideration of decisions should be made by the drinking water officer that made the original decision, unless the drinking water officer is not available to make the reconsideration decision within a reasonable period of time (for example, if the drinking water officer is on extended leave). In that case, another drinking water officer may consider the request for reconsideration.

Decisions resulting from a request for reconsideration should be provided in writing.

5.1.2 Reviews

A review differs from reconsideration in two significant ways. First, a review is conducted by a person other than the drinking water officer that made the original decision. Second, a review is not based on consideration of whether new evidence justifies varying or reversing the initial decision. To the contrary, new evidence cannot be provided or considered in a review.

5.1.3 How are requests processed?

Although there is no specific requirement that a person use a designated form when requesting a review, people should be encouraged to use the standard form found on the Office of the Provincial Health Officer's website. If, however, a person simply writes a letter that provides the basic information necessary to consider a request for review, then that request should be considered and the person should not be required to complete the standard form.

The person requesting the review should send it directly to the provincial health officer. The provincial health officer may undertake the review themselves, or they may, pursuant to section 39.1(4)(a), direct that it be undertaken by a medical health officer. More information on requesting a review is available on the Office of the Provincial Health Officer's website.

5.1.4 Which information can be considered?

Reviews can only be conducted "on the record." This means the person conducting the review can only consider information in the file that was available to the original decision maker when the decision was made. A person is not able to introduce new evidence on a review. If the person believes there is new evidence relevant to the matter, they must request reconsideration from the original decision-maker instead (see 5.1.1 of this chapter of the Guide). The person can also request a review after reconsideration, if the person is still dissatisfied with the decision.

5.1.5 When should other parties be notified?

If a person conducting a review believes that the decision in question could have a material impact on persons other than the party requesting the review, then they should direct the applicant to give notice of the review to those other persons, pursuant to section 39.1(4)(c). This would generally be appropriate in cases where third parties were consulted when the original decision was made, although it would not necessarily be limited to those circumstances.

The reviewing official should specify the type of notice that must be given, and the time by which it must be provided. A sample form of notice to third parties is set out in appendix 21.

5.1.6 Determining the result of a review

Upon completing a review, the decision can be confirmed, varied or reversed, or the matter can be referred back to the drinking water officer, (with or without directions) (section 39.1(4)(d)). This is a decision for the reviewing official to make.

Generally, if the reviewing official is in a position to confirm, vary or reverse the decision based on the information on the record, they should do so. If, however, the reviewing official believes it is more appropriate to refer the matter back to the drinking water officer for further consideration, they may do so. Circumstances in which it may be more appropriate to refer the matter back to the drinking water officer may include, but are not limited to:

- Situations in which the reviewing official believes the drinking water officer should have obtained further information before making a decision
- Situations in which the reviewing official believes the decision should be varied, but the decision as to precisely how the decision should be varied is one best left for the drinking water officer with knowledge of the water supply system

Where the reviewing official has decided it is appropriate to refer a matter back to the drinking water officer, the reviewing official should attempt to provide directions and comments that would help the drinking water officer address any of the factors that, in the opinion of the reviewing officer, resulted in the matter being referred back.

5.2 Application of Act to First Nations' and federal lands

The federal government holds jurisdiction over federal land and First Nations' lands with respect to drinking water. Provincial laws may be applied differently on First Nations' lands in relation to other federal lands.

5.2.1 First Nations' Lands

Health authority staff should consult with their legal counsel in determining whether or to what extent the Act may apply to any particular case involving First Nations' lands.

5.2.2 Federal land

Health authority staff should consult with their legal counsel in determining whether or to what extent the Act may apply to any particular case involving other federal land.

5.3 Other relevant acts

Because drinking water protection is affected by so many factors from source to tap, there are a variety of other pieces of legislation that have relevance to drinking water protection. To some extent, regulation under these other acts has the potential to overlap with regulation under the DWPA.

Section 2 (1) of the DWPA recognizes this principle, and it states that the authority provided under this Act is in addition to and does not restrict authority provided by or under any other enactment that may be used to protect drinking water.

Beyond this, the DWPA does not contain any general rules about how it relates to other legislation. There are, however, a number of sections that contain specific rules relating to other legislation. For example, section 25(10) provides that, in the event of a conflict between an order under section 25 and an order of a health officer under the *Public Health Act*, the order of the health officer prevails.

Similarly, section 23(3) of the DWPA provides that the prohibitions against contaminating drinking water or tampering with the system in section 23 do not apply if the introduction or activity is authorized or required by or under another enactment. This provision serves only to prevent prosecution for an offence under section 23 of the DWPA. Other sections of the DWPA remain applicable and there is no general rule that, if a person is in compliance with another law, they are allowed to violate the DWPA.

For these reasons, it is important to carefully consider the details of each relevant section of the DWPA, and to consider how it may relate to other legislation on the facts of a particular case. If a drinking water officer has any questions in this regard, they should consult with legal counsel.

While there are a wide range of acts that may be of interest to drinking water protection other than the DWPA, a number of the most significant ones are discussed below. This does not represent an exhaustive list of relevant acts, or an exhaustive examination of relevant provisions within the acts noted (or regulations made under the act). In any case that an official has questions regarding the applicability or effect of other legislation as it relates to the DWPA, the official should consult legal counsel, in accordance with the process established by the health authority.

5.3.1 Public Health Act

Any of the powers that may be used to address public health issues generally under the *Public Health Act* continue to apply to drinking water issues. They are complemented—and not displaced—by the DWPA. These *Public Health Act* powers include—but are not limited to—powers under Part 3 and 4 respecting "health hazards," and regulations developed under the *Public Health Act* (see sections 4.3.5 and 4.3.6 of this guide) such as the Health Hazards Regulation. Section 8 of the Regulation outlines requirements regarding setback of wells from possible sources of contamination. Section 7 of the Regulation requires that in rented residences where the *Residential Tenancy Act* applies, landlords must ensure tenants are supplied with potable water. This provides for public health oversight where a rental unit (e.g., secondary suite) is within a single-family residence served by a private water system that is not regulated as a water supply system under the DWPA. It is important that complaints regarding potability of water under section 7 are investigated.

5.3.2 Water Sustainability Act

5.3.2.1 General

The *Water Sustainability Act* — which came into force on February 29, 2016 — updated and replaced the historic *Water Act*. The Water Sustainability Act makes improvements in seven key areas:

1. Protecting stream health and aquatic environments
- Ensuring Environmental Flow Needs (EFN's) are considered
- Expanding prohibitions on dumping debris into streams and aquifers

2. Considering water in land use decisions
- Consider water objectives in resource and land use decisions
- Allows for the development of Water Sustainability Plans

3. Regulating and protecting groundwater
- Licensing groundwater use, except for domestic use
- Improve information on wells and aquifers
- Updates well drilling requirements

4. Regulating water use during times of scarcity;
- Ensuring adequate water for human needs
- Allowing temporary water use restrictions to protect Critical Environmental Flows and fish habitat

5. Improving security, water use efficiency and conservation;
- Provides for Area-Based Regulations to address local issues and conditions
- Allow Agricultural Water Reserves to be created
- Make most water licences reviewable after 30 years
- Ensure water is used beneficially and encourage water conservation

6. Measuring and reporting large-scale water use;
- Require large-volume water users to report water use

7. Providing for a range of governance approaches.
- Supports the creation of advisory groups for surface and groundwater
- Allows for delegation of some activities or decisions to agencies outside of government.

Provisions related to the above themes will be enacted as regulations are developed to support them.

The *Water Sustainability Act* continues the regulatory scheme for the acquisition and management of rights to stream water and expands that scheme to apply to groundwater. Both resources are managed as one. The *Water Sustainability Act* also establishes a Comptroller of Water Rights and water managers, whose role is to make licensing and other decisions regarding the regulation of water use and water works[60] under this act. Section 48 of the act also defines a "professional" as

> a registrant as defined in section 5 of Schedule 1 to the *Professional Governance Act*

A water licence grants the right to use water beneficially for a specific water use purpose. Every groundwater user is required to have an authorization (licence or use approval), except in the following situations:

- Domestic purpose,[61] unless specified otherwise in the Regulations,
- The diversion or use is authorized under the Regulations (well drilling, etc.),

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[60] The term "works" is defined to mean:
(a) anything capable of or used for
(i) diverting, storing, measuring, conserving, conveying, retarding the flow of, confining or using water,
(ii) producing, measuring, transmitting or using electricity, or
(iii) collecting, conveying or disposing of sewage or garbage or
(iv) preventing or extinguishing fires,
(b) booms and piles placed in a stream,
(c) obstructions placed in or removed from streams or the banks or beds of streams, and
(d) changes in and about a stream,
(e) access roads to any of the works referred to in paragraphs (a) to (d) or (f)(i), and
(f) wells and works related to wells, including
(i) wellheads,
(ii) anything that can be or is used for injecting or otherwise adding water or any other substance to a well,
(iii) anything that can be or is used for constructing, deactivating or decommissioning a well,
(iv) anything that can be or is used for exploring for, testing, diverting or monitoring groundwater,
(v) anything that can be or is used for disinfecting a well,
(vi) an injection system attached to a work that is used for conveying, from a well, groundwater that will be used for applying fertilizers or pesticides, and
(vii) anything that can be or is used in relation to a monitoring well or a well made for the purpose of groundwater remediation.
(*Water Sustainability Act*, section 1)

[61] "domestic purpose" means the use of water for household purposes by the occupants of, subject to the regulations, one or more private dwellings, other than multi-family apartment buildings, including, without limitation, hotels and strata titled or cooperative buildings, located on a single parcel, including, without limitation, the following uses:
(a) drinking water, food preparation and sanitation;
(b) fire prevention;
(c) providing water to animals or poultry kept
(i) for household use, or
(ii) as pets;
(d) irrigation of a garden not exceeding 1 000 m2 that is adjoining and occupied with a dwelling;

- Extinguishing a fire,
- Testing the quality or quantity of water,
- Conducting a flow test,
- Using unrecorded water for prospecting for a mineral

One new, mandatory consideration is that the decision maker must consider the reliance of the aquatic habitat on groundwater discharge or stream flow (environmental flow needs) in deciding an application that is on a stream, or an aquifer that is reasonably likely to be hydraulically connected to a stream.

The *Drinking Water Protection Act* operates independently of the *Water Sustainability Act*, and a person who holds a licence under the *Water Sustainability Act* is, like any other person, required to comply with the applicable provisions of *Drinking Water Protection Act* if they are an owner of a "water supply system" as that term is defined in the *Drinking Water Protection Act.*[62]

Similarly, the mere fact that something is authorized under the *Drinking Water Protection Act* does not serve to authorize it under the *Water Sustainability Act*. In other words, if a person has a permit under the *Drinking Water Protection Act* to construct or operate a water supply system, they will still require a separate licence under the *Water Sustainability Act* to draw water from a surface water or groundwater source. Water licences may also specify certain water works that are approved in relation to the licence, and, if changes are made to the system in relation to *Drinking Water Protection Act* issues, the person may require an amendment to their *Water Sustainability Act* licence.

For more information concerning the regulation of surface water under the *Water Sustainability Act*, see http://www.env.gov.bc.ca/wsd/water_rights/licence_application/index.html.

5.3.2.2 Groundwater Protection Regulation

The Groundwater Protection Regulation protects groundwater quality and quantity by setting strict standards for the construction and maintenance of wells, establishing qualifications for well drillers and well pump installers, and requiring that most wells be constructed by qualified well drillers who are registered with the province. The Groundwater Protection Regulation also distinguishes between well related activities that may be carried out by the well owner or property owner, and those activities that must be performed by qualified well drillers, qualified well pump installers and professionals.

Under the *Water Sustainability Act*, the Groundwater Protection Regulation:

- Regulates minimum standards for well construction, maintenance, deactivation and decommissioning, and

[62] As discussed in Chapter 2, section 2.1 (under Domestic Water System) of this Guide, this would not include equipment, works and facilities constructed, operated or maintained under (i) a licence, as defined in the *WSA*, for conservation, power or storage purposes, or (ii) a permit issued under the *WSA*, because these are excluded from the definition of "domestic water system", which is used in the definition of "water supply system". See *Act,* section 1 and Regulation, section 3)

- Recognizes the types of qualified people certified to drill wells, install well pumps and perform related services

All wells under the *Water Sustainability Act* are regulated, including those that provide water for domestic purposes. The Groundwater Protection Regulation regulates:

- Water supply wells
- Monitoring wells
- Recharge/injection wells
- Dewatering/drainage wells
- Remediation wells
- Geotechnical wells
- Closed-loop geoexchange wells

Constructing and decommissioning wells, installing well pumps, disinfecting wells and conducting flow tests are usually restricted activities that can only be performed by qualified well drillers or well pump installers, or professional engineers and geoscientists.

The well driller, professional or other person responsible for constructing a well is required to comply with the provisions of the Groundwater Protection Regulation related to how the well is constructed. This person must ensure that the well meets the minimum standards for the casing material, wellhead completion, surface seal, well caps and covers and well identification. The person must also submit a well construction report to the province if required. Different types of wells have different requirements.

A well pump installer or other professional is responsible for complying with the provisions of the Groundwater Protection Regulation when installing a pump in a well. Provisions include ensuring that the casing is not damaged, maintaining the surface seal, using appropriate materials and installing related equipment.

The Groundwater Protection Regulation requires well drillers who are dealing with artesian wells to:

- Equip wells to prevent backflow
- Produce construction and decommissioning reports for all artesian wells
- Measure and report shut-in pressure
- Report on the management of artesian flows that cannot be controlled

The well owner, and in some cases the well driller, is required to ensure proper maintenance and care, whether or not the well is in service. Requirements include:

- Floodproofing new wells that are part of water supply systems
- Decommissioning any well not used for five years
- Protecting the wellhead
- Attaching a well identification plate to an existing well that supplies a water supply system

Some of these rules are directly relevant to the construction, maintenance, operation, assessment and protection of wells that serve water supply systems.

The groundwater protection provisions of the Water Sustainability Act and the Groundwater Protection Regulation are administered by officials from the Ministry of Water, Land and Resource Stewardship.

Drinking water officers hold some powers under the *Water Sustainability Act*. Specifically, drinking water officers have the ability to request and receive certain types of information respecting well driller and pump installer qualifications, well reports, well water analyses and rights to access land and premises. These provisions are found in sections 51, 57, 63, 89 and 90 of the *Water Sustainability Act*.

The provisions of the *Water Sustainability Act* also contain provisions allowing for the establishment of water sustainability plans. These plans are in some ways similar to drinking water protection plans that can be developed under Part 5 of the *Drinking Water Protection Act*. Given the potential for overlap, the acts provide that if plans are developed under both acts in respect of a particular area, they can be developed jointly. Further, the acts allow the Lieutenant Governor in Council (Cabinet) to pass regulations which would apply the licensing provisions of the *Water Sustainability Act* to domestic groundwater users in specified areas.

5.3.3 Water Utility Act

This act provides that a "water utility" is subject to the control and regulation of the Comptroller of Water Rights under the *Water Sustainability Act.* The term "water utility" is defined as:

> (a) a person who owns or operates in British Columbia equipment or facilities for the diverting, developing, pumping, impounding, distributing or furnishing of water, for compensation,
>
> > (i) to or for more than the prescribed number of persons or, if no number is prescribed, 5 or more persons, or
> >
> > (ii) to a corporation, and
>
> (b) the lessee, trustee, receiver or liquidator of a person referred to in paragraph (a),
>
> but does not include
>
> (c) a municipality in respect of services furnished by the municipality,
>
> (d) a person who furnishes services or commodity only to himself or herself, the person's employees or tenants, if the service or commodity is not resold to or used by others,
>
> (e) the Greater Vancouver Water District under the *Greater Vancouver Water District Act*,

(f) an improvement district as defined in section 1 (1) of the *Water Sustainability Act*,

(f.1) a water users' community as defined in section 1 (1) of the *Water Users' Communities Act*,

(g) a regional district under the *Local Government Act* in respect of the service of the supply of water

(i) in bulk to a municipality or electoral area participating in that service, or

(ii) to consumers in a municipality participating in that service,

(h) a person who supplies water by tanker truck,

(i) a person who sells bottled water, or

(j) a strata corporation, if the comptroller is satisfied that the owner developers within the meaning of the Strata Property Act have ceased to own a majority of the strata lots in the strata plan.[63]

Water utilities can only be established if the Comptroller of Water Rights issues a Certificate of Public Convenience and Necessity under the *Water Utility Act*. Drinking waters officers do not have authority under that act, but officials responsible for regulation of water utilities may consult with drinking water officers in the exercise of their regulatory responsibilities.

For more information concerning the regulation of water utilities, see

https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/private-water-utilities.

5.3.4 Water Protection Act

This act places restrictions on the removal of bulk water from British Columbia, and imposes restrictions on the large scale transfer of water between watersheds.

5.3.5 Local Services Act (Subdivision Regulations)

Under section 2 of the *Local Services Act*, the Lieutenant Governor in Council may establish areas of British Columbia not incorporated as a city, town, village or district municipality as a local area to which this act applies.

Under this act, the Subdivision Regulations have been established. Sections 1.01 and 1.03 set out its scope of application. These sections state:

[63] See section 5.5.1 and Part B of this Guide for more information.

1.01 These regulations apply to the subdivision of all land in the Province except land

(a) within a municipality,

(b) regulated by a bylaw under section 938 of the *Municipal Act*,[64] and

(c) within B.C. Regulation 274/69, the Community Planning Area Number 24 (Gulf Islands) Regulations.

And

1.03 Notwithstanding section 1.01 (b), where a bylaw does not regulate a matter covered by these regulations, these regulations apply to that matter.

The Subdivision Regulations provides that the ability to subdivide is limited by consideration of water supply issues. Specifically, section 4.01 states:

4.01 No subdivision shall be approved

...

(d) if it does not comply with these regulations

And section 4.09 states:

4.09 (1) The design of any community water system[65] to serve the subdivision shall be in accordance with the requirements of any authority having jurisdiction over the system pursuant to

(a) the *Health Act*[66] and the *Water Utility Act*,

(b) the *Health Act* and the *Water Sustainability Act*, when an improvement district has an applicable subdivision bylaw pursuant to the *Water Sustainability Act*, or

(c) the *Health Act* and the *Local Government Act*, when a regional district has an applicable bylaw setting out the terms and conditions of any extension to its community water system,

as the case may be.

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[64] *The Municipal Act* has been replaced by the *Local Government Act.*

[65] A system of waterworks which serves 2 or more parcels and which is owned, operated and maintained by an improvement district under the WSA or the *Local Government Act*, or a regional district, or which is regulated under the *Water Utility Act.*

[66] The *Health Act* has been replaced by the *Public Health Act*.

(2) The community water system approved pursuant to section 4.09 (1) shall be installed as approved before the subdivision is approved.

(3) Notwithstanding the requirements of section 4.09 (2), a subdivision may be approved prior to the construction of the community water system, provided that an arrangement securing performance of such construction satisfactory to the approving officer has been made with

(a) the Comptroller of Water Rights (under the *Water Utility Act*),

(b) an improvement district having an applicable subdivision bylaw adopted pursuant to the *Water Act*, or

(c) a regional district having an applicable bylaw setting out the terms and conditions of any extension to its community water system,

as the case may be, but in no case shall the subdivision be approved before the plans for the community water system have been approved.

5.3.6 Environmental Management Act

The *Environmental Management Act* is the primary statute for regulation of waste discharge and pollution prevention in British Columbia. The *Environmental Management Act* does not provide any specific powers to drinking water officers, but it is a statute that drinking water officers should be familiar with, as there will be ongoing relationships between drinking water officers and officials implementing the *Environmental Management Act*. The *Environmental Management Act* will allow for the establishment of area based plans, which are similar to drinking water protection plans under part 5 of the *Drinking Water Protection Act*, and water sustainability plans under the *Water Sustainability Act*. This legislation allows for plans under it to be coordinated with plans under the *Drinking Water Protection Act* and the *Water Sustainability Act*, as appropriate.

There are a significant number of regulations under this act that may also have relevance to drinking water protection, including regulations respecting contaminated sites, animal waste control and organic matter recycling.

5.3.7 Forest and Range Practices Act

This act sets out a number of stewardship planning and other protection measures respecting forestry and range practices. This includes the ability of the Lieutenant Governor in Council to make regulations:

- Allowing the minister responsible for the *Land Act* to designate an area of land in a watershed as a community watershed and the minister responsible for the *Water Sustainability Act* to establish water quality objectives in relation to a community watershed (section 150). The Minister of Water, Land and Resource Stewardship is currently responsible for these Acts.

- Allowing the minister responsible for the *Wildlife Act* (currently the Minister of Water, Land and Resource Stewardship) to designate areas and set objectives generally in watersheds with significant downstream fisheries values and significant watershed sensitivity (section 150.1)
- Allowing the Minister responsible for the *Forest and Range Practices Act* (section 150.2) to designate areas as lakeshore management zones, and to set objectives in relation to those zones. The Ministry of Water, Land and Resource Stewardship is responsible for section 150.2.
- To classify streams, wetlands and lakes, and make regulations respecting riparian zones (section 150.5)

Drinking water officers should contact a local representative of the Ministry of Water, Land and Resource Stewardship to find out information concerning regulations made pertaining to these sections of the *Forest and Range Practices Act* as well as implications related to regulating drinking water supply systems.

Responsibilities related to forest and range practices are also set out under this act. Sections 59 and 60 of the Forest Planning and Practices Regulation states:

Protecting water quality

59 Unless exempted under section 91 (1) [minister may grant exemptions], an authorized person who carries out a primary forest activity must ensure that the primary forest activity does not cause material that is harmful to human health to be deposited in, or transported to, water that is diverted for human consumption by a licensed waterworks.

Licensed waterworks

60 (1) Unless exempted under section 91 (1) [minister may grant exemptions], an authorized person who carries out a primary forest activity must ensure that the primary forest activity does not damage a licensed waterworks.

(2) An agreement holder must not harvest timber or construct a road within a community watershed if the timber harvesting or road construction is within a 100 m radius upslope of a licensed waterworks where the water is diverted for human consumption, unless the timber harvesting or road construction will not increase sediment delivery to the intake.

The term "licensed waterworks" is defined in section 1 of this regulation to mean:

> a water supply intake or a water storage and delivery infrastructure that is licensed under the *Water Sustainability Act* or authorized under an operating permit issued under the *Drinking Water Protection Act*;

Other relevant provisions may be found in the Government Actions Regulation, the Range Planning and Practices Regulation, and the Woodlot Licence Planning and Practices, all established under this act.

Drinking water officers may wish to consult with Ministry of Water Land and Resource Stewardship officials in cases where the drinking water officer believes this act may have relevance to drinking water issues.

5.4 Relationship between DWO activities and officials from other agencies

In some cases, there may be considerable overlap between the legislative responsibilities of drinking water officers and those of officials from other agencies. In many cases it will be appropriate for these agencies to collaborate. In some circumstances, it may be appropriate for drinking water officers to rely on steps being taken by other agencies if and to the extent those may address concerns held by drinking water officers in relation to the decisions of the other officials (and vice versa).

At the same time, it is essential to ensure that regulatory responsibility is not unduly disregarded because there may be another agency with potentially relevant authority under other legislation. This is especially important when various relevant acts disclose slightly different requirements and procedures that may make reliance on another agency inappropriate from the public health perspective even though it appears that there are two agencies that are equally able to take appropriate action.

The following principles should be applied by drinking water officers with a view to achieving appropriate cooperation with other agencies, while at the same time ensuring appropriate regard for the role and function of drinking water officers under the *Drinking Water Protection Act*.

- Drinking water officers may decide to defer taking action under the *Drinking Water Protection Act* while a matter is being reviewed or action taken under another act, if

  (a) The drinking water officer believes that the action being taken under another act has the potential to address all outstanding issues that exist in respect of drinking water protection

  (b) The drinking water officer remains apprised of the situation and actions being taken by the other agency(ies) and resumes direct involvement if at any time the drinking water officer considers that necessary protect public health.

- Statutory officials must not use powers under one statutory mandate solely and specifically for the purposes of assisting an official with a different statutory mandate. However, information that is obtained by an official for the purposes of the act they are administering, can, subject to the next point, be shared with other relevant agencies.
- Statutory officials must ensure that any sharing of personal information is permissible under the *Freedom of Information and Protection of Privacy Act*, or other relevant legislation.

Provided these basic principles are respected, strong communication and cooperation with other relevant agencies can provide considerable practical benefit to all the regulators involved, and may also be of benefit to the water supplier (or other concerned persons).

5.5 Additional Considerations under the Act

5.5.1 Systems within systems

There are many situations in which a water supply system operating under a valid permit may re-distribute water to a number of connections through a separate water supply system while maintaining public health protection goals without further treatment or complex infrastructure. This is a "system within a system" that involves nothing more than the installation pipes for distribution. The application of the *Drinking Water Protection Act* to this situation separately would be unnecessarily onerous as it would result in the unwarranted use of health authority resources for reviewing and monitoring, and would create unnecessary costs and requirements to the users of these systems, for little, if any, public health benefit.

Common examples of such systems would include:

- Those created by strata properties
- Townhouses
- Mobile home parks
- Small resorts

Section 3 (d) of the Drinking Water Protection Regulation authorizes the drinking water officer, or issuing official, to exempt these systems from the definition of a "domestic water system" in the Act, and the associated requirements for construction permits, operating permits, water sampling and operator training.

The intended outcomes are to:

- Empower the drinking water officer or issuing official with the flexibility to make risk-based decisions on whether a system within system should be exempted from requirements of the *Act*.
- Reduce the need for unnecessary resources (permits, applications, reviews etc.) being put towards creating small systems where water is simply being redistributed from a permitted water supply system.
- Ensure that where water re-distribution requires further treatment, additional infrastructure, or on-going maintenance to prevent a drinking water health hazard, the *Act* will apply.

5.6 Considerations and advice for those with compromised immune systems

Those with compromised immune systems, such as some people with HIV, or undergoing certain types of cancer treatment, may be at higher risk of water-borne infections.

BC's Health Link File Preventing Water-Borne Infections For People with Weakened Immune Systems #56 provides messaging on drinking water and those with weakened immune systems, and is updated form time to time (BC HealthLink website at http://www.healthlinkbc.ca/healthfiles/hfile56.stm). These guidelines provide advice on precautions that those at risk should be taking with drinking water to avoid risk of water borne diseases associated with bacteria, virus or parasites.

The information from HealthLink File #56 should be incorporated into policy and operations manuals as necessary, and/or distributed when the public seeks information on this subject.

5.7 Finding and regulating systems

There are likely many (possibly thousands) systems that meet the definition of a water supply system under the *Drinking Water Protection Act*. In some cases, operators either do not know they are subject to the *Drinking Water Protection Act*, or intentionally operate outside of the Act and regulations. Many of these systems come to the attention of the health authority over time. Water supply system operators have a legal obligation to comply with the Act and report to the health authority. In some cases, health authorities have the resources to systematically look for "underground" systems that have not been identified. There are currently tools, such as databases held by the Ministry of Water, Land and Resource Stewardship that health authorities can use to locate water supply systems. These information tools and their application to find water supply systems are described in Part B: *Strategies, Tools and Procedures That Health Authorities May Use to Find and Regulate Small Systems* of this guide.

5.8 Complaints and enquiries

All agencies receive concerns from time to time pertaining to stakeholder dissatisfaction. In the case of drinking water programs, these often pertain to:

- Complaints regarding a specific public health concern in a community (e.g. drinking water threat).
- Complaints related to services provided by a health authority, or policies a health authority has adopted.
- Complaints regarding a policy or service of the Ministry of Health.

Part B: *Drinking Water Complaints and Inquiries Process* of this guide contains advice on processes to address and respond to complaints when they happen, as well as recommendations on how stakeholders may file their concerns, and what they might expect as an outcome once they are filed.

Drinking Water Officers' Guide Part B:

Best Practices and Technical Assistance

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Ministry of Health

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Determining Appropriate Drinking Water Chemical and Physical Monitoring Guidelines

Version 1.3 / First Published 2014

Ministry of Health

1. Purpose

The purpose of this document is to assist in determining Chemical Standards that are applicable to the water in a water supply system and how these should be monitored. This guideline is particularly relevant for sections 3.1.5.2, 3.2.5.2, 3.2.6 and 4.2.1 of Part A of the *Drinking Water Officers' Guide* (DWOG) as these sections deal with decision-making related to permitting, terms and conditions, and monitoring of water systems.

This guideline provides supplemental guidance for drinking water officer (DWO) decisions on monitoring water for various chemical and physical parameters. It also provides a decision tree to guide the DWO through a decision-making process to help determine if there is sufficient evidence to support the requirement to test for additional parameters in a specific water source. The approach specified also supports local DWOs in determining which parameters a new or existing water supply system should test for and how often the testing should be conducted.

2. Background

Under Section 8(3) of the *Drinking Water Protection Act* (DWPA), a DWO may place terms and conditions on an operating permit respecting monitoring of the drinking water source and the water in the water supply system, as well as standards applicable to the water in the water supply system.

The Ministry adopts the *Guidelines for Canadian Drinking Water Quality* (GCDWQ) as the water quality objectives that B.C.'s water supply systems should strive to achieve when evaluating potability for chemical constituents. One exception to the general adoption of GCDWQ in B.C. is the MAC for Selenium (see DWOG, Part A: Legislative Requirements section 3.1.6.2 for more information). The Maximum Allowable Concentration (MAC) in the GCDWQ generally represents a health-based numerical water quality objective. The DWO will use this and other factors to evaluate the level of risk associated with drinking water.

Source Drinking Water Quality Guidelines (SDWQGs) developed by the Ministry of Water, Land and Resource Stewardship are a distinct set of guidelines that apply to ambient source water *before* it is treated and distributed for domestic use. The GCDWQ are adopted as SDWQGs if they make sense as a source water guideline in B.C. While not directly enforceable, the SDWQGs may be used as a benchmark for the Drinking Water Source-to-Tap Screening Tool and Comprehensive Drinking Water Source-to-Tap Assessment Guideline, tools used by water suppliers to characterize raw drinking water sources.

For most water systems, it would be a significant financial burden to require frequent testing for all chemical and physical parameters listed in the GCDWQ. This approach would not necessarily improve public health outcomes, especially if data indicates that a parameter consistently meets criteria for the protection of public health. This guideline does not specify a testing frequency for a water supply. Rather, it allows flexibility to ensure testing is focused on site-specific parameters relevant to a particular water source. Minor exceedances of the guidelines would normally trigger actions such as:

- Increasing monitoring or sampling,
- Source investigation and management,
- Long term planning to meet the water quality objective, and
- Communication of the situation and the mitigation plan.

Where more significant exceedances occur, DWOs will use their discretion, based on available evidence, to determine at what point the level reaches an unacceptable risk and the appropriate public health response.

3. Process

Any new water source typically requires comprehensive testing. For example, a typical suite of tests may include something similar to the following:

For surface water sources (includes groundwater that is at risk for containing pathogens):

Alkalinity	Fluoride	Nitrite (dissolved)
Ammonia	Hardness	Organic Nitrogen
Calcium	Iron	pH
Chloride	Manganese	Sulphate
Colour	Metals Scan[1]	Total Dissolved Solids
Conductivity[2]	Nitrate (dissolved)	Total Organic Carbon
Corrosiveness[3]	Bacterial indicators	
Turbidity	Bromide (for systems using ozone)	

[1] Aluminum, Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Potassium, Zinc (expand if mineralized to include Mercury)
[2] Conductance/Specific Conductance
[3] Calcium Carbonate saturation/Langelier's index

For groundwater sources:

Alkalinity	Fluoride	Phosphorous
Ammonia	Iron	Sodium
Calcium	Hardness	Sulphate
Chloride	Magnesium	Sulphide
Colour	Manganese	Total Dissolved Solids
Conductivity[4]	Metal Scan[5]	Total Organic Carbon
Corrosiveness[6]	Nitrate	Uranium
	pH	Turbidity

Many analytical labs provide testing packages that cover many of these parameters. Consideration should also be given to appropriateness of testing source water or post-treated water or both.

The DWO may also require additional testing for other parameters should evidence suggest that additional substances of concern exist. DWOs should also consider the type of water source, local community history, known contaminant sources, seasonal variation, and historical water quality reports when deciding on a testing regime. These factors may give clues to what parameters could be of concern in the future.

Where the results of initial testing indicate that additional chemical parameters are less than the GCDWQ, and local history shows that the parameters are unlikely to vary above the MAC, then further routine testing frequency may be reduced. Another consideration in this decision involves determining whether the water will be consumed by persons on an ongoing or seasonal basis, special vulnerabilities of intended users (e.g., school children), or other such matters.

For chemical or physical parameters that are identified as being near the threshold set out in the GCDWQ, the DWO should review the magnitude of the hazard that may be posed by the parameter falling in this range. If the DWO concludes that there is a health concern, he/she should consider requiring routine testing of the parameter at a defined frequency in the operating permit.

The DWO may wish to re-evaluate the testing requirements based on any new potential risks that impact water quality such as a chemical spill, a new industry with new emission sources, a change in land use, an unusual weather event, or other situation. Where there is an established history of stable and predictable chemical results, a DWO may amend the operating permit to waive, or reduce the frequency of testing of a parameter. Where a parameter experiences great variability in values over time, risk increases and therefore increased monitoring frequency should be considered.

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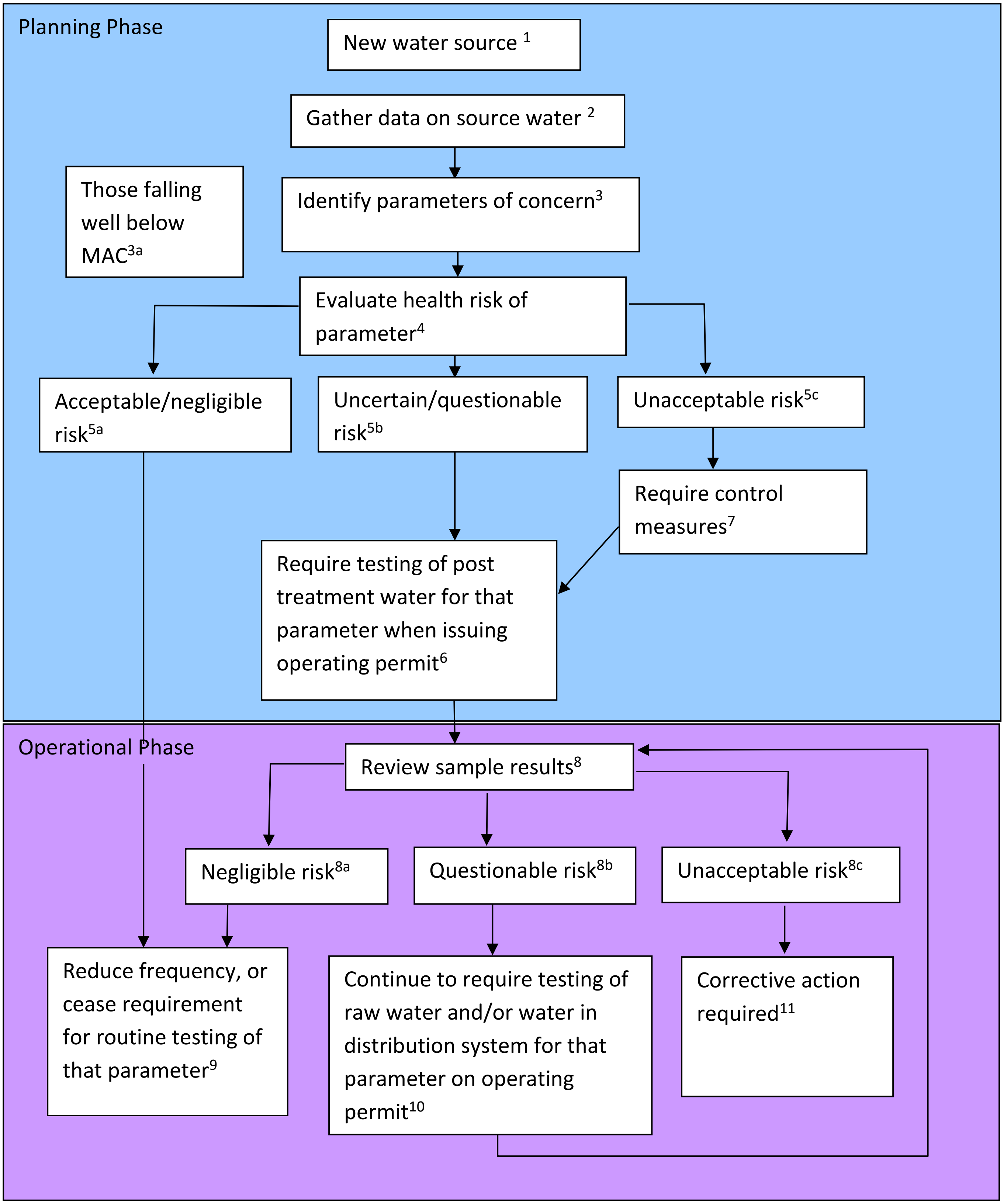
[4] Conductance/Specific Conductance
[5] Aluminum, Arsenic, Barium, Cadmium, Chromium, Copper, Lead, Potassium, Zinc (expand if mineralized to include Mercury)
[6] Calcium Carbonate saturation/Langelier's index

4. Decision Tree for Drinking Water: Requiring Additional Parameters



5. Decision Tree Endnotes

1. A new source for a water supply system under the DWPA, or re-evaluation of an existing system after an incident of contamination, or significant system modification.
2. The DWO should ask the supplier to provide the following information for consideration:
    a. Historical data from nearby water sources
    b. A suite of chemical and physical testing on the new source for health parameters in GCDWQ
    c. Activities in the watershed that may contribute to elevated sample results (e.g., local industry, agriculture, historical chemical spills)
    d. The type of water source (i.e. groundwater vs. surface supply etc.)
    e. The anticipated effect of proposed treatment on parameters (e.g., formation of disinfection by-products)
    f. Anticipated seasonal fluctuations in water quality and quantity

The supplier may accomplish this by providing the health authority a health risk assessment of water quality.

3. The DWO will compare data collected to GCDWQ and/or other standards to identify those which may require further consideration. Those that are measured at or near the MAC, or other standards need further consideration. This may include consideration of the anticipated effect of proposed treatment on parameters (e.g., formation of disinfection by-products)
    a. Subject to consideration given under box 2, those falling well below the MAC or other standards may not require further routine testing.
4. Evaluate the magnitude of the risk for each parameter that is near or exceeding the threshold in the GCDWQ or other standards. The information in Box 2 should be considered in this evaluation.
5. Where the DWO concludes that the risk of a parameter is:
    a. Acceptable/Negligible: no further routine testing is required; unless there is reason to believe the situation has changed. (Where an event such as a chemical spill, or the introduction of a new industry in the community occurs, the DWO may wish to re-evaluate the testing requirements based on this new information).
    b. Uncertain/Questionable: Require periodic sampling of the parameter in question on the operating permit (go to box 6)
    c. Unacceptable – (go to box 7)

6. The DWO should require periodic sampling and reporting of this parameter on the conditions of the operating permit at source and/or distribution system as appropriate.
7. Where source water is found to be unacceptable, the DWO should require mitigation of the parameter to reduce risk, by:
    a. Requiring control measures (e.g., water treatment)
    b. Finding another source
    c. Where water is currently in use, notifying users
    d. Continuing to monitor to verify that control measures are effective (go to box 6)

This may be done through adding or modifying conditions on permit or by an order issued under the DWPA.

8. Once a water supply system is in operation, routine sampling will give an indication of whether the risk:
    a. Is shown to be negligible (e.g., reducing concentration over time)
    b. Requires further monitoring to ensure that risk does not increase, or
    c. Increases to an unacceptable level on a temporary or long term basis.
9. With an established history of stable and predictable chemical and/or physical results, a DWO may amend the operating permit to reduce frequency or waive the requirements for testing of a parameter. The DWO may, however take into consideration that if a parameter monitored is part of a suite of measurements offered by a lab, it may not be of any consequence to reduce testing of a particular parameter.
10. Conditions on operating permit should require regular monitoring to ensure that risk does not increase.
11. Where monitoring reveals that the concentration of the parameter increases to an unacceptable level, the DWO should require notification of users. The DWO should evaluate the magnitude of the exceedance of the guideline, as well as whether the condition of the water is of a temporary or long term nature. As most parameters identified in the *Guidelines for Canadian Drinking Water Quality* are based on lifetime exposure, temporary minor exceedances are usually not a cause for immediate remedial action. However, if there the problem is of a long term nature, the DWO should consider requiring the water supplier to develop a plan for mitigating the problem which includes an established timeline for completion.

6. Definitions

Acceptable/Negligible Risk

- The parameter is below the MAC in the GCDWQ or other prescribed standards

Uncertain/Questionable Risk:

- The parameter is near or exceeds the MAC in the GCDWQ or other prescribed standards; or
- There is inadequate data to determine if levels are consistently below the MAC.

Unacceptable:

- Exceeds the MAC in the GCDWQ, or other prescribed standards; or
- Where no standard exists, the DWO has assessed the risk and determined that a drinking water health hazard exists.

Requests for Investigation of a Drinking Water Threat Under the *Drinking Water Protection Act*

Version 1.2 / First Published 2014

Ministry of Health

1. Purpose

Under section 29 of the *Drinking Water Protection Act*, if a person considers that there is a threat to their drinking water, the person may request the drinking water officer (DWO) to investigate the matter. This document contains a sample template questionnaire form for such investigations.

2. Application

Information for those requesting an investigation under Section 29

Requests for investigation can be made by any person that believes that there is a threat to their own drinking water supply. Section 29 requires requests to be in writing.

A request for investigation should include the information contained in the form below. The questionnaire will assist in documenting the specific facts related to the drinking water threat and provide health authority staff with relevant information that can be reviewed in an expeditious manner to determine if an investigation is warranted.

This form should provide the local DWO with enough information as to determine whether an investigation should be initiated under Section 29, however the DWO may ask for further information depending on the specifics of the case. Consequently, it is recommended that persons making these requests contact the DWO beforehand.

If the DWO decides not to conduct an investigation, they should provide a written explanation as to why the decision was made.

If an investigation is conducted, the DWO must advise of the results of the investigation. When doing so, the DWO should specify their findings regarding whether any threat was found, and what, if any, follow-up action will be taken. DWOs should also provide this information in writing.

Request for a Section 29 Investigation Under the *Drinking Water Protection Act*

Name: **Date:**
Mailing address: **Phone Numbers:**
Address of well property:

1. Is your water supply or residence located on federal or First Nation lands?
☐Yes ☐No ☐Unsure

2. Source of Water
☐ Private Well
☐ Private Surface Water (Provide Name of Stream or Lake) ______________
☐ Permitted Community Water System (Provide Name) ________________ (if municipal option applicable please proceed to question 24)

3. Describe the location of your drinking water supply (i.e. well) on your property. (ex. 20 m from north boundary and 60 m from east boundary of property)

<u>Well Information (If Applicable)</u>

4. Is your well: ☐Drilled ☐Excavated (dug) ☐Driven (sand point) ☐Unsure

5. What year was your well drilled? ____________________ ☐Unsure

6. Name of well driller _________________________ ☐Unsure

7. Do you have a copy of the well Drillers log (Please attach copy if available)
☐Yes ☐No ☐Unsure

8. How deep is the well? ___________**(metres)** ☐Unsure

9. How deep is the water table below the ground? ________________**(metres)** ☐Unsure

10. Does the well draw water from: ☐Sand and/or gravel aquifer ☐Fractured bedrock ☐Unsure

11. During well construction were there any layers of clay, silt, till or hardpan encountered above the well screen or well intake? ☐Yes ☐No ☐Unsure

12. Does the well have a secure well cap? ☐Yes ☐No ☐Unsure

13. Does the well have a surface seal? ☐Yes ☐No ☐Unsure

14. Is the well located in an area where there is known flooding or where water can pond?
☐ Yes ☐ No ☐ Unsure

15. Are there any structures, buildings, material storage, or animals near your well-head? (Please describe)

16. Is your well-head protected by a covered structure? ☐Yes ☐No ☐Unsure

17. Has your well been disinfected in the past? (please describe)
18. Any other relevant information about your well? (Please describe)
19. Have there been any groundwater assessments of your well water supply conducted by a professional hydrogeologist? *(Please provide a copy of the report)*
20. Is water stored at your home stored prior to use in a: Pressure tank Holding tank Other ________________________________ No water storage
21. What type of material is used for the water distribution pipes? **In your home _________________________** **From your well to your home _____________** **From street to your home ________________**
22. Do you currently treat your drinking water supply? No Yes If yes, please specify method used: Chlorine UV Osmosis Boiling Filtration (specify type) ___________________ Other ___________________
23. Are any of the following located close to your water well or surface water intake? *If so, please describe and include approximate distance:*
a. Chemical storage (household or agricultural, including pesticides) Distance: ________metres
b. Fuel storage (above ground or underground) Distance: ________metres
c. Manure storage or application Distance: ________metres
d. Livestock Distance: ________metres
e. Wildlife Distance: ________metres

f. Other wells including abandoned well(s) Distance: ________metres
g. Septic systems, (including your own or those on nearby properties) Distance: ________metres
h. Major roads, highways, railways, pipelines, drainage ditches Distance: ________metres
i. Lake, stream, river, pond or ocean Distance: ________metres
j. Landfill, refuse storage, contaminated sites Distance: ________metres
k. Other (Specify)
24. Have you noticed any taste, odour and/or appearance changes (colour, cloudiness) to your drinking water? If so, when did you first notice the change? (Please provide details)
25. Has anyone become ill as a result of drinking the tap water from your home? (*Please provide supporting documentation if possible, including water test reports, medical testing results and/or doctor's report).*
26. Have there been any water quality tests performed on your drinking water supply (Chemical, Bacteriological, other)? *(Please attach copies of lab reports)*
27. Are you aware if your municipal water supplier has issued a boil water notice or drinking water advisory? If so, what was the nature of the advisory?
28. Have you contacted your municipal water supplier about your concerns? If so, what was their response?

29. If applicable, please provide municipal contact person you have interacted with on this issue.
30. Other evidence which supports your concern about the safety of your drinking water? (*Please provide specific details and attach any relevant supporting documents.)*
31. What initiated your complaint?
32. How do you expect your complaint to be resolved?

____
Name of person requesting an investigation
(Please print)

____________________________ ______________
Signature Date

Strategies, Tools and Procedures Health Authorities May Use to Find and Regulate Small Systems

Version 1.3 / First Published 2014

Ministry of Health

1. Purpose

This document outlines strategies that health authorities may use find small water systems that have not been permitted as required by the *Drinking Water Protection Act.*

2. Background

There are likely many (possibly thousands) systems that meet the definition of a Water Supply System under the *Drinking Water Protection Act* that are unknown to the health authorities. Many of the operators of these systems either do not know that they are subject to the *Drinking Water Protection Act*, or would prefer not to be regulated.

Should health authorities have the resources to systematically find systems that have not been permitted, there are tools such as databases held by the Ministry of Water, Land and Resource Stewardship that health authorities could utilize. This document identifies these tools and provides basic procedures on how they may be used. The document also outlines other strategies that may assist in preventing new systems from falling outside of the regulatory process.

3. Strategies to Find Un-Permitted Systems

3.1. Use the Ministry of Water, Land and Resource Stewardship's Water Licence Information System to find licences for water extraction.

All surface water intakes should have a licence from the Ministry of Water, Land and Resource Stewardship, and information on such systems is found under the Water License Information System (WLIS). Health Authorities can use this database to search for systems that hold licences.

Example procedure to find water supply systems that were issued water works licences since the beginning of 2009:

a) Go to http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input
b) Under **Purpose**, from the dropdown menu choose **Waterworks - other**.
c) Under New Licences or Applications from this date forward; enter the January 1, 2009 date like this: 20090101
d) Click the **Submit** button

This will produce a list of the new applications and licences for this purpose.

This procedure can be done for other **purposes** or **dates,** and/or refined to include only specific geographical areas by selecting the **watershed** or **water district** drop down boxes.

For a list of purposes involving water distribution systems for human consumption, see the **Water Use Purpose Definitions** as listed here: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/water-rights/water_use_purpose_defns.pdf.

3.2. Use the Ministry of Water, Land and Resource Stewardship's Provincial Groundwater Wells and Aquifers (GWELLS) application to search for groundwater drinking water supply systems.

The Ministry of Water, Land and Resource Stewardship has a well database that contains information submitted on a voluntary basis by well drillers. Health Authorities can use this database to search for systems that have been registered.

Example Procedure to find wells that were drilled as drinking water supply systems in a given year:

a) Go to https://apps.nrs.gov.bc.ca/gwells/
b) Under Advanced Search, search by "All field match" and fill out any fields you wish to search by, i.e., **Date of work, Land District** or **City.**
c) Under Additional Fields, add the **Intended water use** field and choose **Water Supply System**.
d) Click the "Search" button.

In the list of results, clicking on the Well Tag Number allows the user to pull up detailed information about the well, including the well construction report located in the Documents section. You can also export search results as an Excel or CSV file.

Please note:

- The GWELLS database does not distinguish between large or small drinking water supply systems.
- Until recently, groundwater reports on WELLS were submitted to this database on a voluntary basis, and it does not represent all wells that may exist.
- The WELLS database may have gaps in owner contact information.

Drinking Water Complaints and Inquiries Process

Version 1.2 / First Published 2014

Ministry of Health

1. Purpose

The Health Protection Branch in the Ministry of Health is contacted from time to time by the public about concerns pertaining to drinking water, including:

- Complaints regarding a specific public health concern in a community (e.g. drinking water threat).
- Complaints regarding service provided by a health authority, or a policy a health authority has adopted.
- Complaints regarding a policy or service of the Ministry of Health's Health Protection Branch.

The purpose of this document is to provide guidance to the public and health protection staff on to how to file concerns, and what to expect once they are filed.

2. How Do I Make a Complaint or Inquiry?

There are a number of ways you can contact the Ministry of Health to make a drinking water complaint or inquiry. It is most efficient if you phone, email or send a letter to the Health Protection Branch:

Health Protection Branch
Population and Public Health Division
Ministry of Health

4th Floor, 1515 Blanshard Street
Victoria, B.C., V8W 3C8
phone: 250-952-1469, fax: 250 952-1713
email: HP-PHW@gov.bc.ca

Hours of operation: 8:30 a.m. to 4:00 p.m., Monday to Friday, excluding holidays

When contacting us, please provide us with as much information as possible, including:

- Your name and contact information.
- The location of your concern.
- The nature of your concern.
- Names of individuals or businesses, or organizations related to your concerns and, where possible, contact information.

3. How Will My Concern Be Addressed?

3.1. Concerns about Drinking Water Systems

Many concerns received by Health Protection Branch staff are about a particular drinking water system, incident, event or situation occurring in the person's community.

Most of these issues fall under the jurisdiction of local health authorities, and are best addressed by their staff. Please contact health authorities directly. Health authority contact information is found on this page.

If you are unable to reach the correct person at the health authority, the Health Protection Branch will be happy to assist by:

- Recording the name, contact information, and location of the complainant.
- Recording any pertinent details provided by the complainant.
- Referring the complainant to the relevant person in the health authority for follow up, and/or providing the complainant with contact information, and sources of further information.

Formal requests for investigations under section 29 of the *Drinking Water Protection Act* must be made **directly to your local health authority in writing**. If you are wishing to request an investigation under this section, Health Protection Branch staff can guide you to the appropriate contact person within your local health authority.

3.2. Concerns about Service Provided by Health Authorities

The Health Protection Branch from time to time receives concerns about service provided by health authorities. The health authority staff do not have a direct reporting relationship with the Ministry of Health. The Branch's initial response will be to help people find the right person in the health authority to follow up on their complaints, usually beginning with the supervisor.

Requests for **reconsideration** of a decision as per Part 6 of the *Drinking Water Protection Act* will be referred to health authorities.

Requests for **review** of decisions as per Part 6 of the *Drinking Water Protection Act* will be referred to the office of the Provincial Health Officer.

If, after following this approach, the complainants are not satisfied with the service they have received from the health authority, concerns can be brought to the Health Protection Branch. For these types of concerns, Health Protection Branch staff will:

- Record the name, contact information, and location of the complainant
- Record any pertinent details provided by the complainant, including:
    - The name of the organization about which the complainant is concerned.
    - Names of the people with whom the complainant has dealt.
    - The nature of the concern.
    - The measures the complainant has already taken to try to resolve the concern.
- Refer the concern to the relevant person in the health authorities for follow up, and provide the complainant with the contact information.

For more information, see the Drinking Water Health Authority Contacts website.

For a link to other public health agency contact information, see this page.

3.3. Concerns about Policies or Services Provided by the Health Protection Branch, Ministry of Health

If you have views about the Ministry of Health's drinking water policies, its services or the way they are provided, or other inquiries, we would like to hear from you. Our staff value ensuring that all enquiries are treated properly and promptly. Let us know if you have an inquiry that needs answering, or if you are unhappy about:

- A decision we have made.
- Any aspect of our work.
- A member of our staff providing incorrect information or treating you unprofessionally.

When contacted, Health Protection Branch staff will:

- Record the name, contact information, and location of the complainant.
- Record any pertinent details provided by the complainant, including:
    - The name of the organization about which you are concerned.
    - Names and or titles of the people with whom you have dealt.
    - The nature of your concern.

Once we have received this information, we will either direct you to the right person or take a note of your complaint or inquiry, and pass it to him or her. We will usually do this within 24 hours, but please allow up to 20 working days for an initial response. If you do not have all the information above, we will work with you try to determine the best person to address your concern.

If your concern falls outside of the Ministry's range of responsibilities we will inform you of this and forward your complaint to the right service agency as quickly as possible.

As a learning organization, we value your feedback. Please let us know if your complaints or inquiries have been satisfactorily resolved and what steps we can undertake to improve our responses. We would also like feedback if you are satisfied with our response.

4. Still Not Satisfied?

If you have already contacted the Health Protection Branch and are still not satisfied, you can contact the Deputy Minister or Minister of Health for further consideration of your matter. Please put your concerns in writing and send them to the Minister of Health. A reply will be provided within 20 working days. Your complaint will be logged and tracked to ensure it is resolved.

Office of the Deputy Minister of Health
1515 Blanshard Street
Victoria, B.C., V8W 3C8
Phone: 250-952-1911
Fax: 250-952-1909

Office of the Minister of Health
Phone: 250-953-3547
Fax: 250-356-9587
E-mail: hlth.minister@gov.bc.ca

If you are unhappy with the minister's response, you can also send a written complaint to the Office of the Premier.

5. Ombudsperson

If you are not able to reach a resolution and you feel that you have been treated unfairly by the Ministry of Health, you can refer your complaint to the Office of the Ombudsperson. The Ombudsperson can:

- Provide information about what steps to take in dealing with a public agency.
- Try to settle complaints through consultation.
- Investigate complaints about administrative unfairness by a public agency.
- Make recommendations to a public agency to resolve an unfair situation.
- Report to the provincial legislature.
- Issue public reports.

Ombudsperson
Local phone: (250) 387-5855 (Greater Victoria area)
Toll-free phone: 1-800-567-3247 (all of B.C.)
In Person: 947 Fort Street – 2nd floor, Victoria, B.C., Canada
Hours: 8:30 a.m. to 4:30 p.m. Monday to Friday
By mail: PO Box 9039 STN PROV GOVT, Victoria, B.C., V8W 9A5, Canada
Fax: (250) 387-0198
Website: https://bcombudsperson.ca/

Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia

Version 1.2 / First Published November 2012

Ministry of Health

1. Objective

To provide a general overview of microbiological drinking water treatment objectives for surface water supplies in British Columbia.

2. Background and Regulatory Framework

There are three main types of microorganisms (pathogens) that pose risks to human health in drinking water: viruses, bacteria and protozoa. The B.C. *Drinking Water Protection Act* (DWPA) (2001) and Drinking Water Protection Regulation (DWPR) (2003) specify water quality standards, monitoring schedules, applicability and recommended treatment aimed at reducing the risks from these pathogens.

Schedule A of the DWPR specifies bacteriological water quality standards for potable water[1] for the protection of human health. These standards represent partial drinking water treatment goals and are consistent with the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Escherichia coli* and total coliform (Health Canada, 2012a).

Schedule B of the DWPR outlines the monitoring schedule and its applicability based on population served. Section 5 of the regulation requires that surface water sources must, as a minimum, receive disinfection. Reducing risks from virus and protozoa through disinfection of drinking water are dealt with through the application of best management principles as outlined in this document and detailed in the *Guidelines for Canadian Drinking Water Quality* (GCDWQ). As no one type of treatment system is effective in treating all hazards, a multi-barrier approach is usually required to adequately address all risks, which typically includes two or more forms of treatment.

[1] Potable water is defined under the *Drinking Water Protection Act* as water provided by a domestic water system that (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment.

The DWPA and the DWPR give drinking water officers (DWOs) the flexibility and discretion to address public health risks through treatment requirements in operating permits to deal with pathogenic risks. Discretion of the drinking water officer also includes, but is not limited to, understanding the source water characterization, effectiveness of system-specific treatment technologies, operational management issues and reasonable time frames to achieve incremental improvements to existing systems. With respect to water quality analyses, the issuing official should ensure that he/she has adequate data to determine that the proposed treatment is adequate to address public health risks in relation to relevant microbiological and chemical/physical parameters.

Existing water supply systems may have some appreciable risk for certain parameters without treatment in place. In such cases, it is acceptable from a public health perspective for water supply systems to present drinking water officers with a continuous improvement plan that addresses implementing treatment for these parameters within a reasonable time period.

3. Purpose and Scope

Under the DWPA, water suppliers have the responsibility to provide potable water to all users of their systems. Drinking water treatment requirements are site specific, risk based and dependent on a number of factors, including source water quality and efficacy of treatment technology.

This document provides the basic minimum framework towards goals for drinking water treatment for pathogens in surface water supply systems in British Columbia. It may also be used as a general reference for assessing progress towards updating or improving existing water supply systems. This document does not address the treatment of groundwater or disinfection of distribution systems.

These objectives rely on the *Guidelines for Canadian Drinking Water Quality* (See Summary table - Health Canada, 2019) as a primary reference for potability. However, given site-specific conditions of water systems in various regions of B.C., it is necessary to apply these guidelines in consideration of a risk assessment of individual cases. In all cases, the drinking water officer must be contacted to confirm the necessary treatment objectives for microbiological parameters when planning or upgrading water supply systems.

4. Treatment Objectives

These objectives provide treatment requirements that address the following microbiological parameters: enteric viruses, pathogenic bacteria, *Giardia* cysts and *Cryptosporidium* oocysts. The general objectives are as follows and described in more detail below:

- 4-log reduction or inactivation of viruses.
- 3-log reduction or inactivation of *Giardia* and *Cryptosporidium.*
- Two treatment processes for surface water.
- Less than or equal to (≤) one nephelometric turbidity unit (NTU) of turbidity.

- No detectable *E. Coli*, fecal coliform and total coliform.

These drinking water treatment objectives provide a minimum performance target for water suppliers to treat water to produce microbiologically safe drinking water. Depending on specific situations, the actual amount of treatment required will depend on the risks identified and may require greater levels of treatment. Water treatment is only one part of the multi-barrier approach to providing safe drinking water. Choosing an appropriate water source, protecting that source and reducing distribution system risks can be essential complementary steps to providing treatment when dealing with microbiological risks.

While there are numerous precautionary treatment steps available to reduce the risk of microbiological contamination of drinking water supplies, no system is fail-safe. Risk management is based on applying scientific evidence that documents the quality and variability of the water source and the efficacy of management measures selected to achieve acceptable public health outcomes.

4.1. 4-log Inactivation of Viruses

Viruses are micro-organisms that are incapable of replicating outside a host cell. In general, viruses are host specific, which means that viruses that infect animals or plants do not usually infect humans, although a small number of enteric viruses have been detected in both humans and animals (Health Canada, 2011). Viruses are ubiquitous and often species-specific. Viruses of concern in drinking water are those that cause human illness or are capable of cross-species transfer. The role of nonhuman viruses as facilitators of pathogens or in transmitting genetic material that could be pathogenic is not clearly understood; hence, overall reductions of viruses in source water are preferred.

Health Risk Management Outcomes for Enteric Viruses

The level of risk deemed tolerable or acceptable by Health Canada for enteric viruses has been adopted from the World Health Organization's (WHO) *Guidelines for Drinking-Water Quality* (WHO, 2004) based on the Disability Adjusted Life Year (DALY) as a unit of measure for risk.

The basic principle of the DALY is to calculate a value that considers both the probability of experiencing an illness or injury and the impact of the associated health effects (Murray and Lopez, 1996a; Havelaar and Melse, 2003; cited from Health Canada, 2011). The WHO (2004) guidelines adopt 10^{-6} DALY/person per year as a health risk management target. Table 1 describes the relationship between viruses in source water and the level of treatment necessary to achieve this health risk management goal.

Table 1: Overall treatment requirements for virus log reduction as a function of approximate source water concentration to meet a level of risk of 1 × 10^{-6} DALY/person per year) (Cited in Health Canada, 2011)

Source water virus concentration (no./100 L)	Overall required treatment reduction for viruses (log_{10})
1	4
10	5
100	6
1000	7

Treatment Objectives for Enteric Virus

A minimum 4-log reduction of enteric viruses is recommended for all surface water sources. Depending on the surface water source, especially those subject to human fecal contamination, a greater than 4-log reduction may be necessary (See Table 1).

Reductions can be achieved through physical removal processes, such as filtration, and/or through inactivation processes, such as disinfection (Health Canada, 2011). Disinfection of water systems is recommended as a means to provide safeguards to the water system. Enteric viruses are readily inactivated by the use of chemical disinfection such as chlorine.

Ultraviolet (UV) light disinfection systems may be used to reduce viruses in water, but the effectiveness of UV varies significantly among different types of viruses. Double-stranded DNA viruses, such as adenoviruses, are more resistant to UV radiation than single-stranded RNA viruses, such as HAV (Meng and Gerba, 1996; cited in Health Canada, 2011).

Because of their high level of resistance to UV treatment and because some adenoviruses can cause illness, particularly in children and immunocompromised adults, adenoviruses have been used by the U.S. EPA as the indicator pathogen for establishing UV light inactivation requirements for enteric viruses in the *Long Term 2 Enhanced Surface Water Treatment Rule* (LT2ESWTR) (U.S. EPA, 2006). Accordingly, the LT2ESWTR requires a UV dose of 186 mJ/cm^2 to achieve 4-log inactivation of viruses (U.S. EPA, 2006).

For water supply systems in Canada, UV disinfection is commonly applied, most often in combination with chlorine disinfection or other physical removal barriers such as filtration (Health Canada, 2011). A UV dose of 40 mJ/cm^2 is considered to be protective of human health as most enteric viruses are inactivated at this dosage; however, this dosage would provide only a 0.5-log inactivation of adenovirus. Additional log removal credits may be obtained through the addition of free chlorine.

For drinking water sources considered to be less vulnerable to human fecal contamination, the drinking water officer may accept an enteric virus such as rotavirus as the target pathogen to determine the UV dose required for 4-log inactivation of viruses. Where a system relies solely on UV disinfection for pathogen control and the source water is known or suspected to be contaminated with human sewage,[2] either a higher UV dose such as that stated in the LT2ESWTR or a multi-barrier treatment strategy should be adopted.

The physical removal of viruses can be partially achieved by clarification and filtration processes. Clarification is generally followed by the filtration process. Some filtration systems, however, are used without clarification (direct filtration). Many treatment processes are interdependent and rely on optimal conditions upstream in the treatment process for efficient operation of subsequent treatment steps.

Drinking water treatment plants that meet the turbidity limits established in the *Guidelines for Canadian Drinking Water Quality: Supporting Documentation — Turbidity* (Health Canada, 2012b) can apply the estimated physical removal credits for enteric viruses. For example, for conventional filtration, the virus credit is 2-log and for direct filtration the virus credit is 1-log.

Alternatively, log removal rates can be established on the basis of demonstrated performance or pilot studies. The physical log removal credits can be combined with the disinfection credits to meet overall treatment goals. In all cases, the drinking water officers must be consulted when planning treatment for a water supply system.

It is recommended that water supply systems should provide, as a minimum, 4-log reduction of viruses for all surface water systems.

4.2. 3-log Inactivation of Giardia and Cryptosporidium

Protozoa such as *Giardia* and *Cryptosporidium* are relatively large pathogenic microorganisms that multiply only in the gastrointestinal tract of humans and other animals. They cannot multiply in the environment, but their cysts/oocysts can survive in water longer than intestinal bacteria, and they are more infectious and resistant to disinfection than most other microorganisms (Health Canada, 2004).

Health Risk Management Outcomes for Giardia and Cryptosporidium

While *Giardia* and *Cryptosporidium* can be responsible for severe and, in some cases, fatal gastrointestinal illness, the *Guidelines for Canadian Drinking Water Quality* have not established maximum acceptable concentrations for these protozoa in drinking water. Routine methods available for the detection of cysts and oocysts have low recovery rates and do not provide any information on

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[2] The Ministry of Health is awaiting further clarification from Health Canada as to what constitutes as *human fecal contamination*. In lieu of clarification, it is best to use as much available information as possible to make an informed decision on a case-by-case basis.

their viability or human infectivity. Until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures should be implemented to reduce the risk of illness as much as possible.

Treatment Objectives for *Giardia* and *Cryptosporidium*

The goal of surface water treatment is to reduce the presence of disease-causing organisms and associated health risks to an acceptable safe level.

Treatment of drinking water is another integral part of the multi-barrier approach. In addition to disinfection, where warranted by source water conditions, physical treatment of surface supplies should be included. Because *Giardia* and *Cryptosporidium* are ubiquitous in surface waters in Canada and more resistant to disinfection than most other infectious organisms, it is desirable that treatment achieves at least a 99.9% (3-log) reduction of *Giardia* and *Cryptosporidium* (Health Canada, 2004).

Giardia may be partially inactivated by large doses of free chlorine, ozone or chlorine dioxide. Filtration can be effective in removing *Giardia* cysts and *Cryptosporidium* oocysts, but the performance is significantly dependant on the methods of filtration and operational performance. *Giardia* and *Cryptosporidium* may also be inactivated using UV disinfection. Many commercially available UV systems have undergone testing to verify that the dosage provided under design operating conditions achieves the 3-log inactivation required.

It is recommended that water supply systems should provide, as a minimum, 3-log reduction of *Giardia* and *Cryptosporidium* for systems that have a water source considered to have low risk of these parasites and have not had an outbreak of the disease. A higher level of reduction may be required if the situation justifies it.

4.3. Two Methods of Treatment (Dual Treatment)

Health Risk Management Outcomes for Dual Treatment of Drinking Water

Some microbiological agents of concern are more resistant to certain forms of treatment than others. Ultimately, the best approach to ensure complete disinfection of water intended for human use is a multi-barrier one, which begins with collecting water from the cleanest source possible.

As most disinfection systems require clear water to ensure maximum efficiency, it may be necessary to combine multiple specific treatment technologies. To provide the most effective protection, the *Guidelines for Canadian Drinking Water Quality* recommend that filtration and one form of disinfection be used to meet the treatment objectives.

Alternatively, two forms of disinfection (for example, chlorination and UV disinfection) may be considered if certain criteria are met.

Filtration Exemption

A water supply system may be permitted to operate without filtration if the following conditions for exemption of filtration are met, or a timetable to implement filtration has been agreed to by the drinking water officer:

1. Overall inactivation is met using a minimum of two disinfections, providing 4-log reduction of viruses and 3-log reduction of *Cryptosporidium* and *Giardia*.
2. The number of *E. coli* in raw water does not exceed 20/100 mL (or if *E. coli* data are not available less than 100/100 mL of total coliform) in at least 90% of the weekly samples from the previous six months. Treatment target for all water systems is to contain no detectable *E. coli* or fecal coliform per 100 ml. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of the samples should have no detectable total coliform bacteria per 100 ml and no sample should have more than 10 total coliform bacteria per 100 ml.
3. Average daily turbidity levels measured at equal intervals (at least every four hours) immediately before the disinfectant is applied are around 1 NTU, but do not exceed 5 NTU for more than two days in a 12-month period.
4. A watershed control program is maintained that minimizes the potential for fecal contamination in the source water. (Health Canada, 2012b)

Applying the filtration exemption criteria does not mean filtration will never be needed in the future. A consistent supply of good source water quality is critical to the approach, but source quality can change. Therefore, the exemption of filtration must be supported by continuous assessment of water supply conditions.

Changing source water quality can occur with changes in watershed conditions. Increased threats identified through ongoing assessment and monitoring may necessitate filtration. Maintaining the exemption condition relies on known current and historic source water conditions, and provides some level of assurance to water suppliers that a filtration system may not be necessary unless the risk of adverse source water quality increases.

It is recommended that dual water treatment should be applied to all surface water.

4.4. ≤1 NTU in Turbidity

Events such as sedimentation from road surfaces, higher surface runoff peak flows, landslides and debris flows increase a condition commonly referred to as "turbidity." Turbidity in water is caused by suspended organic and colloidal matter, such as clay, silt, finely divided organic and inorganic matter, bacteria, protozoa and other microscopic organisms. It is measured in nephelometric turbidity units (NTU) and is generally acceptable when less than 1 NTU, as per the exemption criteria in section 4.3, and becomes visible when above 5 NTU.

Health Risk Management Outcomes for Turbidity

Turbidity is an indicator of the potential presence of human pathogens such as bacteria and protozoa. Furthermore, a greater concentration of organic and/or microbiological matter in source water has the potential to disrupt or overload drinking water disinfection processes, such as UV light and chlorination, to the point that they may no longer effectively control pathogens in the water. In addition, organic matter in the water can react with disinfectants such as chlorine to create byproducts that may cause adverse health effects (Health Canada, 2012b).

Treatment Objectives for Turbidity

In general, turbidity is caused by particles in water and can be effectively reduced by filtration. Depending on the filtration technologies applied to the water, filtered water from well operated filtration systems could have turbidity ranges from 0.1 to 1.0 NTU. The Canadian Guideline on turbidity applies to filtered surface water and is categorized by the type of filtration technology: conventional and direct filtration, slow sand or diatomaceous earth filtration, and membrane filtration. To comply with the Canadian Guideline, continuous monitoring of turbidity is required.

Turbidity is effectively reduced through filtration, using one of a number of common technologies. The goal of treating water for turbidity is to reduce its level to as low as possible and minimize fluctuation. For this reason, when filtration technology is employed, the system should strive to achieve a treated water turbidity target from individual filters or units of less than 0.1 NTU at all times. Where this is not achievable, the treated water from filters or units should be less than or equal to 0.3 NTU for conventional and direct filtration; less than or equal to 1.0 NTU for slow sand or diatomaceous earth filtration; and less than or equal to 0.1 NTU for filtration systems that use membrane filtration. Inability to achieve these objectives in filtered systems indicates a breakdown of the treatment train and potential health impacts to users.

For nonfiltered surface water to be acceptable as a drinking water source supply, average daily turbidity levels should be established through sampling at equal intervals (at least every four hours) immediately before the disinfectant is applied. Turbidity levels of around 1.0 NTU but not exceeding 5.0 NTU for more than two days in a 12-month period should be demonstrated in the absence of filtration. In addition, source water turbidity also should not show evidence of harbouring microbiological contaminants in excess of the exemption criteria under section 4.3 of this document.

It is recommended that turbidity of treated surface water should be maintained at less than 1 NTU. Where filtration is part of the treatment process, the turbidity levels should comply with the Canadian guideline on turbidity, entitled *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity (Health Canada, 2012b)* (expected turbidity reduction depends on the filtration methods). Continuous monitoring of turbidity should be required for water systems with filtration to verify compliance with system performance objectives. Systems that meet the criteria for exemption from the requirement for filtration should be monitored to verify that the system continues to meet the exemption criteria.

4.5. No Detectable E. Coli, Fecal Coliform and Total Coliform

E. coli and other fecal coliforms are members of the total coliform group of bacteria, but *E. coli* is the only member found exclusively in the feces of humans and other animals. Other members of the total coliform group (including fecal coliforms) are found naturally in water, soil, vegetation and feces. The presence of *E. coli* and other fecal coliforms in water indicates not only recent fecal contamination, but also the possible presence of intestinal disease-causing bacteria, viruses, and protozoa.

Health Risk Management Outcome for *E. Coli* and Total Coliform

The absence of *E. coli, fecal coliform* and total coliform is used as an indicator that treated water is free from intestinal disease-causing bacteria. Their presence in drinking water distributed from a treatment plant indicates a serious failure and that corrective action is necessary. The presence of total coliform bacteria in the water distribution system indicates that the system may be vulnerable to contamination or experiencing bacterial regrowth.

Treatment Objectives for *E. coli*, Fecal Coliform and Total Coliform

E. coli, fecal coliform and total coliform are easily controlled with disinfection processes such as chlorine or UV light and can also be reduced by filtration. The DWPR calls for water suppliers to provide water with nondetectable *E. coli*, fecal coliform and total coliform based on sampling frequency established by the DWPR or through agreement with the drinking water officer.

In summary, according to Schedule A of the DWPR (updated 2008), the treatment target for all water systems is to contain no detectable *E. coli* or fecal coliform per 100 ml. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of the samples should have no detectable total coliform bacteria per 100 ml and no sample should have more than 10 total coliform bacteria per 100 ml.

5. Conclusion

These objectives are intended to provide general requirements for surface water supply treatment systems in B.C. and rely on the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2014) as a primary reference for potability and treatment. However, given site-specific physical, chemical and biological conditions of water supplies throughout various regions in B.C., it may be necessary to apply these guidelines based on risk assessment of individual cases.

In all cases, the treatment objectives for microbiological parameters in specific water supply systems must be developed in consultation with a drinking water officer when planning or upgrading drinking water supply systems in the province.

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Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia

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Ministry of Health

Executive Summary

The Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia (this document) provides guidance on what microbiological objectives need to be achieved for a ground water source to be considered potable. The Drinking Water Protection Regulation requires that ground water sources used for drinking water supply systems are disinfected if the ground water is at risk of containing pathogens, and disinfection must be sufficient to achieve these provincial water treatment objectives. This document is specific to microbiological objectives and it does not address parameters around secondary (residual) disinfection or any treatment required to mitigate chemical contaminants.

Determining if a water supply source is at risk of containing pathogens is outlined in a separate document entitled Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (GARP assessment). The GARP assessment considers the likelihood of pathogens being present in the ground water source based on a combination of source water quality results, well location, well construction, and aquifer type and setting. The GARP assessment can result in three outcomes which influence how microbiological treatment objectives for ground water may be achieved:

> **Ground water supplies determined to be 'at risk' of containing pathogens (GARP):** As a minimum, GARP water sources require disinfection by treatment methods equivalent to surface water supplies. This includes treatment that provides 4-log removal of viruses, 3-log removal of protozoa, maintaining less than 1 NTU effluent turbidity, and no detectable E. coli and fecal coliform in delivered water. These objectives are achieved through a multi-barrier approach that consists of at least two treatment processes. As with surface water sources, ground water sources may be exempted from filtration if the ground water source meets the filtration exemption criteria. Subsurface filtration, a natural treatment process unique to ground water sources, is also

recognized as a potential treatment method and may provide upwards of 3-log removal credit for protozoa and 4-log virus removal credit (where supported by site-specific information).

Ground water supplies determined to be 'at risk' of containing viruses (GARP-viruses only): These water sources require treatment to provide 4-log removal of viruses.

Ground water supplies determined to be at 'low risk' of containing pathogens: These water sources are not required to employ disinfection to be considered potable.

The information gathered during the GARP assessment helps inform the Drinking Water Officer of the potential hazards to a water source. This document has been developed to ensure that, where disinfection is necessary, these hazards are sufficiently addressed to ensure potable water.

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1. Objective

Reducing risks from bacteria, protozoa, and viruses by disinfection of ground water at risk of containing pathogens to provide guidance for establishing microbiological treatment objectives for drinking water systems drawing from ground water sources in British Columbia (B.C.) to achieve potable water as set out in the B.C. *Drinking Water Protection Act* (DWPA) (2001). Potable water is defined as water provided by a domestic water system that (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment.

2. Background and Regulatory Framework

2.1. Requirements for Potable Water

There are three main types of microorganisms in drinking water that pose risks to human health (pathogens) and for which microbiological treatment objectives are required: bacteria, protozoa, and viruses. The DWPA provides the regulatory framework for establishing groundwater treatment objectives in terms of potability and prescribed standards.

Section 6 of the DWPA describes the obligations of a water supplier as follows:

Subject to the regulations, a water supplier must provide, to the users served by its water supply system, drinking water from the water supply system that

- (a) is potable water, and
- (b) meets any additional requirements established by the regulations or by its operating permit.

Under the DWPA, water suppliers have the responsibility to provide potable water to all users of their systems, unless exempted under section 3.1 of the Drinking Water Protection Regulation (DWPR) (2003):

The following are exempt from section 6 of the Act:
(a) a small system, if

- (i) each recipient of the water from the small system has a point of entry or point of use treatment system that makes the water potable, and
- (ii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized;

(b) a water supply system, including a small system, if

- (i) the system does not provide water for human consumption or food preparation purposes,
- (ii) the system is not connected to a water supply system that provides water for human consumption or food preparation purposes, and
- (iii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

2.2. Requirement to Disinfect

The requirement to disinfect ground water sources at risk of containing pathogens is given in Section 5 (2) (b) of the DWPR (2003):

For the purposes of section 6 (b) of the Act, drinking water from a water supply system must be disinfected by a water supplier if the water originates from

- (b) ground water that, in the opinion of a drinking water officer, is at risk of containing pathogens.

The Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (MOH, 2017) (GARP assessment) provides an evidence-based procedure that assists public health officials in determining if a ground water source is GARP. Based on the outcome and information gathered during a GARP assessment, disinfection requirements can be established for a specific ground water source.

2.3. Water Quality Objectives (Microbiological)

Reducing risks from bacteria, protozoa, and viruses by disinfection of ground water at risk of containing pathogens is achieved through the application of best management principles as outlined in this document and supplemented by the Guidelines for Canadian Drinking Water Quality (GCDWQ) (Health Canada, 2012a).1 As no single type of treatment system is effective in addressing all hazards, treatment objectives incorporate a multi-barrier approach which typically includes two or more forms of treatment. The specific treatment required depends on the risks posed by the raw quality of the source of the drinking water.

Schedule A of the DWPR specifies bacteriological water quality standards for *Escherichia coli* (E. coli) and total and fecal coliform bacteria for the protection of human health as no detectable bacteria per 100 mL of drinking water.2 These standards represent partial drinking water treatment objectives and are consistent with the GCDWQ Guideline Technical Documents, specifically those for *E. coli* (Health Canada, 2012b) and Total Coliforms (Health Canada, 2012c).

This document provides treatment objectives for the removal or inactivation of protozoa and viruses in addition to bacteria. While the finished water quality for these other groups of pathogens is not explicitly defined in the DWPA or DWPR, they must be addressed for water to meet the definition of potable water (section 1 above). Treatment objectives for any pathogen also become legal requirements when included in the conditions of a water system's construction or operating permit.

The DWPA and the DWPR give DWOs the authority to address public health risks from pathogens by specifying water treatment objectives and requirements in construction or operating permits. Given an understanding of the risks to the ground water source, the DWO may stipulate treatment requirements based on the overall quality of the water source, identify operational management issues, and work with the water supplier to establish reasonable time frames to achieve incremental improvements to existing systems. It is the responsibility of the DWO to ensure that they have adequate information to determine that the treatment proposed by a water supplier will address the microbiological risks from a water supply, in addition to any chemical and physical parameters that need to be addressed.

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[1] Where possible, hyperlinks to guidance documents are provided. Readers should ensure that they are consulting the correct version as documents can be revised or replaced. The version used at the time of writing has been indicated in the text, usually by the date, and a full citation appears in the reference list at the end of this document.

[2] Where more than 1 sample is collected in a 30 day period the standard for total coliform is at least 90% of samples may have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL.

Existing drinking water supply systems drawing from a ground water source may have some appreciable risk for certain pathogens without treatment in place. In such cases, it may be acceptable, from a public health perspective, for a water supply system to present a DWO with an improvement plan that specifies how adequate treatment will be implemented within a reasonable time period.

3. Purpose and Scope

3.1. Purpose

This document provides consistent provincial guidance for drinking water objectives that protect human health by addressing the need to disinfect GARP sources in B.C. The information in this document may also be used as general reference for upgrading or improving existing water supply systems.

A DWO must be contacted to confirm treatment requirements for microbiological parameters when existing water supply systems come under review, when permits are required for the construction of new systems or when upgrades to existing systems are planned. The GCDWQ provides broad, high-level guidance for potability and treatment requirements. However, site-specific conditions and the available resources of water systems in various regions of the province require a flexible approach and the DWO has the discretion to adjust what treatment may be required to make a specific water source potable.

3.2. Scope

This document is intended to provide guidance on:

- the treatment necessary to address microbiological contaminants of GARP sources, and
  the application of subsurface filtration (also called riverbank filtration) treatment credits.

This document does not address:

- secondary (residual) disinfection for storage and distribution systems;
  the determination of a ground water source as GARP (see section 4);
  source water monitoring; and
  treatment for chemical contaminants.

Chemical contaminants can reduce the effectiveness of disinfection methods (e.g., by increasing the chlorine demand or by blocking/absorbing UV irradiation) and can present a long-term risk to human health (such as from arsenic). The GCDWQ provides comprehensive technical documents regarding chemical and physical water quality parameters and these should be consulted for further guidance.

4. Ground Water at Risk of Containing Pathogens (GARP)

The Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (MOH, 2017) (GARP assessment) has been developed to assist public health officials and water suppliers in determining when a ground water source is at risk of containing pathogens. It presents a methodical approach for DWOs to formulate their opinion with a four-stage process, beginning with an initial screening and assessment of the risk factors associated with a ground water source, followed by a determination of risk. Determining whether a ground water source is at risk of containing pathogens is not regarded as a one-time investigation but is subject to the results of ongoing monitoring of source water quality and the hazards to the water source.

For the purposes of setting treatment requirements, ground water sources are regarded as either 'at risk' (GARP), 'at risk from viruses only' (GARP-viruses only) or at 'low risk' of containing pathogens. Drinking water systems that draw from sources determined to be GARP or GARP-viruses only must employ disinfection. Ground water sources determined to be at low risk of containing pathogens do not require disinfection.

Information collected during a GARP assessment should be used by a DWO to rationalize what treatment is required to ensure the reliable delivery of potable water. If a water supplier has reason to believe that the treatment requirements for an existing system could be reduced, they should contact their local DWO to discuss whether a GARP assessment may be warranted.

5. Sources at Low Risk of Containing Pathogens

Ground water sources that are considered at low risk of containing pathogens as a result of a GARP assessment do not require disinfection. However, the DWO may still specify treatment requirements for a water system to address chemical contaminants or other water quality factors.

6. Well Protection

The physical protection of a well from contamination is part of a multi-barrier approach to drinking water safety and is a consideration in the GARP assessment. Wells that are located adjacent to surface waters or sources of contamination and/or wells that are improperly constructed are at risk of being contaminated. If the risk of contamination cannot be fully addressed then the risk to the water source will need to be mitigated by appropriate methods of treatment.

The location and construction of a well should be consistent with legislated construction standards in the Groundwater Protection Regulation (GWPR) (2016) and the Health Hazards Regulation (2011). The B.C. government's Well Protection Tool Kit (MOE, 2006) provides specific guidance on well protection planning and guidance on source protection can also be found in the Comprehensive Drinking Water Source-to-Tap Assessment Guideline (MHLS, 2010). The GWPR also includes specifications for the floodproofing of wells and protection of the wellhead. Wells constructed before 2005 may be exempt from certain sections of the GWPR. However, compliance with, or exemption from, the GWPR does not mean that the source is not GARP. Risks related to well construction and position should be noted and assessed during a GARP assessment along with the other risk factors that need to be considered.

7. Microbiological Treatment Objectives

7.1. Microbiological Treatment Objectives for 'GARP' Sources

Ground water sources classified as 'GARP' as a result of the GARP assessment (section 4) require treatment equivalent to surface water, with the exceptions and special considerations noted in the following subsections and Figure 1. Requirements for surface water treatment can be found in Part B of the Drinking Water Officers' Guide, under the section entitled Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (MOH, 2012).

The site-specific physical, chemical and microbiological conditions of ground water supplies throughout various regions in B.C., and the differences in the resources available to large and small water systems, necessitate the creation of individualized treatment requirements. The DWO and the water supplier should use a collaborative process to determine treatment requirements that meet provincial objectives.

7.2. Microbiological Treatment Objectives for 'GARP-Virus Only' Sources

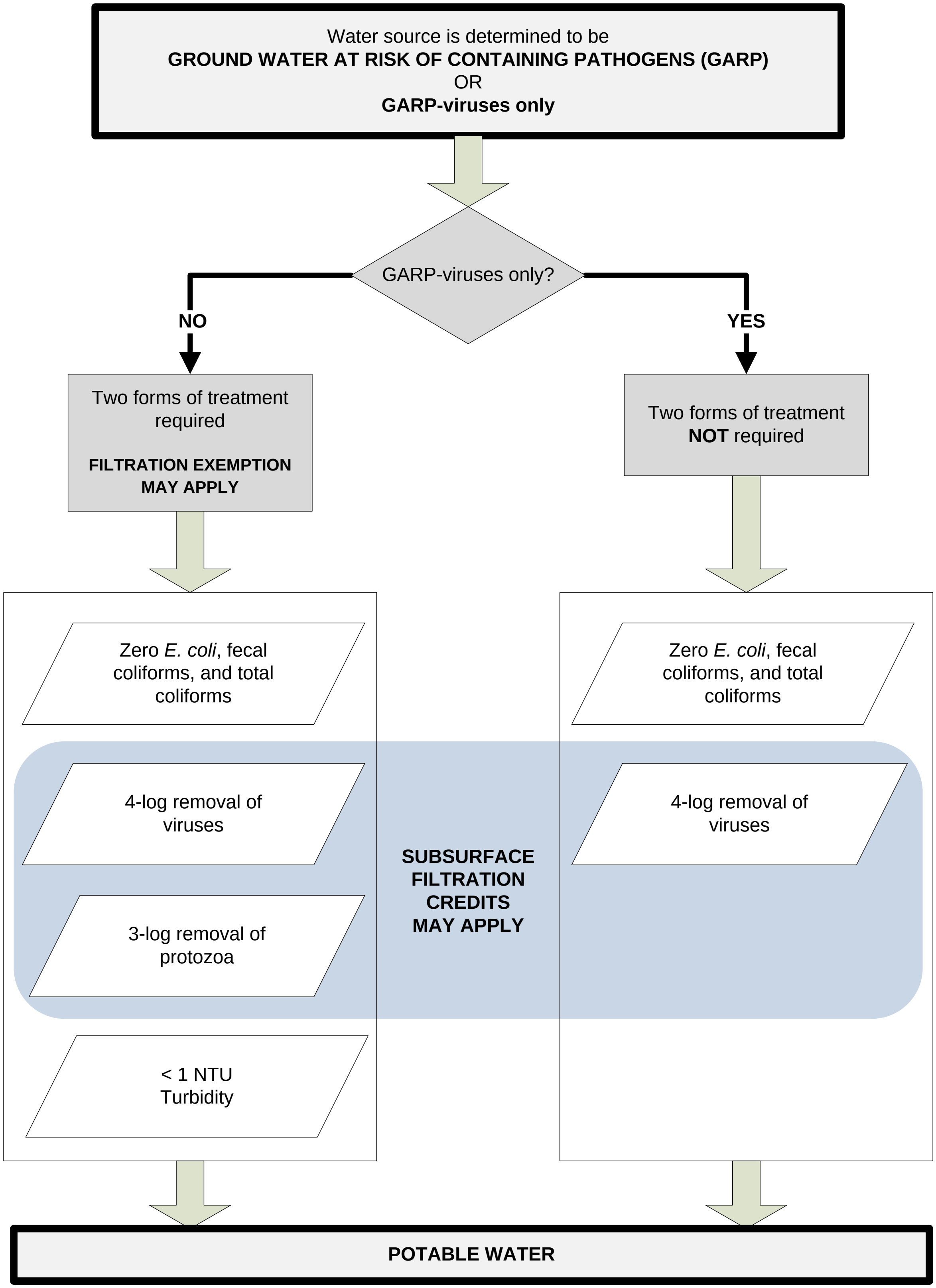
Where the GARP assessment has identified only those risk factors related to the potential presence of viruses (and not protozoa or turbidity) for a ground water source, the DWO has the discretion to limit the microbiological treatment objectives for the water system to only those for viruses (4-log removal) and bacteria (zero E. coli, fecal coliforms, and total coliforms), as outlined in the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia found in Part B of the Drinking Water Officers' Guide (MOH, 2012). A 3-log removal of Cryptosporidium and two methods of treatment would not be required in this case (Figure 1).

7.3. Subsurface Filtration Treatment Credits

Subsurface filtration is a naturally occurring process that filters surface water as it passes through river or lakebed sediments, lake/river bank substrate, and into an aquifer before being drawn up by a well. Engineered filtration structures, such as infiltration galleries, are not naturally occurring and therefore are not considered equivalent to subsurface filtration treatment. Through the filtration process particulates, turbidity, and microorganisms can be removed or inactivated. Numerous facilities that rely on subsurface filtration in the United States and Europe have demonstrated that the process can yield high quality source water (Kuehn & Mueller, 2000). However, the effectiveness of subsurface filtration is site specific and can depend on many factors such as surface water quality, water temperature, ground water flow conditions, dilution rates, surface water-ground water interface characteristics (such as pH, specific surface area of substrate particles, and organic matter content), and aquifer material (Wang et al., 2002). Further, subsurface filtration can vary seasonally and in response to extreme climatic events (Hrudey and Hrudey, 2004). The effectiveness of subsurface filtration may be demonstrated through field data, laboratory tests, and modelling methodologies.

Subsurface filtration may be considered by the DWO for credit of up to 3 log-removal of *Giardia* and *Cryptosporidium* and, in certain cases, credits of up to 4-log removal of viruses (where proven by a demonstration of performance, see Appendix A) for an eligible well drawing from a GARP source. There are no treatment credits available for bacteria since the bacterial treatment requirement in the DWPR is zero detectable *E. coli* and total coliforms. Subsurface filtration can be considered as one of the two treatment processes, only if it has been awarded greater than 1 log-removal credit for *Giardia* and *Cryptosporidium* and the second treatment process achieves the remainder of the treatment objectives.

Figure 1. Microbiological Treatment Objectives for GARP Sources



7.4. Turbidity in GARP Sources

The presence of suspended organic matter, which can strongly suggest the presence of pathogens, is uncommon in ground water systems. Turbidity in ground water that contains organic matter and pathogens may indicate infiltration of surface runoff, subsurface waste discharge (such as from onsite sewerage systems) or a direct hydraulic connection to surface water with unknown quality. Conversely, turbidity from inorganic mineralogical origin in a well, for example from well packing materials or geologic strata, may not harbour pathogens nor provide definitive evidence of surface water impact.

Turbidity, whether caused by inorganic or organic particles, or biological organisms, also has the potential to disrupt or overload drinking water disinfection processes, such as UV light and chlorination, to the point that they may no longer effectively control pathogens in the water. Organic matter in the water can also react with disinfectants such as chlorine to create by-products that may cause adverse health effects (Health Canada, 2012d).

Turbidity of concern is any intermittent turbidity, or consistent turbidity, greater than 1 NTU. The GARP assessment requires identifying if the source of the observed turbidity is organic or inorganic in nature, and whether or not it contributes to a ground water source being at risk of containing pathogens. Any turbidity in ground water must also not compromise disinfection processes.

7.5. Filtration Exemption

Turbidity can impact disinfection processes and the effective operation of distribution systems. Achieving low levels of turbidity prior to where disinfection is applied is the best method to minimize potential interference with disinfection and to reduce sediment loading to the distribution system (Health Canada, 2012d). The GCDWQ also recommends that the minimum level of treatment to meet microbiological treatment objectives should include filtration and one form of disinfection (Health Canada 2011, 2012b, and 2012e).

However, a GARP source may be permitted to operate without filtration if it meets the filtration exemption criteria as described in section 4.3 of the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (MOH, 2012), found in Part B of the Drinking Water Officers' Guide.

To reflect differences between ground water and surface water sources, alternate wording is provided below for filtration exemption criteria '3' and '4':

3. Average daily turbidity levels measured at equal intervals (every four hours or at an interval acceptable to the DWO). Samples are to be taken immediately prior to any disinfection process. Samples should be around 1 NTU and may not exceed 5 NTU for more than two days in a 12-month period.

4. The well is properly constructed and protected to minimize the potential for fecal or other

pathogenic-related contamination in the source water, and a Well Protection Plan[3] (or equivalent satisfactory to the DWO) is in place.

7.6. Other Bacteriological Concerns

Iron and sulphur bacteria can affect aesthetic water quality and the effectiveness of some treatment technologies. They should be tested for separately and addressed appropriately (e.g., the cleaning of the pumping equipment, scrubbing of the well casing, disinfection of the well by chlorination, etc.).

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Appendix A – Subsurface Filtration Details

A1 Treatment Credits Available for Subsurface Filtration

Studies have shown that subsurface filtration is effective in reducing bacterial (WHO, 2006), protozoan, and viral loads (Tufenkji et al., 2002, Weiss et al., 2005, Schijven et al., 2003, and Wang, 2002). For the purposes of these guidelines, however, subsurface filtration is considered only as a form of treatment for the removal of *Giardia* and *Cryptosporidium* and, in certain cases, viruses. There are no treatment credits available for bacteria since the bacterial treatment requirement in the DWPR is zero detectable *E. coli* and total coliforms. Log removal calculations are relevant only if the source concentration, which is often unknown, is determined. As bacteriological analyses are included in all ground water monitoring programs, bacterial removal efficiency is best demonstrated through raw well water sampling. Consequently, subsurface filtration treatment credits are not applied to bacteria. If pathogenic bacteria are present in the raw well water, the water must be sufficiently disinfected regardless of subsurface filtration processes.

A2 Eligibility

A2.1. Giardia and Cryptosporidium Treatment Credits

If the GARP assessment of a ground water source included Microscopic Particulate Analysis (MPA) testing (EPA, 1992)4 and ranked the source as "high risk" under the MPA rating, there is a likelihood of contamination with *Giardia* and *Cryptosporidium* from surface water sources. Wells drawing from these MPA "high risk" sources would be ineligible for subsurface filtration credits.

Removal of *Cryptosporidium* occurs primarily in the ground water-surface water interface. For example, Medema et al. (in Berger, 2002) found that anaerobic spores, surrogates of *Cryptosporidium*, had 3.3 log removal over a 13 m distance from the Meuse River into an aquifer, while only a 0.6 log removal was achieved over 12 m of travel once in the aquifer. Wells utilizing subsurface filtration may be prone to deterioration in water quality during flood conditions. In addition to flood water potentially entering the well casing, high surface water flow rates can disrupt or erode riverbed sediments that form an essential part of the subsurface filtration mechanism. Consequently, in situations where there is a high potential for riverbed scour due to flooding, the DWO may consider the system ineligible for credit.

There are three methods by which to demonstrate subsurface filtration and obtain subsurface filtration treatment credits for Giardia and Cryptosporidium. Each method is independent of the others and can be used as the sole assessment of subsurface filtration efficacy. The accepted methods are noted as follows and described in more detail in Section A3 below:

1) Well/Surface Water Separation
2) Subsurface Filtration Study
3) Demonstration of Performance

Regardless of the method chosen, the well in question must be properly constructed, have a satisfactory well protection plan in place, and must draw from an unconsolidated and granular (e.g.,

[4] The GARP assessment document (MOH, 2015) provides details on MPA analysis.

sand and gravel) aquifer to qualify for credit. The aquifer should have interconnected pores without substantial cementation, as cementation may be indicative of preferential flow pathways.

A number of case studies on subsurface filtration facilities have demonstrated removals in excess of 3-log protozoa (Gollnitz et al., 1997, 2003, and 2005, and Weiss et al, 2005). If a consistent level of removal greater than the credits discussed in this Appendix can be proven by a demonstration of performance study, a DWO may decide to increase the credit being applied accordingly.

A2.2. Virus Treatment Credits

The only means of obtaining subsurface filtration credits for virus removal is through a Demonstration of Performance study. The eligibility criteria for subsurface treatment virus credits are the same as the eligibility criteria for *Giardia* and *Cryptosporidium* treatment credits outlined in section A.2.1.

A3 Treatment Credit Demonstration Methods

A3.1. Well/Surface Water Separation

The effectiveness of subsurface filtration improves with decreasing pore size of the natural filter media and increasing distance from the surface water source. Wells that demonstrate the following are eligible for a 1-log credit for *Giardia* and *Cryptosporidium*:

- are located at least 15 m from a surface water source (i.e., high water mark[5] for horizontal separation, river bed for vertical separation) through the shortest flow path;
- have core samples continuously collected along at least 85% of the well screen depth with composite samples that:
  - are collected at intervals of no greater than 60 cm (2 feet) in length; and
  - have more than 10% of particles passing through a 1.5 mm screen; or
- in the absence of continuous core samples, a DWO may consider wells screened in sand with a grain size of 1 mm[6] or finer where well log information is provided, supplemented by field review and aquifer mapping (if available).

A 1-log credit by the well/surface water separation method cannot be claimed in addition to log credits demonstrated by other methods.

A3.2. Subsurface Filtration Study

Treatment credits for subsurface filtration may also be obtained through the completion of a subsurface filtration study. The hydrogeological conditions should be determined by a qualified

[5] High water mark is the visible high water mark of any lake, stream, wetland or other body of water where the presence and action of the water are so common and usual and so long continued in all ordinary years as to mark upon the soil of the bed of the lake, river stream, or other body of water a character distinct from that of the banks, both in vegetation and in the nature of the soil itself. Typical features may include, a natural line or "mark" impressed on the bank or shore, indicated by erosion, shelving, changes in soil characteristics, destruction of terrestrial vegetation, or other distinctive physical characteristics. The area below the high water mark includes the active floodplain, which is the area of land that receives annual flood events as shown by riparian area conditions.

[6] Sand with a diameter of 1 mm is considered medium sand according to the Unified Soil Classification System (ASTM, 2006) and coarse sand according to the Canadian System of Soil Classification (SCWG, 1998).

professional (QP)7 to characterize the subsurface filtration in question and include the collection of paired (surface water and ground water) MPA samples under or close to worst case conditions.

If the subsurface filtration study determines that filtration is effectively reducing pathogen loads, the water system may be eligible for up to 3-log credits for Giardia and Cryptosporidium reduction. The treatment credits are awarded on a case-by-case basis at the discretion of the DWO following a review of the subsurface filtration study and consideration of how other risk factors identified in the GARP assessment have been managed.

A3.2.1. Subsurface Filtration Study Scope

The scope of the subsurface filtration study, including water quality sample timing and proposed analyses, should be established by a QP for consideration by the DWO prior to the start of the study. The scope of the subsurface filtration study should consider the following factors:

Surface Water Conditions

- Historic flow patterns
- Seasonal variations
- 50, 100, and 200 year flood levels (considering diking, where applicable)
- High water mark
- Likelihood of extreme precipitation events and the impact on surface water quality
- Assessment of potential for riverbank or lake bed scour and flow rates that may cause scour
- Expected flooding frequency
- Clogging potential

Aquifer Conditions

- British Columbia Aquifer Classification System ranking
- Grain size and porosity
- Aquifer stratigraphy and lithology
- Hydraulic conductivity
- Storativity and transmissivity (in confined aquifers)
- Ground water dilution rate (related to the pumping rate)
- Ground water flow directions and gradients (under both natural and pumping conditions)
- Ground water flow rate or velocity

Well Conditions

- The location and construction of a well should be consistent with legislated construction standards
- Time of travel from high water mark to well under various pumping and water level conditions
- Water level readings to capture seasonal fluctuations and recharge events (monthly readings should be completed at a minimum, however, continuous monitoring is ideal); sampling frequency can be reduced if aquifer does not show significant variation
- Pumping test data
- Well capture zone[8]

[7] A qualified professional (QP) is an individual who is registered with the Association of Professional Engineers and Geoscientists of British Columbia with competency in the field of hydrogeology and experience in evaluating sources of ground water supply.

[8] A variety of methods for defining a well capture zone are provided in the BC Well Protection Toolkit (MOE, 2006) – Step 2 (http://www.env.gov.bc.ca/wsd/plan_protect_sustain/groundwater/wells/well_protection/pdfs/step2.pdf).

- Summary of hydrogeological cross sections showing stratigraphy, aquifers, confining layers, well capture zones under high pumping and high surface water stage conditions

Ground Water and Surface Water Quality

- Paired MPA sampling results (see 'MPA Analysis' below)
- Total coliforms, *E. coli*, level and nature (organic vs inorganic) of turbidity
- Field measurements of temperature, pH, electrical conductivity
- Observed variations between ground water and surface water quality with time
- Correlation between variations in surface water and ground water quality employing statistical methods

Many of these factors are studied in Level 2 and 3 hydrogeological investigations in the GARP assessment. If a Level 2 and/or 3 hydrogeological investigation has already been completed for the ground water source in question, the subsurface filtration study need only address any data gaps identified by the DWO.

A3.2.2. MPA Analysis

Details on MPA analysis are provided in Appendix C of the Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP) (MOH, 2015). As is the case with GARP assessments, MPA sample results are intended to contribute to, not replace, the weight of evidence provided in the subsurface filtration study.

The number of samples required to demonstrate eligibility for treatment credits through MPA testing should be discussed with the DWO. At a minimum, two paired samples should be collected from the ground water and the surface water source to which it is hydraulically connected. Studies on MPA test results have found, however, that one or two tests cannot reliably predict future values (Jacangelo et al., 2001). Consequently, one MPA sample pair must be collected annually during worst case conditions to maintain this treatment credit. The DWO may request that additional samples be taken to provide greater clarity on the efficacy of subsurface filtration.

During MPA sample collection, additional samples should be collected for analysis of turbidity, electrical conductivity, temperature, pH, total coliform, and *E. coli* to compare surface water quality with ground water quality.

A review of the MPA test results, not just the risk ranking, should be completed as it provides a picture of the surface water indicators present in the water sample. Analysis of MPA indicator counts in both the surface water and ground water sources may enable a rough estimation of protozoa log-removal.

A3.2.3. Alternatives to MPA Testing

MPA analysis provides both a physical count of the surface water indicators and a systematic means of determining the risk that a ground water sample, and by extension, the well, may have surface water interaction. Analysis for *Giardia* and *Cryptosporidium* surrogates, such as bacterial spores *Bacillus subtilis* or *Clostridium perfringens* may be considered as alternative test parameters to MPA for the subsurface filtration study, at the discretion of the DWO. As bacterial spore analysis provides only quantitative results, consideration should be given to increasing the number of samples required or to completing the sampling as part of a more intensive demonstration of performance (below).

A3.3. Demonstration of Performance

A demonstration of performance is a thorough sampling program that involves completing a subsurface filtration study, but with a far more rigorous testing protocol. The testing protocol may involve increased testing frequencies, longer study durations, additional sample locations, and an expansion of the parameters to be tested. It should include the collection of a sufficient number of paired samples from the surface water source and the collection well, with samples taken from the well after the estimated lag time has passed.

In addition to the study of *Giardia* and *Cryptosporidium* removal, the demonstration of performance study can include a testing protocol to demonstrate virus removal. Since *Giardia* and *Cryptosporidium* concentrations, as well as virus concentrations, in both surface and well water samples may be too low to calculate required log-removals, log-removal calculations can be based on the concentrations of a number of relevant surrogates. A summary of potential surrogates (such as *Bacillus subtilis* or *Clostridium perfringens*) for protozoa can be found in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) Toolbox Guidance Manual (EPA, 2010). MS-2 bacteriophage or other F-specific RNA bacteriophages are potential surrogates for viruses (Schijven et al., 2002). Dilution of surface water by ambient ground water may also skew the effectiveness of subsurface filtration and, therefore, calculated log-removals should be adjusted for expected dilution effects.

Section 4.7 of the LT2ESWTR Toolbox Guidance Manual also provides detailed information on testing and monitoring protocols that could constitute a sufficient demonstration of performance plan. Water suppliers should retain a QP to develop a demonstration plan according to this or other suitable criteria. Credits granted may differ from the log removals determined by the study at the DWO's discretion.

A4 Credit Maintenance

Turbidity monitoring is necessary to maintain the treatment credit for all methods used to obtain subsurface filtration log-removal credit. Average daily turbidity levels should be established through sampling at equal intervals (at least every 4 hours) immediately prior to where the disinfectant is applied. The DWO may specify different sampling requirements and intervals. Turbidity levels of around 1.0 NTU for 95% of the measurements per month and not exceeding 3.0 NTU should be demonstrated.9

In addition, to maintain a treatment credit obtained as a result of a subsurface filtration study or demonstration of performance, water suppliers should collect and submit for analysis at least one pair (ground water and surface water) of MPA samples (and virus surrogate samples, if virus credit was obtained) annually or at a frequency agreed upon by the DWO. The timing of the sample should coincide with the reasonable worst case conditions, as identified during the initial MPA sampling. If the sample yields a risk ranking for the ground water source that is higher than the ranking for which

[9] Log-credit for subsurface filtration allows for reduced or no treatment for *Giardia* and *Cryptosporidium*. Therefore, subsurface filtration is considered an integral part of disinfection. An increase in turbidity at the well may be indicative of a failure of the treatment barrier provided by subsurface filtration. In comparison, a system with a filtration exemption (as outlined in MoH's "Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia" section of the Drinking Water Officers' Guide) does not rely on filtration to help reduce *Giardia* and *Cryptosporidium*, rather sufficient disinfection technologies are employed. This is why the allowable upper limit for turbidity in systems that have credit for subsurface filtration is lower (3.0 NTU) than the 5.0 NTU maximum permitted for a system that has a filtration exemption.

the credit was awarded, a second MPA sample should be collected. Similarly, if the calculated virus removal efficiency calculated with annual sampling results is lower than that for which the virus removal credit was granted, a second pair of samples should be collected. The DWO may decide that an adjustment to the previously awarded treatment credits is warranted based on the sample results.

If any single MPA ground water sample is ranked as "high risk" or if the ground water quality does not meet the turbidity requirements, the water supplier should investigate the source of the water quality deterioration and report the findings to the DWO. The DWO will then assess whether a treatment credit for subsurface filtration remains appropriate for the system.

British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems

Version 1.2 / First Published August 2016

Ministry of Health

1. Overview

Distribution systems are at risk of breaches in system integrity that could negatively impact the microbiological quality of the potable water. Water suppliers should focus on prevention and use a multi-barrier approach to protecting the water as it travels through the distribution system from the source/treatment facility to the consumer.

The best risk management practice (BMP) of maintaining a disinfectant residual in the drinking water as it travels through the distribution system is often referred to as "secondary disinfection" or "residual disinfection." It is an important BMP that is strongly recommended for most systems due its unique ability to help the water supplier respond quickly to potential incidents of water quality degradation and its ability to control the growth of microorganisms. Drinking water officers and other issuing officials may require water suppliers to use secondary disinfection for distribution systems that are at risk for pathogen contamination and/or significant microbial growth.

1.1. Objective

To provide provincial guidance to drinking water officers and water suppliers for making decisions related to implementing the multi-barrier approach to protecting and maintaining microbiological water quality in water supply distribution systems. This includes specific guidance for implementing the best risk management practice of secondary disinfection.

1.2. Regulatory Framework

Potable water is defined under section 1 of the *Drinking Water Protection Act* as water that is "safe to drink and fit for domestic purposes without further treatment." Further to this, section 6 of the act requires potable water from the water supply system. The definition of a water supply system in the act includes the distribution system, which is the portion of the water supply system used to convey potable water from the treatment plant or source to the users served by the system. This means potability must be maintained, in accordance with section 6 of the act, as water travels through the distribution system to system users.

The use of disinfectants in the distribution system (secondary disinfection) is an industry practice to maintain the microbiological quality of the potable water because potable water in distribution systems is vulnerable to degradation and contamination (see Section 2.1 of this document). This practice is independent of the primary disinfection requirements based on source water quality as outlined in section 5(2) of the Drinking Water Protection Regulation, which requires a water supplier to disinfect water originating from a surface source or a ground water source that is at risk of containing pathogens.

The act and regulation give drinking water officers the flexibility and discretion to address public health risks. They do this on a case-by-case basis using available system-specific information (e.g., system records, source-to-tap risk assessment and documentation from qualified professionals).

A drinking water officer may request, require as a condition on the operating permit, or order a water supplier to use specific risk management practices, including the addition of a secondary disinfectant, to protect potable water as it travels through the distribution system.

1.3. Purpose and Scope

This document provides general guidelines on using a preventative, multi-barrier approach to maintaining potable water in the water supply distribution system and includes specific guidance on the use of the best risk management practice of secondary disinfection. The guidelines are consistent with the act, regulation and *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012a).

This document does not address primary disinfection (i.e., "the application of a disinfectant in the drinking water treatment plant, with a primary objective to achieve the necessary microbial inactivation" (Health Canada, 2009a)). With respect to primary disinfection, the guidelines are based on the assumption that systems are in compliance with the act, regulation, policy, and any conditions on the operating permit. See Appendix A for further resources about these and other issues.

This document does not provide guidelines on water supply systems exempt from section 6 of the *Drinking Water Protection* Act (see section 3.1 of the Drinking Water Protection Regulation concerning non-potable water, and point-of-entry and point-of-use water supply systems).

Site-specific conditions may warrant a flexible approach to maintaining water quality in the distribution system. Such an approach should incorporate these guidelines in conjunction with a risk assessment of individual cases in collaboration with the drinking water officer.

2. Background

2.1. Factors Affecting Microbiological Water Quality in Distribution Systems

The purpose of the distribution system is to convey potable water from the treatment plant or source (if treatment is not required) to the consumer. Potable water is a "perishable product" that is at risk of degradation and contamination as it travels through the distribution system. Degradation and contamination in the distribution system can affect the aesthetic quality of drinking water, as well as its safety if the water is at risk of contamination or regrowth/growth of pathogenic microorganisms (e.g., bacteria, protozoa and viruses).

Several factors can impact or degrade microbiological water quality in the distribution system:

- Biological stability of the water.
- Conditions in the distribution system.
- Formation of biofilms.
- Contamination from outside the distribution system.

These risk factors can be threats to public health as demonstrated by documented outbreaks associated with distribution systems (Hrudey and Hrudey, 2004; Payment and Robertson, 2004; Wilson et al., 2009). The following sections provide further detail on these factors.

2.1.1. Biological Stability of the Water

The potable water entering the distribution system is not sterile; it typically contains microscopic particles, nutrients, and live and inactivated microorganisms (Liu, Verberk and Van Dijk, 2013). The composition and quantity of this material in the water distribution system depends on the source water quality characteristics, technology used for disinfection and/or treatment, and storage conditions. The material often includes biologically available nutrients that support the growth and multiplication of bacteria and biofilm (see section 2.1.3), which increases the risk of degradation of the microbiological water quality (Ashbolt, 2015; LeChevallier et al., 2015b). For example:

- Potable water produced from surface water sources and some high-risk ground water sources is highly likely to contain biodegradable organic matter that can contribute to significant bacterial growth, particularly if treatment does not have the ability to remove it (LeChevallier et al., 2015b).
- Water chemistry can also indicate a source of nutrients (e.g., a significant concentration of biologically available nitrogen and/or phosphorus) (Ashbolt, 2015).

Biologically stable water is potable water that is "at low risk of supporting significant bacterial growth" (Liu, Verberk and Van Dijk, 2013). In other words, the nutrient levels in the potable water are reduced and/or maintained at a level that significantly reduces the ability of the water to support growth.

2.1.2. Conditions in the Distribution System

Most bacteria need specific conditions to multiply, such as: nutrients, dark spaces, warmth, moisture and time. Water distribution systems can have many of these conditions. System design and operational practices can have a limiting effect on conditions to limit microbiological growth and biofilm formation. For example, retention time is an important factor associated with growth. The longer water remains in the distribution system, the more opportunity there is for bacterial growth. Systems with many dead ends or systems that do not have a high turnover of water[1] are at risk for having stagnant zones in the distribution system that contain "old water," particularly if they do not practice regular flushing.

2.1.3. Formation of Biofilms

The particles, nutrients and microorganisms in potable water (as discussed in section 2.1.1 of this document) can attach to surfaces in the distribution system within a slime layer to form unique microbiomes referred to as biofilm. Technically, biofilm is a complex mixture of microbes, and organic and inorganic material accumulated amidst a microbially produced organic polymer matrix, which is attached to the inner surface of the distribution system (USEPA, 2002b). Most of the microorganisms and biomass in the potable water in distribution systems exists as biofilms (LeChevallier et al., 2015a).

Biofilms can be associated with water quality deterioration. They can affect the aesthetic quality of drinking water by having a negative impact on the taste, smell and visual qualities of the drinking water. They can also cause physical damage to the distribution system by corroding the inner surface of metal pipes and blocking valves (American Academy of Microbiology, 2012; USEPA, 2002a).

Biofilms can have a negative impact on human health when they contain pathogenic organisms. Biofilms provide environments in which pathogens can survive and accumulate, and are associated with the proliferation of opportunistic pathogens such as *Legionella pneumophila* (American Academy of Microbiology, 2012; USEPA, 2002a). Whenever the biofilm is disturbed, there is potential for these pathogens to be released back into the water in high concentrations.

2.1.4. Contamination from Outside the Distribution System

Under certain circumstances, contact between the potable water in the distribution system and outside influences can provide a means for pathogenic contamination. Table 1 shows some common means by which pathogens can enter the distribution system (FCM, 2003; Kirmeyer et al., 2001; USEPA, 2002a). Once pathogens are introduced to the distribution system, favourable conditions (e.g., temperature and dead ends) may provide a suitable environment for bacterial growth and pathogen survival in biofilms (USEPA, 2002b).

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[1] Systems with low turnover may be too large for the number of system users (e.g., communities with declining population) or may need a large capacity for occasional use (e.g., communities with large fluctuations in population during the year due to seasonal tourism or seasonal workers, and communities that retain large quantities of water for fire suppression).

Table 1: Potential sources of contamination to potable water in the distribution system from outside sources

Source of Contamination	Explanation
Treatment breakthrough	Pathogens may escape treatment and enter the distribution system.
Potable water storage reservoirs	Storage reservoirs can be susceptible to outside contamination if they are not adequately designed and/or maintained.
Cross connections and backflow	A major contamination event can occur during negative pressure and backflow events.
Transient contamination	Intrusions can occur via leaky pipes, valves, joints and seals if there is a negative pressure event.
Water main installation, breaks and repair	The interior of pipes can be contaminated during installation and repair, particularly if appropriate steps (e.g., flushing and/or chlorination) are not taken to decrease risk before, during and after construction.

3. Guidelines

Water suppliers should focus on prevention and take a multi-barrier approach to protecting the microbiological water quality in the distribution system (see section 3.1). The water supplier should use the information gleaned from a source-to-tap risk assessment to determine any system-specific factors (e.g., the design and installation of system components (see Appendix B) and the biological stability of the potable water) that could negatively impact the ability of the distribution system to protect the microbiological quality of the potable water. The water supplier should, in conjunction with the drinking water officer, use this information to determine the most appropriate combination of best risk management practices (BMPs) to implement, based on the system-specific risks.

From a public health perspective, the BMP of secondary disinfection is strongly recommended in most circumstances due its unique ability to help the water supplier respond quickly to potential incidents of water quality degradation and its ability to control the growth of microorganisms (see section 3.2).

The following sections provide information about the multi-barrier approach, and include specific guidance of the use of secondary disinfection as a component of the multi-barrier approach.

Information about protective system-specific design elements and other BMPs can be found in other documents (see Appendix A and B). This guidance recommends water suppliers consult with a drinking water officer when conducting risk-management planning for their distribution systems.

3.1. The Multi-Barrier Approach to Maintaining Water Quality in the Distribution System

The multi-barrier approach to safe drinking water involves implementing a series of integrated procedural and physical risk management practices throughout the water supply system. These practices work together to prevent or reduce the contamination of drinking water from source to tap in order to protect public health (Health Canada, 2002; Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group, 2004).

A comprehensive multi-barrier system should have the ability to manage identified and unforeseen risks, and take action to minimize or prevent harm in the case of an event in which one or more of the risk management practices fail. This approach is considered the standard for protecting drinking water by the World Health Organization, Health Canada, and the Ministry of Health and regional health authorities in British Columbia.

There are several BMPs that, when used together, form a robust multi-barrier approach to protecting the drinking water as it travels through the distribution system. They include, but are not limited to:

- Employing knowledgeable certified (where applicable) operator(s), and ensuring their training is adequate and remains current.
- Operating system components as per good engineering and operational practices that include routine maintenance (Appendix B).
- Employing a cross-connection control program.
- Maintaining hydraulic integrity.
- Using secondary disinfection (FCM, 2003).
- Using an extensive distribution-system monitoring program.
- Maintaining comprehensive service-and-monitoring records to demonstrate due diligence.
- Implementing an asset management plan that includes a replacement and rehabilitation schedule.
- Creating and maintaining a comprehensive emergency response and contingency plan that includes a communication and risk assessment strategy to resolve issues with the distribution system.

The above BMPs aim to achieve the following goals:

- Promptly identify potential or actual risks, and take action to prevent or minimize harm to water users.
- Minimize biological growth and accumulation of other contaminants in the distribution system.

- Eliminate identified contamination of the drinking water from outside the distribution system network.
- Minimize harmful interactions between the drinking water and pipe material.

As no one BMP is capable of achieving all of the goals laid out above, a combination of BMPs is necessary, and should be tailored to a water supply system's particular needs, to protect drinking water as it travels through the distribution system.

3.2. Operating with Secondary Disinfection

3.2.1. What is Secondary Disinfection?

The BMP of maintaining a disinfectant in the drinking water as it travels through the distribution system is often referred to as "secondary disinfection" or "residual disinfection." It can be achieved by maintaining a residual of the primary disinfectant in the distribution system or by adding disinfectant to the distribution system.

Although this document uses the term "secondary disinfection," it pertains to both methods. Secondary disinfection differs from primary disinfection in that the concentration of disinfectant used will not necessarily be large enough, or have the necessary contact time, to deactivate pathogens to the extent needed to meet the definition of potability under section 6 of the act.

Not all disinfectants are capable of maintaining a residual as they degrade too quickly (e.g., ozone and chlorine dioxide), or do not produce a residual effect (e.g., ultraviolet light) (Health Canada, 2009b; Health Canada, 2012b). Currently, chlorine and chloramines are considered the most effective secondary disinfectants (Black & Veatch Corporation, 2010; Federal-Provincial-Territorial Committee on Drinking Water and CCME Water Quality Task Group, 2004; Health Canada, 2012b).

3.2.2. Why is Secondary Disinfection Recommended?

Secondary disinfection contributes to the achievement of the best management goals described in section 3.1 by:

- Indicating potential breaches in distribution system integrity.
- Aiding in the control of biofilm growth.
- Inactivating some pathogens in the distribution system.

As with any other distribution system BMP, the use of secondary disinfection alone will not protect water quality. Many of the other BMPs are primarily aimed at preventing microbiological risks through physical controls on which secondary disinfection will have no effect. For example, secondary disinfection will not prevent contaminants from breaching the physical integrity of a water supply system.

Secondary disinfection, however, does provide a valuable, multifunctional layer of protection that is simple and cost effective. It is unique among other BMPs because it can help the water supplier respond quickly to potential incidents of water quality degradation if there is an unforeseen break-down in the preventative BMPs. In this capacity, it generally compliments a water supply system's set of other BMPs for protecting the water in the distribution system. The following subsections provide a brief overview of the unique qualities and advantages to applying secondary disinfection.

Indicating Potential Breaches in Distribution System Integrity

Secondary disinfectants can be used as a sentinel to indicate potential breaches in water supply system integrity because the disinfectant concentration drops as it oxidizes constituents encountered in the distribution system water. With regular monitoring, a water supplier can establish a baseline secondary disinfectant concentration for different parts of the system during normal operating conditions. Any observation of lower than expected concentrations could be an indicator of potential threats to the drinking water, such as:

- Biofilm or bacterial regrowth.
- An intrusion event.
- Stagnant water.
- Primary treatment process failure/emerging source water quality challenges.

Chlorine can be more effective in this capacity than chloramine because chloramine is a more stable compound that does not degrade as quickly as chlorine (USEPA, 2002a; Health Canada, 1995).

The Drinking Water Protection Regulation requires monitoring for specific bacteriological parameters that are indicative of fecal contamination or other water quality problems, but it can take several days to obtain test results from a sample. This lag time may expose system users to potentially contaminated water before warnings are issued.

Secondary disinfectant monitoring is not a specific indicator of fecal contamination, but real-time monitoring of fluctuations in disinfectant concentrations can provide immediate indications of potential hazards in the system. This gives the water supplier the opportunity to investigate and respond **immediately** to any threats to the system.

Aiding the Control of Biological Growth

Secondary disinfectants can contribute to the biological stability of potable water because they can break down biodegradable organic matter and inhibit the growth of biofilm. Although both chloramines and chlorine can resist biofilm growth in systems, chloramines are more effective at penetrating existing biofilm to reduce growth (USEPA, 2002a). The concentration of secondary disinfectant needs to be high enough to outweigh the natural growth tendency.

Inactivating Pathogens in the Distribution System

Secondary disinfectants can inactivate some pathogens in the distribution system (USEPA, 2002a). Secondary disinfection is most effective against minor contamination events (e.g., marginal intrusions and pathogens sloughing away from biofilm). The concentration of disinfectant used in the distribution system will not necessarily be large enough or have the necessary contact time to control a major contamination event. Additionally, secondary disinfectants are not considered to be effective at inactivating protozoan pathogens.

3.2.3. When is Secondary Disinfection recommended?

Drinking water officers and other issuing officials have discretionary authority to require secondary disinfection for distribution systems that are at risk for pathogen contamination and/or significant biofilm/microbial growth. It is generally expected that new water supply systems and new system components (e.g., reservoirs) provide secondary disinfection. Existing systems requiring secondary disinfection should develop a continuous improvement plan for implementation. See section 3.3 for information about circumstances in which water supply systems may be allowed to operate without it.

The type of disinfectant used for secondary disinfection depends on the characteristics of the distribution system. For example, a physically long system, or one with long retention times, may need chloramine because it is a more stable chemical disinfectant and will not degrade as quickly as chlorine.

Water suppliers considering the addition of a secondary disinfectant should conduct an analysis of the potable water and distribution system components to determine any potential unintended consequences due to potential chemical interactions. For example, water with high iron and/or manganese concentrations can form a precipitate in the presence of chlorine under certain conditions (Black & Veatch Corporation, 2010). Consequently, water suppliers should ensure they understand the consequences of their specific water chemistry and consult with their drinking water officer before using a secondary disinfectant.

3.2.4. What is the Recommended Operational Range for Disinfectant Concentration?

The concentration of the disinfectant will depend on the type of disinfectant used and the individual system characteristics (e.g., biological stability of potable water, physical infrastructure characteristics and operational practices). Systems that use most (if not all) of the BMPs listed in section 3.1 and have protective factors built into the design (see appendices B and C), may have the ability to operate with a minimal concentration; whereas, other water supply systems may require a higher concentration due to the absence of some BMPs or other factors.

Water suppliers should maintain secondary disinfection at concentrations that will maximize benefits while minimizing the impact on the aesthetic quality of the drinking water (e.g., taste and smell) and disinfection by-product formation.

Chlorine

The *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2009a) state that there is no evidence to demonstrate that free chlorine is toxic to humans at the concentrations needed to maintain distribution system integrity, normally less than 5 mg/L. The guidelines suggest that chlorine "concentration be determined on a system-specific basis to ensure effectiveness of disinfection and maintenance of an appropriate residual, while minimizing by-product formation and aesthetic concerns" (Health Canada, 2009a).

A generally accepted target range concentration for free chlorine at distribution system end points is at least detectable to 0.2 mg/L for control of bacterial growth (LeChevallier, Welch and Smith, 1996). Due to individual characteristics between systems, most distribution systems in Canada operate with a free chlorine concentration in the range of 0.4 to 2.0 mg/L leaving the treatment plant, and 0.04 (detectable) to 0.8 mg/L at distribution system end points (Health Canada, 2009a).

Individual sensitivities to chlorine in the population vary widely. Sensitive individuals may notice it at levels as low as 0.6 mg/L, but the majority of people will not likely detect it at the concentrations discussed in this guideline (Health Canada, 2009a). At these concentrations, taste and odour related to chlorine or its by-products are generally within the range of acceptability for most consumers.

Chloramine

Health Canada (1995) recommends a maximum acceptable concentration of 3.0 mg/L for chloramines in drinking water. A generally accepted target concentration for chloramines as they enter the distribution system is at least 2.0 mg/L with a residual of no less than 0.5 mg/L throughout the distribution system (Health Canada, 1995).

3.2.5. What are the Recommended Monitoring Practices?

In addition to the microbiological monitoring requirements of Schedule A of the Drinking Water Protection Regulation, the water supplier should monitor for the secondary disinfectant. The drinking water officer may specify monitoring locations and frequencies that differ from those listed in the regulation for microbiological monitoring. Records should be kept for inspection and to provide a context by which the operator may identify water quality issues by a change in disinfectant residual for a particular location.

Water supply systems using chloramines should consider monitoring for N-nitrosodimethylamine (NDMA), which is a by-product of chloramination. The *Canadian Guidelines for Drinking Water Quality* recommend a Maximum Acceptable Concentration of 0.04 µg/L of NDMA in drinking water. Other recommended monitoring parameters for chloraminated systems include: ammonia, monochloramine, dichloramine, nitrite, nitrate, HPC, pH and alkalinity.

3.3. Operating Without Secondary Disinfection

3.3.1. Is There an Opportunity to Operate Without Secondary Disinfection?

Water supply systems may be allowed to operate without secondary disinfection if they demonstrate to the satisfaction of the drinking water officer that the physical characteristics of the system and the other BMPs in place adequately protect the microbiological water quality. Water suppliers should be able to say yes to the following questions and provide sound rationale (as confirmed by the drinking water officer) to demonstrate their ability to protect the water without secondary disinfection:

1. Does the system select or produce biologically stable water?
2. Do the physical characteristics (e.g., design elements) of the system in conjunction with the use of a comprehensive set of the other BMPS provide the ability to proactively manage risks to the distribution system?
3. Does the system transport microbiologically safe water to system users as demonstrated by the water supplier's monitoring records (e.g., no history of recurring or persistent indicator organisms)?
4. Does the system display an ongoing commitment to meet the BMPs as demonstrated by the water supplier's monitoring records, compliance with conditions on permit, annual reports and inspection records?

The use of a comprehensive set of the BMPs listed in section 3.1 (e.g., maintaining hydraulic integrity and using a cross-connection control program) is highly recommended. Appendix B provides a list of BMPs for designing, building, operating and maintaining distribution system components for maintaining water quality. Appendix C provides some examples of protective factors related to design elements and operations. Section 3.1 and these appendices provide information for water suppliers to consider when developing the rationale to support question #2.

No one factor outweighs the others. A water supplier should have the ability to demonstrate the use of a well-rounded suite of BMPs and protective factors, and that they work together to protect microbiological water quality.

3.3.2. Ongoing Evaluation of Water Supply Systems Operating Without Secondary Disinfection

Systems operating without secondary disinfection need to be re-evaluated on a recurrent basis to ensure they continue to function within an acceptable range of risk. Reasons a water supply system may be required to implement secondary disinfection include, but are not limited to:

- The system is experiencing the recurring or persistent presence of indicators that demonstrate the BMPs in place are no longer effective or that contamination risks are not being managed to the satisfaction of the drinking water officer.
- The drinking water officer notes a lack of commitment or ability on the part of the water supplier to meet the BMPs.

Appendix A: Sources of Further Information

Distribution System Hazards Affecting Microbiological Water Quality

Water-Borne Illnesses Associated with Distribution Systems

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Appendix B: Design, Installation and Operation of Distribution System Components

The following is a list of best risk management practices (BMPs) for designing, building, operating and maintaining distribution system components for maintaining water quality (FCM, 2003).

This list is based on a policy statement of the American Water Works Association (AWWA, 2012), research from the Water Research Foundation, the *Guidelines for Canadian Drinking Water Quality* (Health Canada, 2012a), documents from the U.S. Environmental Protection Agency, and a document produced by the Federation of Canadian Municipalities (FCM, 2003).

AWWA's suite of practice manuals and standards provide information on many of the BMPs listed below.

Design

- Design distribution system and storage facilities in accordance with engineering best practices, including:
  - Minimizing water age and dead ends.
  - Maintaining sufficient physical separation from sources of underground contamination (e.g., sewers).

Installation

- Use certified materials (i.e., NSF/ANSI standard 61).
- Properly install and disinfect distribution system components (AWWA Standard C651) and storage facilities (AWWA Standard C652).

Operation

- Operate distribution system and storage facilities in accordance with best practices.
- Flush and swab water mains.
- Regularly inspect and maintain valves and hydrants.
- Regularly monitor, inspect and maintain storage facilities.
- Control internal corrosion.
- Control blending of water sources.
- Communicate and engage regularly with stakeholders (e.g., system users and drinking water officer).
- Promptly respond to and communicate water quality issues.
- Use a calibrated water quality model of the distribution system.

Appendix C: Protective Factors Associated with Design Elements and Operations of Water Supply Systems

In addition to using the best risk management practices listed in section 3.1 of these guidelines, the following protective factors should be considered when a water supplier is developing rationale for operating without secondary disinfection.

Table 2: Protective Factors Associated with Design Elements and Operations of Water Supply Systems

Protective Factor	Description
System design: short retention time	• Systems with short retention times throughout the distribution system may be able to demonstrate that water quality is adequately protected through source protection and treatment. • The longer water remains in the system, the more opportunity there is for pathogen contamination and re-growth. • Systems at risk for having "older water" include, but are not limited to: o Large systems[2]: the larger the system, the higher the risk. o Underutilized systems (e.g., capacity is greater than is needed or there is seasonal variation). o Systems with multiple dead ends.
System design: simple distribution system	• Simple distribution system design allows an operator to reasonably manage each of the system components. • Complex systems (e.g., many pressure zones) generally have difficulty maintaining water quality in the distribution system as there are many components to manage.

[2] As per the Drinking Water Protection Regulation, a small system is a water supply system that serves up to 500 individuals during any 24-hour period.

Protective Factor	Description
System design: few sources of contamination	• System design should avoid, to the extent possible, predisposing the system to increased risks of contamination. • This includes minimizing submerged mains and maintaining sufficient vertical and horizontal separation from sanitary and storm sewers.
System operation: flushing and/or shock chlorination	• The use of regular flushing and/or shock chlorination can help control biological growth.
Maintenance: low leakage	• Systems with low rates of water loss from leakage are at lower risk for contamination via intrusions during pressure differentials than systems with higher rates.
Monitoring: alternative microbial and real-time parameters	• Monitoring is necessary to continually demonstrate that distribution system barriers are consistently maintaining the microbiological quality of the water. • Systems operating without secondary disinfection could use additional monitoring parameters (in addition to legislated parameters) in lieu of monitoring for residual. • This could include: o Using a comprehensive combination of microbial indicators that are specifically indicative of biofilm growth (e.g., heterotrophic plate count (HPC) bacteria, Pseudomonas and Aeromonas). o Using alternative real-time parameters (e.g., turbidity, pressure, flow, conductivity, pH and temperature). • Water suppliers should establish background levels of the different parameters at normal operating conditions. Observed changes in background levels of any of these parameters could indicate a reduction in distribution system integrity, requiring further investigation.
Asset management	• As systems age, they are increasingly at risk for breaches in integrity. • Adherence to a defined asset management plan as well as adhering to the BMPs listed in section 3.1 and appendix B ensures that aging infrastructure is regularly maintained and replaced in order to manage this risk.

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Decision Protocol for Assessing and Managing Cyanobacterial Toxins in B.C. Drinking Water and Recreational Water

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Ministry of Health

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1. Introduction

Cyanobacterial blooms in drinking water supplies and recreational water bodies provide a challenge to both communities and regulators. These are often recurring events; however, predicting the timing, magnitude, duration, and potential health impact of a cyanobloom is complex (Burch et al., 2016). Effective management should be based on critically appraised, reliable sources of available information. This protocol is intended to provide strategies and resources to assist local governments, health authorities, and water system operators to assess and manage risks related to cyanobacterial bloom formations in waterbodies used for both recreational and drinking water purposes. It includes strategies for engaging stakeholders, choosing appropriate evaluation methods, and protocols and actions to take to reduce risks from blooms.

2. Background on Cyanobacteria

Cyanobacteria, also known as blue-green algae, are naturally occurring microscopic organisms found in waterbodies. It is estimated that there are between 2000 and 8000 species of cyanobacteria worldwide (Nabout et al., 2013). In Canada, cyanobacteria can occur in waterbodies at any time of year, although rapid proliferation causing blooms (known as cyanoblooms) occurs predominantly in the summer (USCDC NCEH 2015). In many cases, cyanoblooms tend to recur in the same waterbodies year after year, although not continuously (Burch et al., 2016).

Some species of cyanobacteria can produce secondary metabolites, known as cyanotoxins. During a cyanobloom, high concentrations of cyanotoxins may occur, which can be harmful to human health (Svircev et al. 2017). Cyanoblooms can be comprised of multiple species, not all of which are capable of producing cyanotoxins, but every cyanobloom should be treated as toxic until known otherwise. There are multiple types of cyanotoxins (e.g., nodularin, saxitoxin, cylindrospermopsin etc.); however, in Canada microcystins (MC) are generally regarded as the most important from a human health perspective (Health Canada 2018). There are almost 100 different variants of MC (Qi et al. 2015), with MC-LR, the most common MC variant, being classified as Group 2B, possibly carcinogenic to humans (IARC Monographs 94, 2010).

Factors inducing the production of cyanotoxins are complex. Environmental factors, such as temperature, light, nitrogen, total phosphate, carbon availability (in the form of bicarbonate, carbonate, and carbon dioxide), and pH, can all be important (Orihel et al. 2012; Hamilton et al. 2016; Pick 2016; Levy 2017). Water column stability is also important. Collectively, these factors create an ecological niche with plentiful nutrients, warm temperatures, and low water column mixing. In this ecological niche, cyanobacteria are able to out-compete phytoplankton, and a toxic bloom may form (Figure 1).

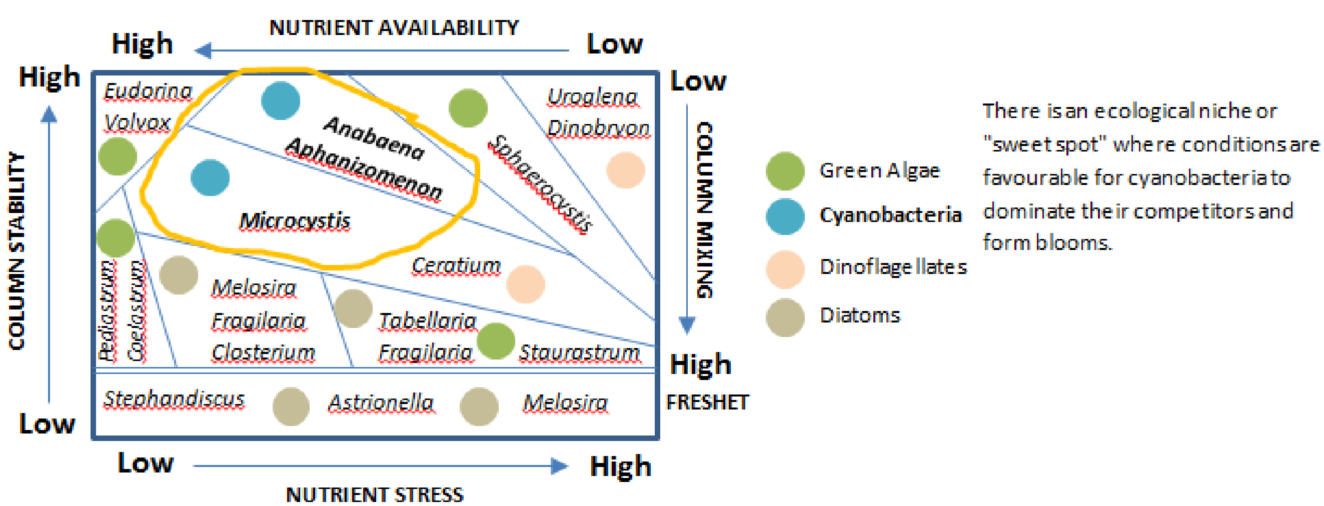


Figure 1. Dominant algal assemblages determined in terms of the relative availability of limiting nutrients and column mixing (after Reynolds, 1980)

Because toxin production varies greatly among different strains of the same species, differences in genetics, metabolic processes, and environmental conditions may also be important in the production of cyanotoxins. When present, cyanotoxin concentration can vary dramatically both spatially and temporally in the waterbody. Therefore, different parts of the same waterbody may have different concentrations, and this should be considered when deciding on testing protocols. Toxin levels do not necessarily coincide with maximum algal biomass. There can be significant variation in the amount of toxin per unit biomass of cyanobacteria over time, independent of changes in the cyanobacterial population. Cyanotoxins may persist in the aquatic environment, even after a cyanobloom has broken down and is no longer visible (Health Canada, 2018). For Microcystin, this lack of degradation may persist for 1 to 3 months, depending on the water body, initial microcystin concentration, and water temperature (Jones et al, 1994 Lahti et al., 1197b).

Cyanotoxins may be membrane bound within the cyanobacterial cells (intracellular) or occur free in the waterbody (extracellular) (Health Canada 2018). Most toxin release occurs as cells age and die, and passively leak their cellular contents; however, some active release of toxins can also occur from young, growing cells (Merel et al. 2013). It is therefore important to measure total MC due to the large number of MC variants and the possibility of both intra- and extracellular MC occurrence.

More information on algae blooms in B.C. can be found on the website Algae Watch.

3. Guidance on Strategies for Evaluating and Managing Cyanobacteria and Cyanotoxins

Strategies for evaluating cyanobacterial blooms and potential cyanotoxin risk may range from simple bloom observation to comprehensive testing of cyanotoxin levels. The most appropriate management strategy for a given water body or community will depend on history, resources available, and the magnitude of potential impact on the community:

- Comprehensive sampling programs may be appropriate for waterbodies that receive high recreational use or are sources for community drinking water supply systems in areas where human, technical, and financial resources are readily available.
- Limited sampling/testing and/or reliance on qualitative observations may be appropriate for remote waterbodies, waterbodies upon which there is limited human activity, waterbodies within which bloom events are rare or unlikely due to mitigating characteristics within the waterbody, and waterbodies for which an extensive profile has been developed. In locations where blooms are recurrent problems, sampling may be of limited value other than to confirm what is already known, and resources may be better directed to implementing short or long-term mitigation measures and or communicating information to allow users to make them aware of risks so they can take steps to protect themselves and their families.

To help inform decisions on an appropriate management strategy for a particular water body, information may be gathered for consideration such as: nutrient loading and cyanobacteria species present in the watershed, geographical and seasonal trends, the population affected exposure type (route of exposure), the resources available, and potential actions available in response to evaluation.

3.1 Watershed Information

Where available, information such as: source water assessment studies, previous bloom events, nutrient loading (phosphorus or nitrogen) from agricultural or other land use disturbance activities, and geologic/geographic considerations may be useful in developing a profile for the water body.

If the water body of concern has been sampled by the Ministry of Environment & Climate Change Strategy (ENV) then both historical and/or current water quality information may be available on the ENV website at https://catalogue.data.gov.bc.ca/dataset/949f2233-9612-4b06-92a9-903e817da659.

Detailed information on how to use this data can be obtained through the Environmental Monitoring System (EMS) web reporting tool, also located on the ENV website https://www2.gov.bc.ca/gov/content/environment/research-monitoring-reporting/monitoring/tools-databases/ems-web-reporting. Appendix B is a list of lakes that the ENV samples as part of the Provincial Lakes Monitoring Network. These lakes are sampled twice per year (early spring and late summer). Sampling includes water chemistry, chlorophyll a, and plankton analysis for species identification and quantity. All of this information may assist in determining if any testing/sampling for cyanotoxins is necessary, and at what frequency, for a given waterbody. Provincial Lakes Network data can also act as representative of lake water quality for nearby lakes. Long-term planning, which includes the effective management of nitrogen and phosphorus sources, may enhance watershed protection and reduce the incidence of cyanoblooms in a given region.

3.2 Benefits and Limitations of Sampling

Sampling and testing for the presence and concentration of cyanotoxins should be considered as part of a management strategy for assessing potential impacts to human health, and where drinking water systems may need detailed information with which to fine tune their water treatment facilities. However, sampling may provide limited, or no benefit in other situations.

All toxin sampling and testing systems have limitations with regards to accuracy of results, and how precisely they represent a given bloom situation within a waterbody. Cyanobloom conditions can change rapidly, and are dependent on a number of factors, such as the weather and circulation patterns (currents) within the waterbody. However, it is important to recognize that the cyanotoxins may persist for a period of time after the bloom itself has dissipated.

Where sampling is carried out, implementing a robust sampling protocol will provide a more accurate picture than a single sample regarding the level of risk the bloom poses to public health or the waterbody ecosystem. Sampling duration, location and frequency, as well as history of the site should be carefully considered when planning sampling programs. If the decision is made to conduct sampling/testing, the decision trees for drinking water and recreational water (Appendix A) may be utilized to ensure consistent sampling and interpretation of results, and alignment with the Guidelines for Canadian Drinking Water Quality.

3.3 Community Resources

Agencies involved with the initial screening of suspect blooms, as well as cyanotoxin testing of raw and drinking water sources may include local governments, water system operators, and/or Health Authority Environmental Health Officers. Operational decisions need to be made in each community regarding which agencies are to be involved with the screening and/or cyanotoxin testing of a given water source, and the level or degree of screening/sampling required for the waterbodies of a given region (if any). For example, in certain regions it may be the health authorities who do the sampling; in other regions, local governments may take on that role. Additionally, drinking water supply system operators may take on the role of screening/sampling where it is determined to be necessary. See Appendix C for factors to consider in the preparation of a contingency plan in advance of bloom season.

3.4 Communicating With the Public

Communities should work with their local Health Authority to ensure that an effective messaging protocol is in place to inform the public about bloom events; especially when drinking water sources are affected. Local government, private industry, and the health authority may need to work together to coordinate messaging (see Appendix D) regarding recreational water sources that are at risk and where swimming should be avoided. Dogs swimming in recreational water are at risk of illness or death due to ingestion of cyanotoxins, and there is no mandatory reporting of these incidents by veterinary clinics to government agencies. However, cases received by clinics may be reported to the Ministry of Agriculture (Health Centre Veterinary Pathologist), the Public Health Veterinarian at the BCCDC, or the Ministry of Environment & Climate Change Strategy on a voluntary basis.

3.5 Sampling, Portable Test Kits, and Laboratories

Sampling agencies should make themselves familiar with this protocol and work together to develop local communication protocols prior to bloom events. Agencies should understand their respective role(s) regarding observation, sampling, and decision making for a given source of drinking or recreational water.

This protocol refers to field test kit methods and laboratory testing. Field test kits have a range of detection limits and levels of accuracy/reliability vary. To limit the potential for error when using this protocol, field testing (using test kits for MC) is intended to determine MC presence or absence only (versus a specific quantifiable concentration). If field tests show the presence of MC, water samples should be forwarded to an analytical laboratory to confirm the presence and determine the concentration of MC, after which next steps should be determined based on these results.

There are a number of commercial MC test kits available that are suitable for field use. These are discussed in the recent Health Canada report 'Evaluation of Field Test Kits to Detect Microcystins' (Rodriguez et al., 2015). These test kits include technologies based on ELISA, immunochromatography, and phosphatase inhibition. When choosing a portable test kit, it is important to select the one that is appropriate for the range of MC concentrations you are screening for (i.e., 0.5 µg/L to 5 µg/L for drinking water, and a higher range for recreational water). In some cases, where the test kit range is below threshold (i.e., if using a kit to test recreational water that has been designed for detecting lower concentrations) dilution of samples with fresh water may be required to provide test results within the range of interest.

Several BC laboratories are equipped to test for MC, and sampling agencies should determine, in consultation with the local Health Authority, protocols for sampling, and where and how to send samples for analysis well before any bloom event occurs. Descriptions of appropriate laboratory techniques are discussed in section 6 (Analytical methods) of Health Canada's guidance on cyanobacterial toxins (Health Canada, 2018).

3.6 Stakeholder Responsibility for Sampling and Testing for Bloom Events

Responsibility for cyanobacterial sampling, testing, decision making, and risk communication should be determined prior to the occurrence of bloom events. Communication between agencies is essential to ensure that an effective 'division of labour' is agreed upon, as well as an appropriate scope of sampling and testing of a given waterbody (i.e., which lakes are to be tested and at what frequency). Accordingly, agencies should consider the level of risk for a given waterbody as it relates to the allocation of available resources.

Stakeholder Roles and Responsibilities

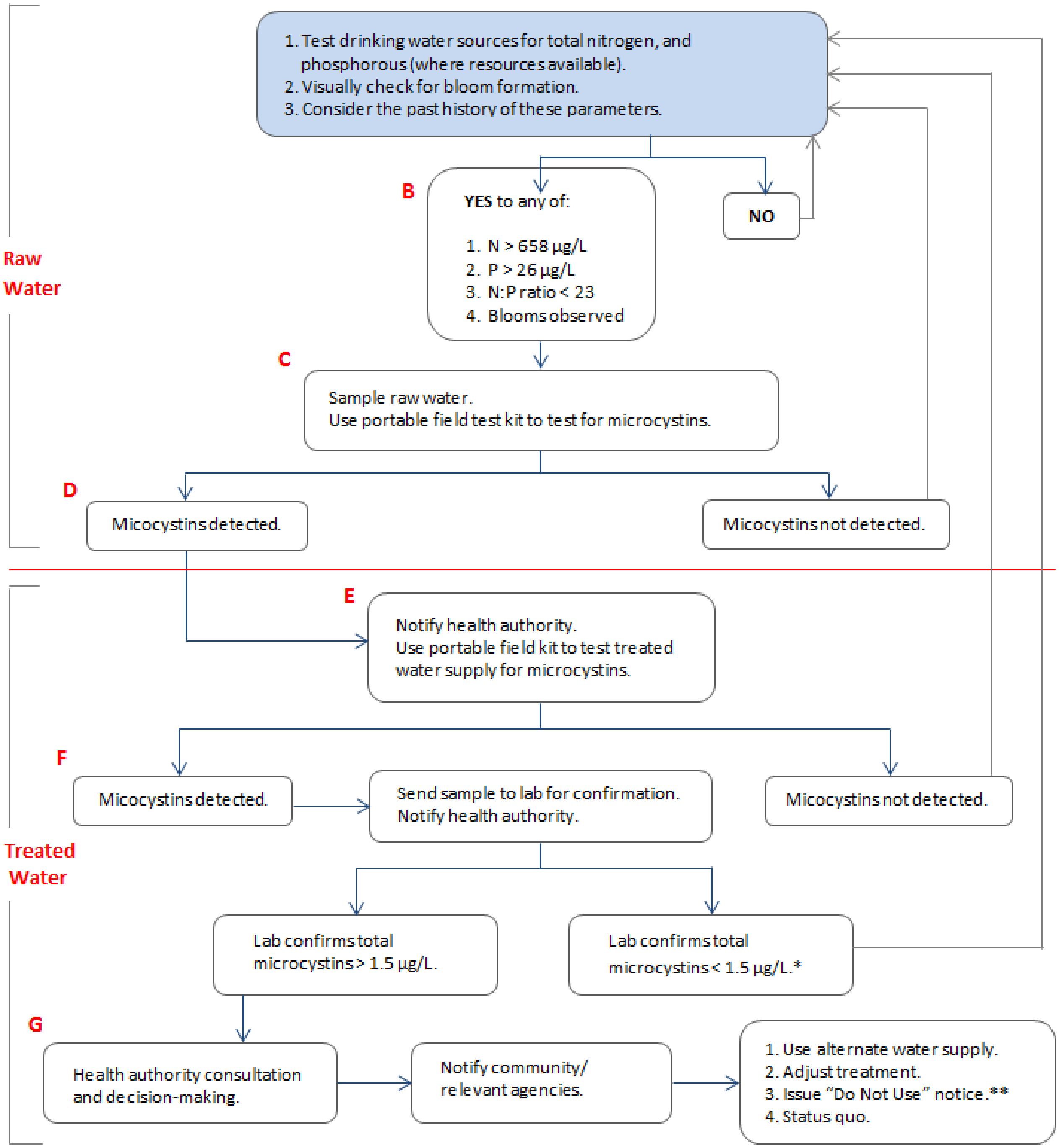
Organization	**Roles**	**Example of Responsibilities***
Single family residence	Source water protection, Observer, Sampler	• Minimize loading of nutrients (nitrogen and phosphorus) to source water • Observe water and report any suspected bloom events to ENV (complaints email box or RAPP line) or local Health Authority if there are concerns around drinking water supply • Act as volunteer water sampler for laboratory or on-site analysis
Local government	Source water protection, Observer, Sampler	• Manage land use planning and sewage services to minimise nutrient loading to source water • Develop watershed protection plans in conjunction with residents, industry, NGOs, neighbouring local governments (if applicable), and Regional Health Authorities • Optionally, employ designated water quality samplers • Issue and rescind beach closures • Update local advisories via web, radio, print, bulletin board, etc
Regulated water supplier	Advocate source water protection, Provide potable water	• Collaborate with local authorities on source water protection • Observe conditions daily at intake daily non-bloom phases and more frequently during blooms • Carry out raw water monitoring program in accordance with operating permit and directions from Health Authority • Monitor water treatment processes to ensure potability • Carry out treated water monitoring program in accordance with operating permit and directions from Health Authority • Notify users in the event of drinking water advisories (Do not drink, Do not use)
Regional Health Authority	Education, Statutory decision maker under *Drinking Water Protection Act* and *Public Health Act*	• Ensure compliance with drinking water operating permits • Review water quality analyses • Provide health advice regarding drinking and recreational water quality • Participate in recreational/drinking water sampling • Issue and rescind beach closures • If necessary, require water supplier to issue drinking water advisories • Participate in provincial recreational and drinking water committees

Organization	Roles	Example of Responsibilities*
		• Provide health services to users impacted by cyanobacterial toxins
Provincial Government – Ministry of Environment & Climate Change Strategy	Ambient water quality protection, Water Quality Data collection and management, Public contact for bloom identification, Statutory decision maker under *Environmental Management Act*	• Conduct ambient water quality monitoring at selected lakes • Publish data on ambient water quality to support decision makers • Respond to public reports of blooms to assess the likelihood of cyanobacteria (i.e., visual confirmation and/or local knowledge) • Participate in provincial recreational water committee • Publish information on Algae Watch website
Provincial Government – Ministry of Health	Policy, Education	• Establish provincial guidance on drinking and recreational water • Participate in health authority recreational water committee and lead drinking water committee • Participate in national drinking water committee • Publish HealthLinkBC advisories

* The responsibilities of different stakeholders are not fixed, and can be renegotiated to suit the local situation as required. Contact the regional local government and health authority for more information.

Appendix A - Protocol Decision Trees

Part A: Procedure for Screening/Quantitative Analysis for Communities Engaging in Sampling/Testing for Cyanobacteria Toxins in Drinking Water ('Decision Tree')



* If microcystins are detected in treated water above 0.4ug/L, drinking water authorities should inform the public in the affected area that an alternate suitable source of drinking water (such as bottled water) should be used to reconstitute infant formula.

**Notice in effect until 2 consecutive water samples (raw & treated) tested & confirmed to be <1.5 ug/L for microcystins.

Drinking Water Decision Tree for Cyanobacteria (Part A) – Step Descriptions

Step A: Initial screening for suspected blooms. Examine water for total nitrogen and/or phosphorus, and visually check for bloom formation.

- Test for nitrogen/phosphorus:

  Spring turnover typically results in an increase in water nutrients cycled to the surface. This nutrient cycling coupled with increased sunlight and temperature can provide ideal conditions for a cyanobloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending cyanobloom, indicating a need for increased frequency of visual checks.

- Visually check for cyanobloom formation:
  - As cyanoblooms tend to recur in the same water supplies, waterbodies that have historically exhibited cyanoblooms should be visually monitored for bloom formation. Additionally, waterbodies that experience changes in variables such as temperature, size, water depth, and nutrient content, may be susceptible to cyanoblooms and should be considered for increased monitoring. Public inquiries/complaints may also serve as a flag to inspect for cyanoblooms.
  - A cyanobloom is identified by the appearance of 'soupy' water. Colours can range from grey, tan, blue-green, or bright blue, to reddish. The appearance of cyanoblooms may also be described as resembling fine grass clippings or small clumps. Changes in Secchi depth readings (i.e., cloudiness/turbidity) may be a sign of an impending cyanobloom (see Appendix E for more on cyanobloom algae identification).

Step B: If 'yes' to any of nitrogen (N) >658 µg/L; phosphorus (P) > 26 µg/L; an N:P ratio <23; changes in secchi depth; or cyanoblooms observed (see appendix E for bloom identification) – go to Step C. If "no," return to Step A.

- High levels of nitrogen and phosphorus, as well as a low ratio of nitrogen:phosphorous (N:P) can contribute to cyanoblooms and consequently the presence of MC if MC-forming species are present.

- According to Orihel et al. (2012), 95% percent of the cases where MC concentrations exceed the WHO drinking water guideline occur when phosphorus concentrations are above 26 µg/L and nitrogen concentrations are above 658 µg/L (Orihel et al., 2012). Maximum concentrations of MC occur in hypereutrophic lakes at mass ratios of N:P < 23. The probability of MC concentrations exceeding all toxin thresholds is highest when N:P ratios are < 20, and drop to near zero above an N:P ratio of 40 (Orihel et al., 2012).

- As growth conditions and nutrient content of each waterbody is unique, these numbers are provided as a screening reference for anticipating the risk of a bloom, and are not intended to be exact thresholds. For rationale on cyanobloom observation, See step A above.

Step C: Sample raw water. Use a portable field kit to test for presence of MC.

- Raw water samples should be collected prior to any treatment. Sampling from a reservoir should be done as close to the inlet and/or the bloom formation as possible. When choosing a sampling location, be aware that cyanobacterial species/cell abundance and biomass vary spatially within a water body (e.g., cells may be transported by wind currents).
- For the purpose of this decision document, presence of MC means > 1.0 μg/L using a portable test kit. See Rodriguez et al. (2015) on selecting a portable test kit. Be aware that toxins may persist following the collapse of blooms, particularly in the late summer and early fall, when the onset of colder temperatures and decrease in light intensity result in decreased rates of cyanotoxin degradation. This reduced degradation may indicate a need for sampling for cyanotoxins during and after the collapse of a bloom.

Step D: If MC are detected (> 1.0 μg/L) with a field test kit, go to step E, and alert the Health Authority of a potential issue. If MC are <1.0 μg/L, return to step A.

Step E: Use a portable test kit to test the <u>treated water</u> supply for MC.

- Samples should be taken at a tap located after the water plant or from within the distribution system.

Step F: If the portable test kit indicates MC are present (> 1.0 μg/L) in the treated water, send a sample to a laboratory equipped to analyse for MC for confirmation, and immediately notify the local Health Authority.

- **<u>The presence of MC indicates that there is a potential concern for infants who use formula reconstituted from that water. Consult the Health Authority regarding informing the public that an alternate source of drinking water should be used for reconstituting infant formula.</u>**
- Contact the Health Authority to confirm an appropriate laboratory for microcystin testing. Samples should be sent (in coolers) to the laboratory for analysis. Specific protocols for sampling

and storing water samples *en route* to the laboratory should be identified in consultation with the laboratory, prior to a cyanobloom occurring to ensure accuracy of analyses.

Step G: If lab results indicate the seasonal MAC of 1.5 µg/L has been exceeded, the Health Authority should be contacted immediately for consultation and decision making.

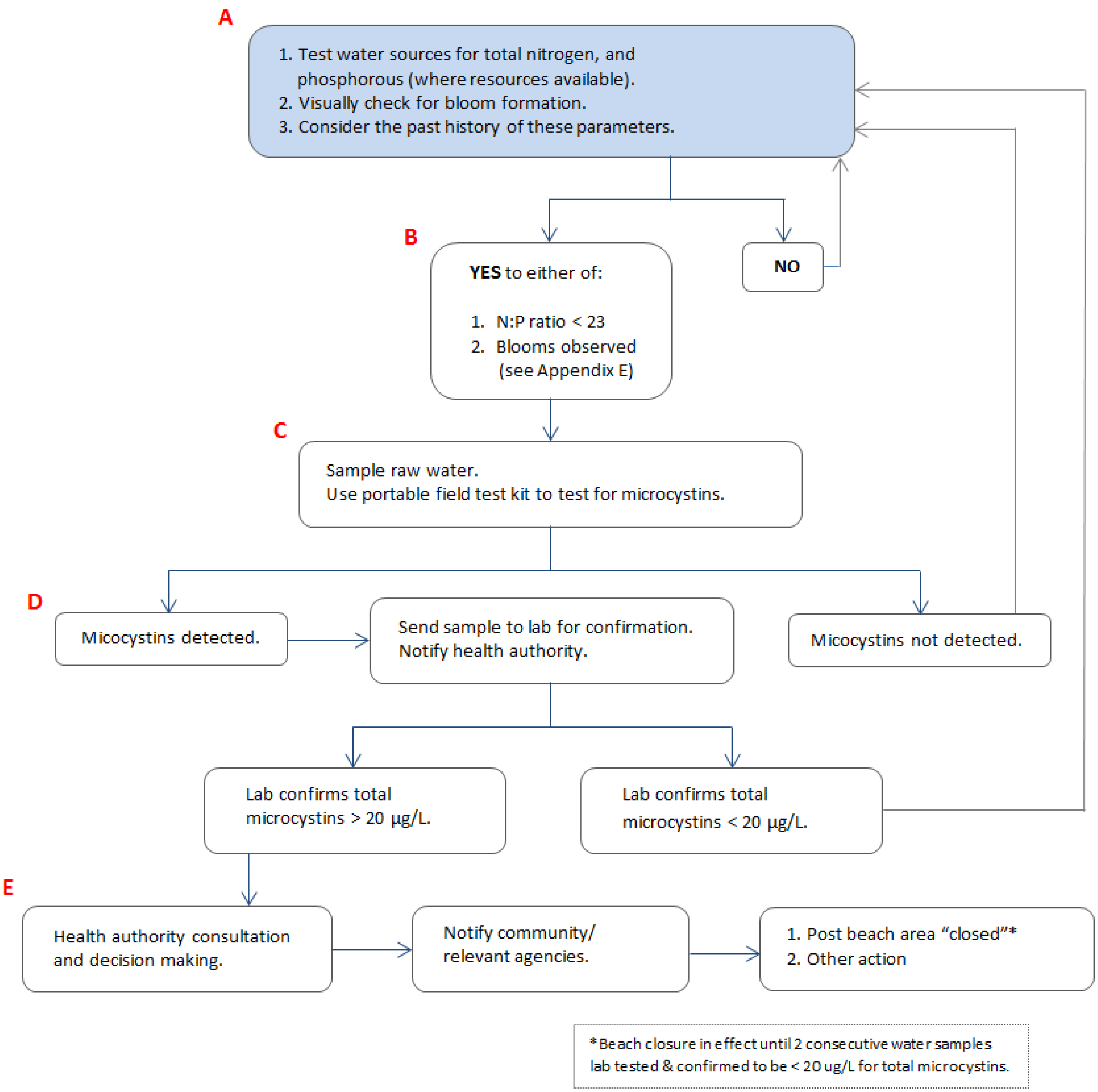
Where laboratory analysis indicates that MC concentrations are near or exceed the seasonal MAC of 1.5 µg/L, the Health Authority should be consulted to determine a short and long term course of action. Health agencies, municipal councils, and water supply system operators should be included in these discussions. Factors to consider may include the history of the site, the size and location of the bloom, available treatment technology, uses of the source water (recreational vs domestic) and monitoring of environmental conditions that might affect the bloom (e.g., wind). Water system operators may be able to provide information regarding the historical occurrence of cyanoblooms/MC for a given system.

In response, the water supplier may need to do one or more of the following:

- Re-sample the treated water supply using field kit or laboratory analyses; conduct other monitoring.
- Use alternate water source or supply.
  - Discussions regarding alternative supplies should be reviewed with the Health Authority.
- Adjust treatment (if doing so will be effective in removing MC).
  - Discussions regarding treatment adjustments should be reviewed with the Health Authority.
- Issue 'do not use' advisory (see Appendix D for suggested messaging).
  - As blooms may be of short duration (ranging from days to weeks), the Health Authority may recommend that a 'do not use' advisory be issued, and that consumers seek alternative supplies of safe drinking water until the risk passes.
  - Any 'do not use' advisory should remain in effect until two consecutive water samples within 48 hours (for both raw and treated supplies) are tested and confirmed to be less than their respective thresholds for MC.
- Maintain the status quo (continue monitoring).
- Other actions as required by the Health Authority.

Long-term issues and/or recurrence of cyanoblooms may require planning to incorporate specific treatment to correct the problem, and the use of an alternate water source in the interim. See Appendix F for more information on cyanobacteria management strategies for unregulated water systems. Note that the treatment process for microcystins may result in changes to other chemical parameters of the water.

Part B: Procedure for Screening/Quantitative Analysis for Communities Engaging in Sampling/Testing for Cyanobacteria Toxins in Drinking Water ('Decision Tree')



Recreational Water Decision Tree for Cyanobacteria (Part B) – Step Descriptions

Step A: Initial screening for suspected blooms. Examine water for total nitrogen and/or phosphorus; visually check for bloom formation.

- Test for nitrogen/phosphorus:

  Spring turnover typically results in an increase in water nutrients cycled to the surface. This nutrient cycling coupled with increased sunlight and temperature can provide the conditions that lead to a cyanobloom. Testing for phosphorous and/or nitrogen may serve as an alert for impending cyanoblooms, indicating a need for increased frequency of visual checks.

- Visually check for bloom formation:

  As cyanoblooms tend to recur in the same water supplies, waterbodies that have historically exhibited cyanoblooms should be visually monitored for bloom formation. As well, waterbodies that experience changes in variables such as temperature, size, water depth, and nutrient content, may be susceptible to cyanoblooms and should be considered for increased monitoring. Public inquiries/complaints may also serve as a flag to check for cyanoblooms.

  A cyanobloom is identified by the appearance of 'soupy' water. Colours can range from grey, tan, to blue-green, bright blue, or reddish. The appearance of cyanoblooms may also be described as resembling fine grass clippings or small clumps. Changes in secchi depth readings (i.e., cloudiness/turbidity) may be a sign of an impending cyanobloom (see Appendix E for more on cyanobloom algae identification).

  Be aware that cyanotoxins may persist following the collapse of a cyanobloom, particularly in the late summer and early fall, when the onset of colder temperatures and decrease in light intensity results in decreased rates of cyanotoxin degradation, which may indicate a need for sampling for cyanotoxins during and after collapse of the bloom.

Step B: If 'yes' to any of a N:P ratio < 23; or cyanoblooms observed (see Appendix E for bloom identification) – go to Step C. If "no," return to Step A.

- High levels of nitrogen and phosphorus, as well as a low ratio of nitrogen:phosphorous (N:P) can contribute to cyanoblooms and the presence of MC if MC-forming species are present.
- According to Orihel et al. (2012), concentrations of MC occur in hypereutrophic lakes at mass ratios of N:P < 23. The probability of MC concentrations exceeding all toxin thresholds is highest when N:P ratios are < 20, and drop to near zero above an N:P ratio of 40.

- As growth conditions and nutrient content of each waterbody is unique, these numbers are provided as a screening reference for anticipating the risk of a bloom, and are not intended to be exact thresholds.
- For rationale on bloom observation, see step 'A' above.

Step C: Sample raw water. Use a portable field kit to test for MC.

- Samples should be taken as close to beaches or recreational sites as possible. However, if sampling agency resources are available, it is suggested that samples from several sites be taken and tested for the presence of MC, as cyanobacterial biomass varies spatially within a waterbody (i.e., cells may be transported by wind currents).
- See Rodriguez et al. (2015) on selecting a portable test kit.

Step D: If MC is detected with a field test kit (> 20 µg/L), send a sample to laboratory for quantitative analysis.

- For the purpose of this decision document, presence of MC means > 20 µg/L using a portable test kit.
- Contact Health Authority to confirm an appropriate laboratory for MC testing capability.
- Samples should be sent (in coolers) to the laboratory for analysis. Specific protocols for sampling and storing water samples *en route* to the laboratory should be identified in consultation with the laboratory, prior to a cyanobloom occurring to ensure accuracy of analyses.

Step E: Health Authority consultation and decision making.

Where laboratory analysis indicates that levels of MC are near or exceeding the threshold of 20 µg/L, the Health Authority should be consulted to determine a short and long term course of action. Health agencies, municipal councils, and water supply system operators should be included in these discussions. Factors to consider may include the uses of the site (i.e., swimming), the size and location of the bloom, the environmental conditions that might affect the bloom (e.g., wind), and the history of the water body.

The authority responsible for the recreational water body may need to do one or more of:

- Resample water immediately, and send to laboratory for confirmation of result.
- Take appropriate action(s), which may include:
    - Post beach area closed notice and notify community

    - See attached template (Appendix D) for wording.
    - The HealthlinkBC fact sheet on cyanobacteria blooms is available at http://www.healthlinkbc.ca/healthfiles/hfile47.stm to help convey information to communities.
    - Any beach closure should remain in effect until two consecutive water samples within 48 hours are tested and confirmed to be less than 20 μg/L for total MC.

- Notify local water supply operator that toxins have been found in their area.

- Other actions recommended by Health Authority.

Appendix B – Sampled Lakes

The following is a list of lakes that are sampled by ENV as part of the Provincial Lakes Network. Lakes are sampled twice per year in early spring and late summer. Sampling includes water chemistry, chlorophyll a, Secchi disk, and plankton analysis for species composition and quantity.

Region	Okanagan	Vancouver Island	South Coast	Kootenay	Skeena	Omineca-Peace	Thompson	Cariboo
	CHRISTINA L @ CHRISTINA	COWICHAN LAKE STATION # 1	DEER LAKE AT CENTRE	COLUMBIA LAKE	LAKELSE LAKE	NADSILNICH (WEST) L	SHUSWAP LK OPPOSITE MARBLE P	WILLIAMS LAKE
	CHRISTINA LAKE NORTH BASIN	COWICHAN LAKE STATION # 2	ALTA LAKE	WINDERMERE L	DIANA LAKE	TABOR L	SHUSWAP LK WEST OF SORRENTO	CHIMNEY LAKE
	KALAMALKA L SOUTH	COWICHAN LAKE STATION # 3	BROHM LAKE; MIDLAKE	MOYIE LAKE, NORTH	MORICE LAKE, CENTER	CLUCULZ L EAST ARM	SHUSWAP LK OFF BROKEN PT	DRAGON LK
	KALAMALKA LAKE DEEP BASIN	ELK LAKE, CENTER	Chilliwack Lake	MOYIE LAKE, SOUTH	BURNS L	CLUCULZ LAKE WEST	SHUSWAP LK OFF ENCOUNTER PT	HORSE LK
	KALAMALKA LAKE SOUTH END	LANGFORD LAKE	Sasamat Lake	SLOCAN LAKE, N. END	BURNS LAKE, DEEP STN #2	FRASER L MIDDLE	SHUSWAP LK OFF ARMSTRONG PT	PUNTZI LAKE
	MABEL L @ SOUTH END (PE00173)	QUAMICHAN LAKE	Como Lake	SLOCAN LAKE, S. END	BABINE LAKE, CENTER	FRASER L WEST BASIN	SHUSWAP LK OFF CANOE PT	BOWRON LAKE
	MABEL L @ TSUIUS CREEK	BAINBRIDGE LAKE, DEEP STN	BURNABY LAKE	PREMIER LAKE	BABINE LAKE, STN. 2	STUART LK EAST	ADAMS LAKE, CENTER	BIG LAKE
	MARA SOUTH	BRANNEN LAKE	ALPHA L CENTRE	TROUT LAKE	BABINE LAKE, STN. 4	MOBERLY LAKE	PENNASK LK NEAR CENTER	BRIDGE LAKE
	MARA LAKE OPPOSITE FOSSETT	LIZARD LAKE	NITA LAKE	WHITESWAN LAKE	KATHLYN LAKE	SWAN L	STUMP LK AT CENTER	HORN LAKE
	OKANAGAN L CENTRAL	QUATSE LAKE	LOST LAKE, CENTRE	ST. MARY`S LAKE	TYHEE LAKE @ DEEP STN	CHARLIE L	NICOLA LK AT DEEPEST PT.	LAC LA HACHE
	OKANAGAN L D/S KELOWNA	SHAWNIGAN LAKE, #1	GREEN LAKE CENTRE	SUMMIT LAKE	FRANCOIS LAKE CENTRE	CHARLIE North arm	WHITE LAKE	MCLEESE L.
	OKANAGAN L NORTH	SHAWNIGAN LAKE, #2	SAKINAW LAKE	JIMSMITH LAKE	FRANCOIS LAKE EAST END	ONE ISLAND LAKE	MONTE LAKE AT CENTER	SPANISH LAKE
	OKANAGAN L SOUTH	SHAWNIGAN LAKE, #3	LOIS LAKE, CENTER	TIE LAKE	FRANCOIS LAKE WEST END	NALTESBY (Bobtail) LK.	ROCHE LAKE AT CENTRE	TATLA LAKE
	OSOYOOS L OPP. MONASHEE CO-OP	SHAWNIGAN LAKE, WEST ARM	Buntzen Lake	WASA LAKE	DECKER LAKE	PURDEN LK DEEP STN.	Peter Hope	CANIM LAKE WEST END
	OSOYOOS L SOUTH BASIN	COMOX LAKE INLET BASIN			ROUND LAKE, DEEP STN	SUMMIT LK	BIG BAR LK AT CENTER	CANIM LAKE S. OF BOSS CK.
	OSOYOOS LAKE CENTRAL BASIN	COMOX LAKE MAIN BASIN			SEYMOUR LAKE, CENTER	CARP L	BONAPARTE LK WEST END	
	SKAHA L OPP. GILLIES	COMOX LAKE OUTLET BASIN					PAUL LAKE AT CENTER	
	SKAHA L SOUTH BASIN	SPROAT LAKE - FABER ARM					GUN LAKE AT CENTER	
	SKAHA L WEST	SPROAT LAKE - STIRLING ARM					HEFFLEY LAKE AT CENTRE	
	SUGAR L @ SITKUM CR.	SPROAT LAKE - TAYLOR ARM					LAC LE JEUNE AT DEEPEST PT	
	WOOD LAKE DEEP BASIN	SPROAT LAKE - WEINER ARM					LOON LK AT ROCK BLUFF	
	ELLISON LAKE CENTRAL						DUTCH LK OFF ISLAND	

Green=shallow <10m (epi only)
Blue= intermediate depth 10- 20m
Black= deep (epi & hypo samples)
Brown shaded = Defer to 2018 or later

Appendix C - Cyanobacteria Preparation Checklist and Contact List Template

Preparation is crucial to an effective response to cyanobacterial blooms. The process will go more smoothly if preparations are made in advance, and collecting and analysing samples are practiced in advance. Water supplier and/or local governments should develop and establish a plan prior to bloom season for both recreational and drinking water sources that are or may be vulnerable to cyanobacterial blooms. This plan should lay out what to do if a cyanobacterial bloom is visually detected in the water source. It should:

- identify the agencies responsible for sampling (establish clear responsibility for water sources requiring sampling);
- describe the sampling strategy (parameters, frequency, timing, locations) to be followed for the duration of the bloom with respect to both routine sampling and re-sampling when MC is detected;
- identify the analytical laboratory or laboratories that can do MC analysis;
- outline individual responsibilities for how to collect and deliver samples to the laboratory, and ensure specific sampling protocols for the selected laboratory are known and followed;
- specify the method(s) of MC detection/analysis that can be used with the laboratory;
- identify the appropriate contact people to receive laboratory results and who they must notify if MC is detected;
- identify which authority/authorities are responsible for deciding further notifications/actions;
- identify which authority will take the lead role in notifying communities and other appropriate agencies or authorities;
- set out a communications plan describing the circumstances and target groups for notification, including when an advisory is issued or rescinded, and what situation calls for which messaging;
- include sample messages and questions/answers to deal with different situations (e.g., MC detected above guideline; MC detected below guideline level but still of concern for infants) and provide clear guidance to the public;
- identify corrective actions (e.g., water treatment adjustments) and triggers for such actions;
- ensure steps are in place for different situations (e.g., long-lasting as opposed to short-lived blooms; and
- identify closing procedures and follow up (e.g., keep a record of the bloom: start and end date of cyanobloom and cyanotoxin detection, species identified, cyanotoxins present, actions taken, authorities involved, and lessons learned).

The following is an example contact list of relevant agencies:

Organization	Role	Contact Name	Phone	Email
Health Authority				

Water Supplier				
ENV				
Local Government				
Laboratory				
Media				

Appendix D - Suggested Messaging

1. **Microcystins detected in drinking water:**

Notice: Do Not Use Water for Reconstituting Infant Formula
Issued By:___________

Use format of Appendix 21 of the Drinking Water Officers' Guide

Suggested Messaging:

This notice is being issued because blooms of cyanobacteria (blue green algae) have been detected in the water supply.

The Drinking Water Officer, in consultation with the Medical Health Officer, advises that the seasonal maximum acceptable microcystin concentration of 0.0015 mg/L (1.5 µg/L) has not been exceeded, and there is no reason for a health warning for the general population, including young children.

However, because of the increased exposure of infants relative to body weight, as a precaution, an alternate suitable source of drinking water (such as bottled water) should be used to reconstitute infant formula. **Boiling is not effective** in reducing or removing these toxins. Exposure to toxins produced by cyanobacteria may cause nausea, vomiting, diarrhea, or fever.

2. **Do not use water notice:**

Notice: Do Not Use Water

Issued By:___________

Use format of Appendix 21 of the Drinking Water Officers' Guide

Suggested Messaging:

- This notice is being issued because blooms of cyanobacteria (blue green algae) have been detected in the water supply, and the *seasonal maximum acceptable concentration of 0.0015 mg/L (1.5 µg/L) has been exceeded.*
- Exposure to toxins produced by cyanobacteria may cause nausea, vomiting, diarrhea, or fever in humans and pets.
- Consumers should seek alternative supplies of safe drinking water.
- **Boiling is not effective** in reducing or removing these toxins, although some point-of-use devices may be effective.
- Dialysis treatment units in the community should also be notified, especially if it is a first-time occurrence for blooms on this supply.
- A health fact sheet on microcystin (It's your health: Blue green algae (cyanobacteria) and their toxins) is available at http://www.healthlinkbc.ca/healthfiles/hfile47.stm

3. Recreational Water

Notice: Beach Closed

*Issued By:*___________

Suggested Messaging:

- This notice is being issued because blooms of cyanobacteria (blue green algae) have been detected in the water supply, and the recommended Health Canada guideline of 20 μg/L for recreational water has been exceeded.
- Exposure to toxins produced by cyanobacteria may cause nausea, vomiting, diarrhea, or fever in humans and pets.
- People and pets should not drink, or swim in water until further notice.
- Anyone who comes in contact with a cyanobacterial bloom should rinse off with a source of clean, uncontaminated water.

4. Communication Best Practices:

Best Practice	Application in Water Advisory Notice
1. Tell them who you are.	The community drinking water provider (utility name).
2. Establish that you care.	To protect your health.
3. State the action they need to take.	The tap is currently only safe for external use. Do not boil the water, because boiling makes it worse.
4. Share the potential consequences.	If you swallow the water, you may experience nausea, diarrhea, vomiting, or liver and kidney damage (note: message depends on the MC concentrations detected and should be developed in consultation with the Health authority).
5. Provide the date.	FROM [DATE].
6. Point to more information.	For more information and advice please [CONTACT INFO].

Appendix E - Algae Identification and Testing

Algae identification – Impact Assessment Biologists with ENV may be able to identify the algae to the genus or species level but for definitive identification samples will need to be sent to a lab. Photos of the bloom (with a request for identification) can be sent to ENV at EnvironmentalComplaints@gov.bc.ca

Field Tests:

Both the jar test and the stick test can help to identify algae; however they may not be able to identify when multiple species are present.

Jar Test - Cyanobacteria float to the top or remain suspended in the water column



Stick Test – long strands are probably NOT cyanobacteria

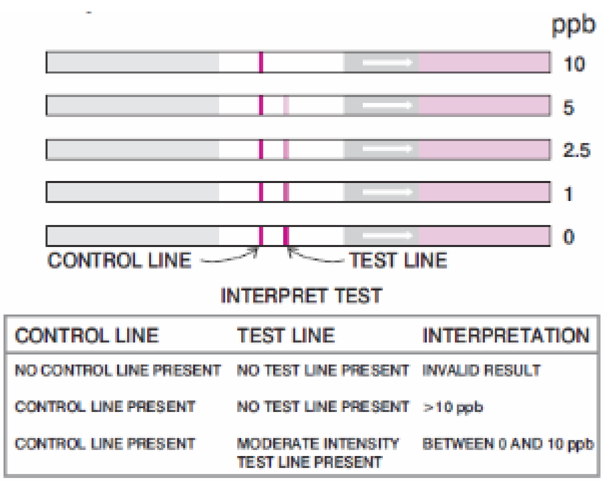

GREEN ALGAE BLUE-GREEN ALGAE

Reference for Jar Test: Dani, 2016

Microcystins

Quantitative – the field test kits can test for ranges of microcystins present but for greater accuracy, a sample should to be sent to a lab.

Presence/ Absence – field test kits are ideal for presence/ absence tests and often can give a range of values.



CONTROL LINE	TEST LINE	INTERPRETATION
NO CONTROL LINE PRESENT	NO TEST LINE PRESENT	INVALID RESULT
CONTROL LINE PRESENT	NO TEST LINE PRESENT	>10 ppb
CONTROL LINE PRESENT	MODERATE INTENSITY TEST LINE PRESENT	BETWEEN 0 AND 10 ppb

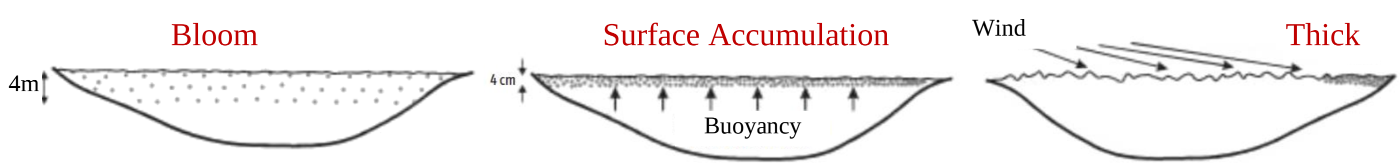
Sample field test interpretation from an Abraxis test kit.

Appendix F - Cyanobacteria Decision Support for Unregulated Water Systems

All surface water should be treated with filtration and disinfection to control pathogens. This is often referred to as 43210 treatment, meaning 99.99% reduction in viruses, 99.9% reduction in cysts, 2 independent treatment devices, 1 turbidity unit maximum, and 0 coliform bacteria in treated water - see 'Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in BC' in the [Drinking Water Officers' Guide.]()

Algae and cyanobacteria are always present in ponds and lakes. Algae are microscopic plants. Algae can cause aesthetic problems with taste, odour and turbidity in drinking water. The presence of algae does not imply an environmental or human hazard as long as the cells remain thinly dispersed. Cyanobacteria are naturally occurring microscopic organisms found in waterbodies, and are different to algae. By contrast, cyanobacteria can produce toxins that may be harmful to human and animal health. Visible blooms, whether algae or cyanobacteria, should be considered potentially harmful when cells are visible throughout the water column or surface accumulations or thick scum are present, until testing has been conducted.

Cyanobacteria are present at low levels in most lakes. Environmental conditions can concentrate them up to 1000 times.



Cyanobacteria can sometimes produce dangerous toxins that may damage the liver and brain if ingested or inhaled (droplets) in high concentrations. You can avoid these potential health risks by using bottled water (or another safe source) for all ingestion (cooking and drinking) during bloom events. Also, try baths rather than showers during blooms, and avoid swimming in any bloom. Contact with cyanotoxins also causes skin irritation in some people, but this causes no lasting harm.

If there is a visible build-up of algae (a bloom) seen, the *first step* is to try to **determine if it is** cyanobacteria **(**blue-green algae) Photos of a suspected bloom can be emailed to EnvironmentalComplaints@gov.bc.ca with a request for assistance to identify the algae. An alternative is to call the RAPP line 1-877-952-7277.

Filamentous green plant algae bloom.
→ Not likely dangerous

Planktonic cyanobacteria bloom.
→ Possibly dangerous

During active <u>plant algae</u> blooms, the water is at low risk of containing significant cyanotoxins, but algae is known to cause aesthetic taste and odour problems. Aesthetic issues are not hazardous to human health, but may affect how you feel about drinking the water. You may prefer to use an alternate drinking water source during these non-hazardous blooms.

During active <u>cyanobacteria</u> (blue-green algae) blooms, the safest approach is to use an alternate source of water for drinking, washing, and preparing food, and brushing teeth, such as bottled water, potable water hauled to a storage tank (cistern), or well water. Because of the increased sensitivity of infants, it is especially important to adopt a precautionary approach and use safe (e.g., bottled) water to reconstitute infant formula.

If the water intake is <u>outside</u> of the active cyanobacteria bloom, water may be used for potable uses as long as extra monitoring and precautions are used – check filter frequently for signs of cyanobacteria and replace or backwash as needed. Granular activated carbon and/or reverse osmosis is recommended to remove dissolved cyanotoxins if the bloom is widespread. **Boiling water does not remove cyanotoxins – it concentrates them.**

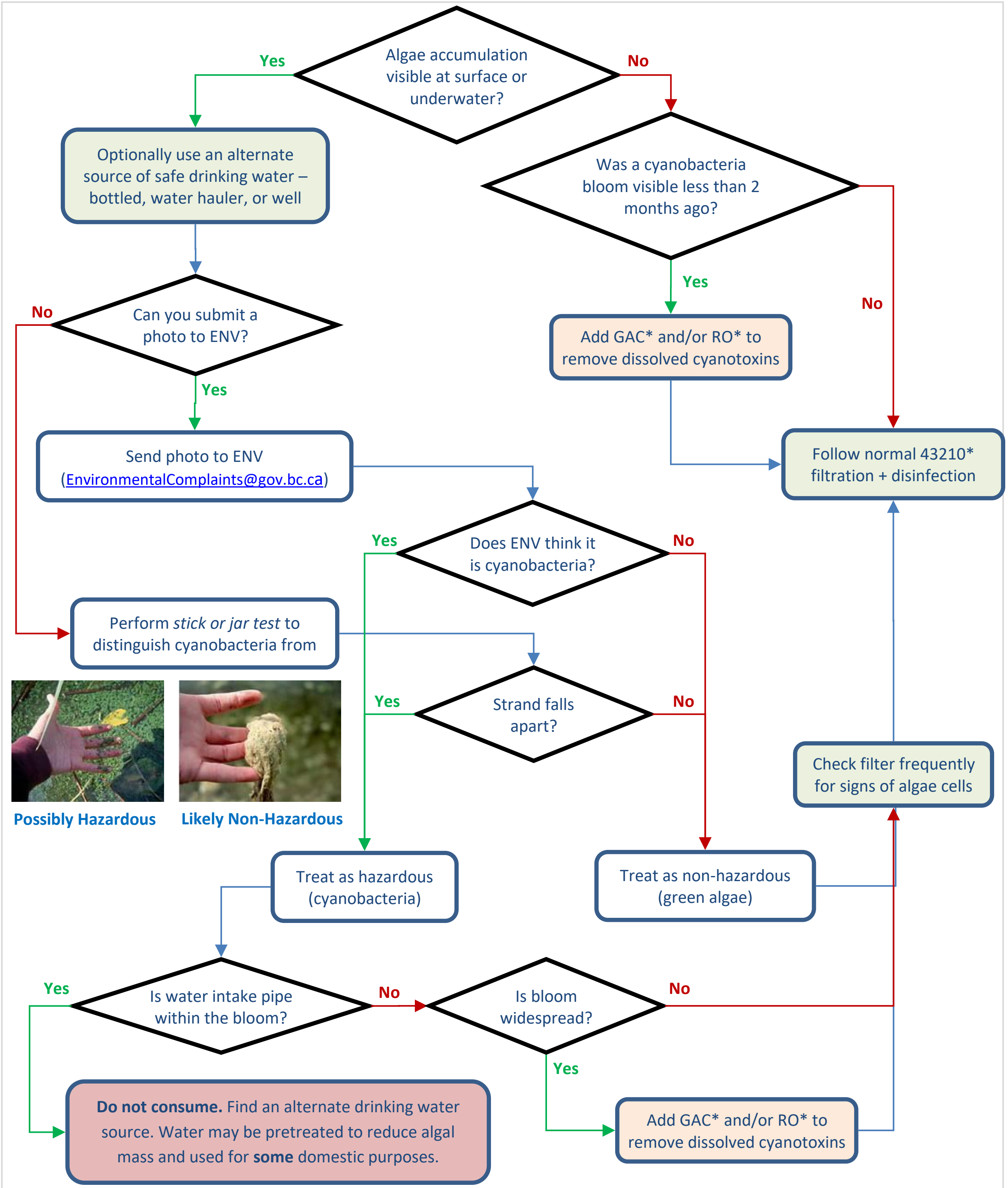
If the water intake is <u>within</u> any active bloom (whether cyanobacteria or plant algae), the mass of algae will likely overwhelm most filtration systems. If possible, move the intake away from the bloom or to >4 metres depth. If the intake cannot be moved, another source of drinking water must be found. Microfiltration, activated carbon, and reverse osmosis should be bypassed. With coarse pre-filtration (20 to 5 micron) to reduce algal mass, water drawn from an active bloom may be used for non-contact purposes such as toilet flushing.

Regulated water suppliers or individuals who cannot switch to an alternate source should contact the Regional Health Authority for more information on options to maintain service during cyanobacteria blooms.

Any test is indicative of water quality only at the time and location of sampling. During an active bloom, water conditions can vary dramatically from place to place and even hour to hour. Testing kits for cyanotoxins give same-day results for detecting the presence or absence of cyanotoxins. Packs of 20 tests cost about $600 (e.g., *Abraxis*). These may be useful to ensure a water treatment system is removing toxins, or to ensure significant levels of toxins are not present in lake water between bloom events. Quantitative laboratory tests for cyanotoxins ($120) or to identify and enumerate algae species ($80) are also available. Results take one to two weeks (e.g., *MB Laboratories* in Sidney, BC).

Homeowners should be cautious about relying on pull test and field test kit results to make decisions about cyanobacteria (blue-green algae) health risks. If in doubt, use bottled water or another safe water source for all ingestion (drinking and food preparation) during and up 1 to 3 months after cyanobacteria blooms disappear.

A decision support tree is included on the next page.


Algae accumulation visible at surface or underwater?
Yes
No
Optionally use an alternate source of safe drinking water – bottled, water hauler, or well
Was a cyanobacteria bloom visible less than 2 months ago?
Yes
No
Can you submit a photo to ENV?
No
Yes
Add GAC* and/or RO* to remove dissolved cyanotoxins
Send photo to ENV (EnvironmentalComplaints@gov.bc.ca)
Follow normal 43210* filtration + disinfection
Does ENV think it is cyanobacteria?
Yes
No
Perform *stick or jar test* to distinguish cyanobacteria from
Strand falls apart?
Yes
No
Possibly Hazardous
Likely Non-Hazardous
Check filter frequently for signs of algae cells
Treat as hazardous (cyanobacteria)
Treat as non-hazardous (green algae)
Is water intake pipe within the bloom?
Yes
No
Is bloom widespread?
No
Yes
Do not consume. Find an alternate drinking water source. Water may be pretreated to reduce algal mass and used for **some** domestic purposes.
Add GAC* and/or RO* to remove dissolved cyanotoxins

Example scenarios for blue-green algae (cyanobacteria) occurrence, recommended water uses, and treatment.

Scenario	Total Microcystins (µg/L)	Recommended Use for Water	Treatment Objective	Example Processes	Comments
No recent bloom, no evidence of cyanobacteria in lake, or isolated bloom far from intake	< 1.5	Potable	Pathogen control (43210)	Pre-filtration + Microfiltration + { Chlorination, UltraViolet, Reverse Osmosis, or Boiling }	Base case disinfection
Bloom close to intake or 1 to 3 months post-bloom*	Possibly > 1.5	Potable	Pathogen control (43210) + cyanotoxin removal	As above, but add: Activated Carbon and/or Reverse Osmosis	Check filters and replace or backwash frequently for signs of algae. Replace activated carbon frequently.
		Non-potable**	Reduction of suspended solids and turbidity	Pre-filtration + Optional Chlorination	Check filter and replace or backwash frequently for signs of algae. Optional chlorination may reduce skin irritation.
Intake in algae bloom*	Possibly >> 1.5	Non-potable **	Reduction of algae mass	Bypass potable filtration systems. Pre-filtration + Optional Chlorination	Algae will overwhelm and clog filtration system. Optional chlorination may reduce skin irritation.

* If possible, move intake to deeper water (>4m deep) after bloom has passed.
** Use alternate source of potable water (eg bottled).

Description of water treatment processes [*applicable certification standard for treatment devices*]

- **43210**. Treatment achieving 99.99% reduction in viruses, 99.9% reduction in cysts, 2 independent treatment devices, 1 turbidity unit maximum, and 0 bacteria.
- Microfiltration (**MF**). MF uses pore sizes from 0.1 µm to 1 µm-absolute to remove parasitic protozoan cysts [*NSF 53 for cysts*].
- Ultrafiltration (**UF**). UF uses pore sizes from 0.01 µm to 0.1 µm to remove parasitic protozoan cysts and bacteria.
- Chlorination (**Cl_2**) uses unscented bleach as a disinfectant to kill pathogenic bacteria and enteric viruses. 1 ppm × 15 min contact time [*NSF 60 optional*].
- UltraViolet (**UV**) disinfection uses strong UV light to inactivate bacteria, viruses and cysts [*NSF 55 Class A or equivalent*].

- Reverse Osmosis (**RO**) pushes water through an incredibly fine membrane to remove almost all impurities, including cyanotoxins. RO is usually only installed on one or two drinking water taps in the home (point-of-use) [*NSF 58 or equivalent*].
- **Boiling** uses temperatures above 70°C to kill bacteria, viruses and cysts, but ***does not remove cyanotoxins***.
- (Granular) Activated Carbon (**GAC**) uses carbon to adsorb organic chemicals, including cyanotoxins [*NSF 42 or equivalent*].
- **Pre-filtration** uses coarse membranes or a back washable sand filter (effective pore size 5 to 20 μm) to reduce the mass of large particles [*NSF 61*].

Appendix G - Regulatory Agency Contacts for Reporting Bloom Events

***When contacting regulatory agencies, use the word 'algae' in subject line describing the concern. Include the name of the lake or water body, along with the general area or name of the nearest community.**

Ministry of Environment & Climate Change Strategy, Environmental Protection
Email: EnvironmentalComplaints@gov.bc.ca
Tel: RAPP line 1-877-952-7277
Use the Algae Watch Observation submission form to report bloom events and learn more at:
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/algae-watch

Northern Health Authority
Email: php@northernhealth.ca

Regional Offices:

Northwest (Terrace) 250-631-4222
Northern Interior (Prince George) 250-565-2150
Northeast (Fort St John) 250-263-6000

Island Health Authority
Email: Gateway_office@viha.ca
Tel: 250-519-3401 (Rory Beise) or 250-737-2010 (Heather Florence)

Interior Health Authority
Regional Offices:
Kootenay 250-420-2220
Okanagan 250-549-5714
Thompson 250-851-7340

Fraser Health Authority
Email: feedback@fraserhealth.ca
Tel: 250-870-7903

Vancouver Coastal Health Authority
Email: HealthProtectionCG@vch.ca
Tel: 604-885-5164

First Nations Health Authority
Environmental Health: 1-844-666-0711123

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Fraser Health Authority: Timothy Millard

Island Health Authority: Heather Florence, Rory Beise

Ministry of Environment & Climate Change Strategy: Cindy Meays, Deb Epps

First Nations Health Authority: Alec Johnson

North Salt Spring Waterworks District: Meghan McKee

Decision Tree for Responding to a Turbidity Event in Unfiltered Drinking Water

Version 2.2 / First Published 2009, Revised 2013

Ministry of Health

1. Objective

The *Decision Tree for Responding to a Turbidity Event in Unfiltered Drinking Water* (decision tree) is intended to provide water supply system operators and health authority drinking water officers (DWOs) with a tool to help:

- Plan for future turbidity events in unfiltered drinking water from systems meeting the filtration exemption criteria.
- Provide quick response to acute turbidity events.

This tool will help decision makers take proactive measures to mitigate potential health risks from pathogens **before** there is a threat to public health. The decision tree applies to unfiltered[1] surface water and groundwater at risk of containing pathogens and should be incorporated into a water supply system's standard operating procedure.

The decision tree is not intended to provide guidance for determining if a drinking water system is in compliance with provincial treatment objectives or to be used as an alternative to providing appropriate treatment.

2. Introduction

Turbidity is caused by suspended organic and colloidal matter - such as: clay, silt, finely divided organic and inorganic matter, bacteria, protozoa, and other microscopic organisms. Turbidity can increase following events, such as, landslides, higher surface runoff, peak flows, debris flows, or road sedimentation due to construction. Turbidity does not necessarily pose a threat to human health, but

[1] For information about what to do in the case of a turbidity event related to filtered water, please speak to the local Drinking Water Officer immediately.

it can be an indicator of the potential presence of human pathogens. It also has the potential to disrupt or overload drinking water disinfection processes, such as ultraviolet (UV) light and chlorination, to the point that they no longer effectively deactivate pathogens.

The decision tree outlines the steps for evaluating the health risks associated with the turbidity event and the appropriate course of action. Appendix A contains expanded explanations for each step within the decision tree. Appendix B contains turbidity-related risk factors that should be considered when determining the appropriate course of action.

3. Filtration

Under section 6 of the *Drinking Water Protection Act*, water supply systems must provide potable water to all users. This is an important responsibility. The Ministry of Health developed the following documents to set out minimum performance targets for treating surface water and groundwater at risk of containing pathogens (GARP) which are considered to pose increased risk to human health:

- *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia*
- *Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP)*
- *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*

    - These documents endorse the recommendations from the *Guidelines for Canadian Drinking Water Quality* which state that systems using surface water or GARP sources should use filtration and one form of disinfection. A second form of disinfection may be considered in lieu of filtration if certain criteria are met[2]. The filtration exemption criteria can be found in the *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia* and the *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*. Should a water system qualify for an exemption, it is important to remember that these criteria need to be reassessed on an on-going basis to confirm continued validity. It should not be considered a permanent exemption as source water quality can change with alterations in watershed conditions.
    - If turbidity is an on-going issue for a water system, the filtration exemption should be re-evaluated. The decision tree is only to be used for isolated incidents.

4. Communication and decision-making

- Under section 10 of the *Drinking Water Protection Act*, water suppliers must have a written emergency response and contingency plan that includes a strategy for communication with users of the system. Response to a turbidity event should be part of this plan.
- It is important for water system operators and DWOs to maintain open dialogue during any emergency situation. The two parties should reach agreement regarding the degree of

[2] If a system does not use filtration and does not meet the filtration exemption criteria, it is not in compliance with the *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia* or the *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*. In this situation, system operators should consult with the local DWO about the steps that need to be taken in order to be compliant.

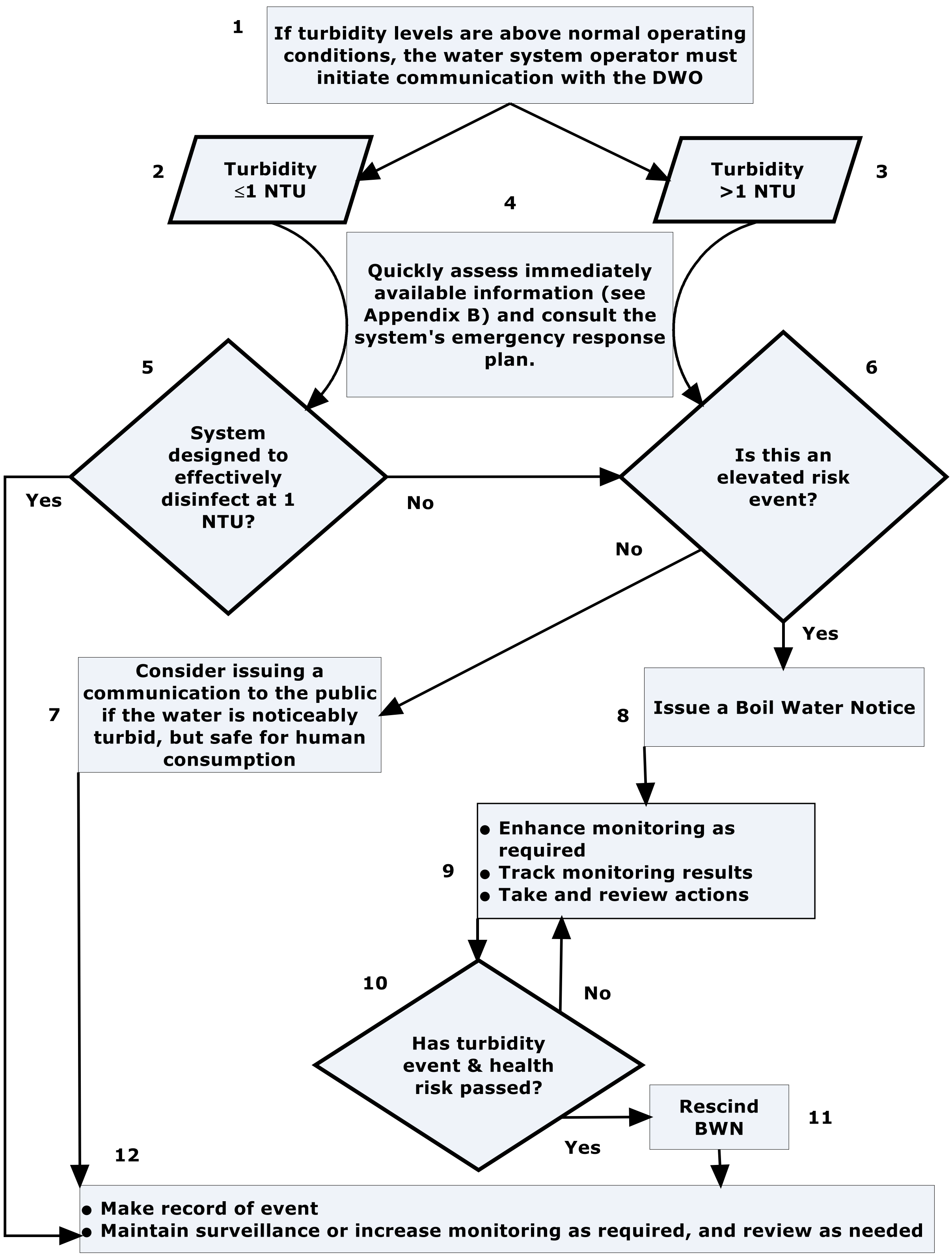
potential health risk associated with a turbidity event and its related considerations (set out in appendix B). There should be agreement on the appropriate public communication and/or water quality monitoring strategy. In circumstances where there is no agreement, the DWO has the authority to request or order the water system operator to comply.

- When a notice regarding turbidity is issued, the risk event(s) underlying the turbidity should be communicated to the public, as well as the scientific evidence. For example, if a Boil Water Notice (BWN) is issued, the notice should specify if sampling evidence indicates the presence of potential indicator organisms or if the BWN is based on other available (or lack of available) evidence or information. The situation may change over the course of an event, and further testing and new data may allow the water supplier to rescind the BWN. It is the responsibility of the water supplier to provide the scientific evidence that the drinking water is safe for human consumption. A DWO has the authority to order the issuance of a BWN should there be a failure on the part of the water supplier to provide the information that is needed to assess the health risk posed by the turbid drinking water.

5. Definitions

- **Boil Water Notice (BWN)** – Notice provided to water users to boil their water before any use that may involve ingestion of the water. A BWN infers that an adverse microbiological health risk exists if the water is ingested. A BWN is issued by the system operator at their own discretion or on request or order by the DWO. Consultative agreement between the operator and the DWO is the preferred approach. The DWO should verify that the BWN has been issued to users of the system.
- **Drinking Water Officer (DWO)** –The DWO is responsible for enforcing drinking water legislation, ensuring water systems are operating within the parameters of their permits and providing advice/orders during events that have potential to adversely affect public health. The local medical health officer is appointed as the DWO. The medical health officer has the authority to designate the duties of a DWO to environmental health officers. Generally, it is these designated environmental health officers that perform the front-line DWO duties.
- **Filtration** – A treatment process for the removal of particulate matter that has been approved by the issuing official (a person authorized under the Drinking Water Protection Regulations to issue a construction permit, operating permit or other permit required under the Drinking Water Protection Act). The filtration system has been granted removal credits for pathogens and is operating as expected.
- **GARP** – Groundwater at risk of containing pathogens – For more information, please see the Ministry of Health document: *Guidance Document for Determining Ground Water at Risk of Containing Pathogens (GARP).*
- **Medical Health Officer (MHO)** – A physician appointed under the Public Health Act to advise and report on local public health issues within a health authority. The MHO is responsible for fulfilling the role of a DWO unless the MHO delegates this responsibility to another qualified individual.
- **Nephelometric Turbidity Unit (NTU)** – This is the unit of measurement that is used for evaluating the level of turbidity (suspended and colloidal particles and/or microscopic organisms) in water.

Decision Tree for Responding to a Turbidity Event in Unfiltered Drinking Water



Appendix A: Expanded notes for the decision tree

- The following notes provide an expanded explanation for each box in the decision tree. The numbering below corresponds to the numbering in the decision tree boxes.

Box 1. In the case that a system operator identifies a turbidity spike above normal operating conditions, that system operator should first determine if it is possible to remove the source of the turbidity from the system (e.g., switch to an alternate source). The system operator must notify the DWO of a turbidity event immediately. The level of the measured turbidity will determine which box the system operator, with consultation from the DWO, should proceed to from this point:

- Less than or equal to 1 Nephelometric Turbidity Units (NTU), move to box 2.
- Greater than 1 NTU, move to box 3.

Box 2. This box applies when the turbidity level is <1 NTU. Generally, cases of turbidity that measure ≤1 NTU are not associated with adverse health effects when treatment by disinfection is provided. There are, however, some circumstances in which this condition may not apply. For example, if the water system is designed to operate at an extremely low NTU (e.g., 0.25) than it may become overwhelmed at a measurement above that level even if it is still below 1 NTU (e.g., 0.99 NTU). It is important to investigate all turbidity spikes regardless if the measurement is ≤1 NTU. From here, investigators should proceed to box 4.

Box 3. This box applies when turbidity levels are >1 NTU. Turbidity spikes above this threshold should be investigated because turbidity levels >1 NTU are associated with a greater probability of adverse health effects. The actual health risk may depend on a number of factors that include the parameters under which the system is designed to operate. Other factors to consider include identifying the source of the turbidity to assess the potential for pathogens harmful to human health (e.g., organic vs. inorganic material) and whether harmful pathogens have been identified through bacteriological water monitoring during previous similar turbidity events. From here, investigators should proceed to box 4.

Box 4. Assessment: Each of boxes 2 and 3 moves through box 4. This is the stage in which stakeholders quickly assess the situation for the purpose of decision-making. Decision makers may consult with the system's emergency response plan for prescribed actions. Monitoring and water testing takes time – to wait for results before taking action could put the public at risk for adverse health effects. Only evidence that is immediately available should be considered in this step. Appendix B contains potential risk factors that should be considered during the assessment. Once assessment information is gathered, continue on to box 5 for measurements of ≤1 NTU or box 6 for measurements >1 NTU to make decisions about the safety of the water and corresponding actions.

Box 5. Decision: *Disinfection sufficient?* - If the water system is designed to provide disinfection up to 1 NTU, adjust disinfection and maintain surveillance or increase monitoring as required. Proceed to box 12 and review as needed. Documented evidence must be available to demonstrate that disinfection at this level of turbidity is effective. If historical evidence demonstrates disinfection could be insufficient at this level, or no data is available, continue to box 6 for further investigation.

Box 6. **Decision: *Is this an elevated risk event?* –** This box applies to a turbidity event when the level is >1 NTU or if there is evidence indicating that disinfection is insufficient for turbidity spikes ≤1 NTU. The information assessed in box 4 is used to determine the risk level of the turbidity event. The DWO has the discretion to default to a determination of elevated risk should the water system operator not provide compelling evidence to the contrary (as per Appendix B).

Box 7. Proceed to box 8 and issue a BWN if:

- The emergency response plan prescribes this action in this circumstance;
- Risk factors of concern demonstrate an adverse risk to human health;
- Historical evidence indicates a relationship between adverse health effects and similar turbidity events; or
- There is no strong documented evidence (current or historical) of a low level of risk.

In some circumstances, a BWN may not be necessary. For example, the treatment system is designed to effectively disinfect at the measured turbidity level (e.g., measured at 3.0 NTU and designed to effectively disinfect up to 3.5 NTU), or there is documented evidence of an acceptable low level of risk (e.g., historically, similar turbidity events have not been related to adverse health effects). It is the responsibility of the water supplier to provide solid evidence to the DWO that either of these situations applies. Under these circumstances, decision makers can increase disinfection processes as required and continue to box 7.

Box 8. ***Issue a communication to the public:*** A public communication may be issued to notify users that the water is turbid, but there is a low risk of adverse health effects. This communication should explain the reason (e.g., water line flushing, harmless algae bloom, etc.) for the turbidity as well as provide contact information should they have any further questions. The decision to issue a communication (as well as the form of communication – informal notice or formal advisory) should be jointly agreed upon by the water system operator and the DWO. This is not a requirement, but something to consider for mitigating concerns in consumers. Proceed to box 12.

Box 9. ***Issue Boil Water Notice:*** Issue a BWN with the guidance of the water system operator's emergency response and contingency plan. A BWN is issued by the system operator and the DWO should verify that the users of the system have received the notice. Proceed to box 9.

Box 10. ***Evaluation***: When a BWN is issued, it is important to increase/enhance monitoring as required and track the results of monitoring. This may include bacteriological or other water tests. This is done to determine when the event of concern has passed. If possible, the water supplier should undertake actions that can mitigate the turbidity. It is also important to review decisions on an ongoing basis to ensure that the water system operator has taken appropriate action. Continue to box 10.

Box 11. ***Decision***: This box provides two options:

- If monitoring demonstrates continuing elevated risk, stay on the BWN and continue monitoring (proceed back to box 9).
- If monitoring demonstrates that the turbidity event and elevated health risk has passed, rescind the BWN (proceed to box 11).

Box 12. ***Rescind BWN***: When conditions have returned to normal (i.e., the health risk is no longer elevated), the BWN may be rescinded. The DWO should provide oversight to the process of rescinding the BWN by the water system operator to ensure that users of the system are notified. Proceed to box 12.

Box 13. Record turbidity events, causes, and actions taken so they can be reviewed in case of a future similar event. At this stage, the system should be back to normal operating conditions; although, there may be increased monitoring during and after the turbidity event (e.g., post-treatment bacteriological testing, distribution system bacteriological testing, operational parameters, disinfectant residuals, illness among users and possibly other parameters).

Appendix B: Turbidity-related risk factors: considerations for health risk assessment[3]

1. Source Water

1. Has there been contamination or a spill in which there is likely to be human pathogens? For example:
   - Sewage.
   - Animal waste.
   - Any substance likely to contain fecal material (e.g., agricultural run-off).
2. Are there recent changes in the hydrological characteristics of the watershed due to factors such as ground disturbances (e.g., mining, road work or other development projects) or vegetative cover disruptions (e.g., mountain pine beetle or planting/harvesting)?
3. Has precipitation been abnormally intense and/or have there been anomalies in weather (e.g., the amount and timing of rain, snow or snowmelt)?

2. Treatment System

1. Has the turbidity level exceeded the level for which the system has been designed or validated (e.g., system designed to operate effectively for turbidity levels ≤3.5 NTU but the current turbidity level is 4 NTU)?
2. Have there been failures in the treatment train? For example:
   - Power outage.
   - Existing treatment outcomes from chemical disinfection cannot be maintained (e.g., loss of chlorine residual).
   - Decrease in UV dose or lamp failure.
   - Decrease in UV transmittance (the amount of light passing through the water).

3. Other Considerations

1. Is there evidence of indicator organisms in the distribution system?
2. Is there evidence of illness related to the current event?
3. Has there been a history of health concerns under similar turbidity conditions? Or, is there lack of evidence to the contrary? There should be documented historical evidence demonstrating a lack of elevated health risk; otherwise, all involved parties should consider a precautionary approach and issue a BWN.

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[3] There is the possibility that some of these questions may not be applicable to all systems. Additionally, this is not an exhaustive list of risk factors. Should the answer to any of these questions be 'yes,' it is possible that the water is not safe for human consumption.

Water Systems For Class D & E Slaughter Establishments and Other Unregulated Uses

Version 1.2 / First Published 2014

Ministry of Health

1. Purpose

To clarify the circumstances when a domestic water system serving one single family dwelling and used for other purposes is not regulated as a water supply system under the *Drinking Water Protection Act* (DWPA).

2. Position

The use of water supplied by a domestic water system to one single family dwelling, for a purpose that does not come within the definition of "domestic purposes," as defined in the DWPA, does not require the system to be regulated as a water supply system under the DWPA.

3. Application

There are many uses to which water supplied by a domestic water system to one single family dwelling may be put which will not change the status of the water system and require it to meet the requirements under the DWPA. One of these is the use of water in the slaughtering process by the holders of Class D or E licences issued under the Meat Inspection Regulation. Water used in Class D and E slaughter facilities is regulated under the *Food Safety Act* (FSA), Meat Inspection Regulation, which requires that it be potable. In determining whether or not the water is potable, an Environmental Health Officer may rely upon those water quality standards which are in common use in the field of public health protection.

Other uses of water which are not domestic in nature could include:

- watering animals;
- irrigating crops;

- washing buildings or machinery;
- cooling machinery; and
- industrial uses.

Examples of uses which could change the status of a water system so that it is to be regulated as a water supply system are:

- supplying water to a second dwelling; or
- supplying water to a food service establishment where food was being prepared and the water is likely consumed directly by the public

4. Questions and Answers

Q. Is a slaughter establishment a food establishment, as defined in the FSA?

A. Yes, a slaughter establishment is a food establishment for the purposes of the FSA, with the result that inspectors appointed under the FSA are authorized to inspect and take action with respect to slaughter establishments.

Q. Does the fact that slaughter establishments are food establishments for the purposes of the FSA mean that the Public Health Act Food Premises Regulation applies to them?

A. No. The Public Health Act Food Premises Regulation applies to food premises, as defined in the Food Premises Regulation. The FSA and the Meat Inspection Regulation apply to slaughter establishments.

Q. Must the water for a Class D or E slaughter establishment come from a water supply system for which the water supplier holds a valid operating permit issued in accordance with the DWPA?

A. No. The only requirement for water used during slaughter in a Class D or E slaughter establishment is that the water must be potable.

Q. If a Class D or E slaughter establishment is supplied with water by a domestic water system that serves only one single family residence, and the slaughter establishment has a separate sink and toilet for the use of the people working in the slaughter establishment, does this change the status of the water system into a water supply system regulated under the DWPA?

A. An argument could be made that the existence of a separate toilet and sink for sanitation purposes would attract the application of the DWPA. The Health Protection Branch suggests that the Drinking Water Officers assess this situation in the same way they do those where separate sanitation facilities are provided in out buildings on agricultural property, which is supplied by a domestic water system serving one single family residence. A similar situation would be an auto body shop with a separate toilet and sink, where the water for the shop is supplied by a single domestic dwelling; this would not be considered a water system under the DWPA.

Q. Must the water used in the slaughtering process be potable?

A. Yes. This refers to the water actually used in the process, not the source water from which it is drawn. Secondary treatment of water that is used (with bleach for example) may be all that is required if there are ongoing concerns with the source water.

Q. Could the standards set out in Schedule A to the Drinking Water Protection Regulation be used as the standard for measuring the potability of water used in the slaughtering process?

A. Yes, as could the standards set out in the Meat Inspection Regulation Class D and E Licensing Policy and Procedures Manual.

Obligations of the Water Suppliers of Drinking Water Treatment Systems that have Point of Use/Point of Entry Devices

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Ministry of Health

1. Objective

To clarify the obligation of water suppliers operating decentralized drinking water treatment systems.

2. Background

The *Drinking Water Protection Act* (DWPA) contains requirements for drinking water suppliers to ensure the water supplied to their users is potable and meets any additional requirements established by the Drinking Water Protection Regulation (DWPR) and the water supply system's operating permit. The DWPR sets out requirements for drinking water quality — including treatment, construction and operation of water systems, monitoring, reporting, and public notification should health hazards arise.

The DWPR includes options for small water systems (systems serving under 500 people in a 24 hour period) to provide potable water via a decentralized system that utilizes Point-of-Use (POU) or Point-of-Entry (POE) devices.[1]

Section 3.1(a) of the DWPR contains the specific amendment pertaining to POU/POE devices:

The following are exempt from section 6 of the [Drinking Water Protection] Act:

(a) a small water system, if:

[1] POE provides each service user with a device that treats all the water entering the property, house or building (ensures that all of the water entering the service user's system is treated). POU provides a device for individual locations within the building where potable water is required (e.g., a single outlet or faucet such as a kitchen sink).

(i) each recipient of the water from the small system has a point of entry or point of use treatment system that makes the water potable.

(ii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that ae permanent, distinct and easily recognized.[2]

3. Water Supplier Obligations

Section 3.1(a)(i) of the DWPR exempts small systems with POU/POE devices from section 6 of the DWPA, but it does not exempt suppliers from providing potable water to end users. This provision provides an alternative to the construction and operation of a centralized treatment facility by permitting decentralized treatment for individual homes. The effect is to shift the requirement to provide potable water from one section of the DWPA to another section under the DWPR.

The shifting of the requirement to provide potable water does not exempt the water supplier from other obligations under the DWPA or DWPR. The provision of potable water to the end user is not a one-time obligation. The provision of potable water is an on-going obligation that water suppliers are expected to meet by monitoring water quality, maintaining systems and dealing with operational failures. There is nothing in the DWPA or DWPR to suggest that a water supplier is absolved of these ongoing responsibilities.

Section 4(1) of the DWPR provides that all water supply systems are prescribed for the purposes of sections 7, 8, 10, 11, and 22(1)(b) of the DWPA. These sections outline obligations with respect to Construction Permits, Operating Permits, Emergency Response and Contingency Plans, Water Monitoring Requirements and Assessment Response Plans. In the case of water supply systems using POU/POE devices, the water monitoring requirements under section 11(1) of the DWPA are limited to water that has been treated by the POU/POE device.

POU/POE devices are not excluded from definition of a domestic water system due to section 3(c) of the DWPR, which refers to "building system." The definition of a "building system' refers to systems to which the B.C. Plumbing Code applies that receive water from a water supply system operating under a valid permit under the DWPA. The B.C. Plumbing code (now contained within the B.C. Building Code as Book II (Plumbing Systems)) makes no provision for POU/POE systems; rather, it sets out the requirements for plumbing for distributing potable water within homes (e.g., pipes, taps and toilettes). POU/POE systems are considered to be part of the water supply system and requirements for their construction and operation are regulated by the provisions of the DWPA and DWPR.

The exemption from section 6(b) of the DWPA does not apply to the regulations made under the DWPA or to all of the requirements on the operating permit of a water supplier. The only effect of section 3.1(a)(i) of the DWPR is to exempt the water in the distribution system from the source up to

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[2] Section 6 (DWPA):
Subject to the regulations, a water supplier must provide, to the users served by its water supply system, drinking water from the water supply system that
(a) is potable water, and
(b) meets any additional requirements established by the regulations or by its operating permit.

the point of connection with a POU/POE device from meeting the requirement of being potable and meeting any additional requirements established by the regulations or by the system's operating permit related to water quality. This exemption no longer applies once the water enters the treatment device as section 3.1(a)(i) states specifically that the exemption is contingent on there being a POU/POE device that "makes the water potable."

Guidelines on Evaluating and Mitigating Lead in Drinking Water Supplies, Schools, Child Care Facilities and Other Buildings

Version 1.1 / First Published April 2019

Ministry of Health

Table of Contents

1. Purpose and Scope

This document provides guidance to drinking water officers on the roles and responsibilities of stakeholders in the reduction of lead in drinking water at the tap. This document also provides guidance and tools for:

- Screening communities to identify those with increased risk of corrosive water;
- assessing typical lead concentrations in drinking water at the tap in communities;
- screening and assessing typical lead concentrations of water in schools, child care facilities and other buildings; and
- possible mitigation strategies and examples of communication material.

This document does not address collecting or assessing human exposure data such as blood lead reporting, or assessment of broader human lead exposure beyond drinking water. It also focusses on lead corrosion only, and does not discuss other corrosion products including copper and iron, that can cause significant aesthetic and economic impacts if unchecked.

2. Intro/Background

Ingestion of lead can be hazardous to human health, especially for young children and infants, as they absorb lead more easily than adults and are more susceptible to its harmful effects. Even low level exposure may harm the intellectual development, behaviour, size and hearing of infants and children. Lead can also cross the placenta during pregnancy to affect the unborn child, and can be released into breast milk.

The degree of harm from lead exposure depends on a number of factors including the frequency, duration, and dose of the exposure(s) and individual susceptibility factors (e.g., age, previous exposure history, nutrition, and health). The degree of harm also depends on an individual's total exposure to lead from all sources in the environment – air, soil, dust, food, and water. Common sources of lead exposure for children are chips and particles of deteriorating lead paint found in house dust and soil. While drinking water is the second largest source of exposure when lead levels in water are above 5 µg/L, there is currently no evidence that drinking water in BC is a significant source of dietary lead intake. It is important to note that people often consume water from numerous sources throughout the day (i.e. workplaces, schools, homes, restaurants), thereby the lead concentration in water from any one source may only represent a small portion of total daily intake. Nonetheless, it is important to minimize lead intake from all sources as much as possible, and where Drinking Water Officers consider drinking water is at risk of having elevated concentrations of lead, take steps to reduce lead in drinking water to levels as low as is reasonably achievable.

Under the *Drinking Water Protection Act* (DWPA), drinking water supply systems in BC are responsible for monitoring water they deliver to verify it is within acceptable limits for lead and other metals. The Guidelines for Canadian Drinking Water Quality (GCDWQ) suggest:

The maximum acceptable concentration (MAC) for total lead in drinking water is 0.005 mg/L (5 µg/L), based on a sample of water taken at the tap and using the appropriate protocol for the type of building being sampled. Every effort should be made to maintain lead levels in drinking water as low as reasonably achievable (or ALARA).
Note: Five micrograms per litre (µg/L) is also sometimes expressed as 5 parts per billion (ppb).

Most drinking water supply systems in BC deliver water that has levels of lead well below 5 µg/L. Lead is usually not found in drinking water when it leaves the treatment plant. Instead lead tends to leach out of pipes and fixtures in buildings or homes, or service lines connecting homes to water mains[1]. The extent of leaching depends on the nature of the plumbing materials used, the corrosiveness of the water (i.e. the extent to which the water can cause a chemical reaction that will cause a deterioration in the material used in the pipes), and the length of time that the water is stagnant in the plumbing. The longer water remains in contact with leaded plumbing, the more opportunity there is for lead to leach into the water. As a result, older facilities with intermittent water use patterns and older plumbing materials, such as schools, child care facilities and office buildings, may have elevated levels of lead in their drinking water. The water sits in the pipes of these facilities for long periods (overnight, weekends, and holidays), which

> Under the National Plumbing Code (NPC), all fittings must comply with the American Society of Mechanical Engineers (ASME) 112.18.1 / Canadian Standards Association (CSA) B125.1 standard for plumbing supply fittings. In 2012, these standards revised the requirement for "lead-free" components from 8% down to 0.25% lead as a weighted average with respect to the wetted surfaces of pipes, pipe fittings, plumbing fittings, and fixtures. This means that fixtures produced as late as 2012 could legally contain 8% lead – enough to cause an exceedance of the MAC on stagnant ("first flush") water samples.
>
> **Anecdote:** A city in Northern BC was conducting a survey of lead content in the drinking water in their various facilities. In one new building, built in 2013, the lunchroom tap surprisingly failed its first-flush sample. The City responded by changing the tap to a newer model with an NSF certification. The retest for lead was lower, but again exceeded the MAC. Only when the shutoff valve was also replaced did the sink pass the first-flush lead test.

[1] Service lines connect individual buildings to the water supply system distribution main. Service line ownership is shared. The utility typically owns the portion up to the property line and the home or building owner owns the portion on their property. Before the 1960s, service lines were commonly made of lead in some communities.

allows the leaching of lead to occur. If the water entering the building is corrosive, the lead will leach more quickly. Corrosive water may sometimes be described as "acidic" or "aggressive."

Since 1989, the BC Building Code has restricted the lead content in components in the construction of potable water lines and fixtures. This restriction reduces the amount of lead available to react with corrosive water and lowers the risk of lead leaching into drinking water supplies. As a result, in buildings constructed on or before that time, there may be a greater probability of finding elevated lead levels in the water from service plumbing, especially if the corrosiveness of the water entering the building and the water use patterns in the building are conducive to lead leaching.

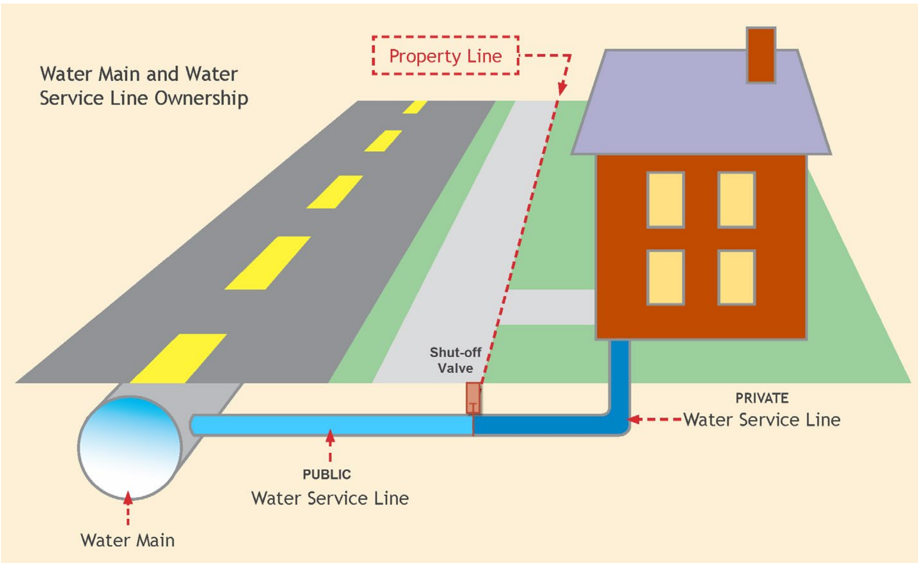
The quality and characteristics of the delivered water not only impact lead solubility and lead speciation (i.e., the chemical and mineral form of lead), they also impact the behaviour of pipe scales (i.e., a coating that forms inside of pipes) that contain lead. Physical disturbances or changes in water quality and flow velocity can cause lead particles found within pipe scales to become dislodged and released into drinking water. These lead particles can cause intermittent spikes in the lead concentrations found in drinking water. Screened aerators on kitchen taps may trap these particles and should be periodically cleaned.

3. Roles and Responsibilities

The question of responsibility for lead in drinking water is unique in that water delivered by water suppliers may be potable at the point of delivery, but may have characteristics that make it susceptible to leaching lead and other metals from pipes, solder and fixtures after it is delivered to the property. This may result in significant portions of the community being affected or localized problem areas affecting some buildings or neighborhoods in a community but not others. The problems can also be localized within buildings, affecting only some taps depending on water use patterns, plumbing configurations and materials, and differences in plumbing fixtures.

The issue of who is responsible for lead in drinking water is complex given that lead in drinking water may come from the pipes and fixtures contained within private properties, or services lines. Water suppliers are not responsible for the maintenance or replacement of plumbing beyond service lines and other fixtures upstream of the curb stop where water is delivered, after which it becomes the responsibility of the property owner (see Figure 1). So while the water supplier may own the water supply system, property owners own the pipes and plumbing on their property. This shared ownership also means a shared responsibility to mitigate excessive lead concentrations found at the tap. Property owners are responsible for the condition of their building's plumbing and for taking any necessary remedial action to minimize lead exposure deriving from the plumbing and fixtures in their property, such as replacing leaded plumbing and fixtures, installing treatment devices to remove lead, or implementing a flushing program. Where the characteristics of the water (i.e., the corrosiveness) are expected to significantly contribute to leaching, the water supplier has the responsibility to take reasonable steps to mitigate likelihood of a hazard being associated with the water being delivered to the end user.

Figure 1: Water service line responsibilities. Modified from: https://www.alexandriava.gov/uploadedImages/health/info/AlexandriaWaterService.jpg



Several statutes play a role in ensuring that drinking water does not pose a health risk for consumers. These include: the *Drinking Water Protection Act,* the *BC Plumbing and Building Code,* the *Public Health Act,* the *School Act* and the *Community Care and Assisted Living Act.* As these statutes apply concurrently, the overlap indicates a shared responsibility of all parties involved.

- The *Drinking Water Protection Act:*
  - Requires water suppliers to deliver potable water to customers. While the DWPA may not directly compel water suppliers to ensure potability beyond the point where it is delivered to the consumer, health authorities may impose conditions on permits that require water suppliers to take actions to reduce the likelihood that the water they deliver contributes to a drinking water health hazard.
- The BC Building Code:
  - Speaks to plumbing standards within buildings. However, this statute is only applied at the time of construction and many buildings constructed prior to 1989 can be assumed to be at an increased risk for lead leaching from plumbing under certain water conditions.
- The *School Act* and the *Community Care and Assisted Living Act* (Child Care Licensing Regulation):
  - These Acts protect children in schools and in licensed child care facilities. Medical Health Officers may act as School Health Officers under the *School Act* and may conduct inspections, and where necessary impose requirements for the

construction and/or operation of the facilities. Similarly, Licensing Officers (who are delegates of the Medical Health Officer) inspect child care facilities, issue licences to operators of child care facilities, and where necessary impose requirements for the health, safety and well-being of children who attend child care, the physical premises and/or operation of the facilities. Similarly, where there is reason to believe there are children at risk due to lead exposure in residential care facilities, action may also be warranted to assess and mitigate these situations.

- The *Public Health Act:*
    - Requires landlords to provide potable water to tenants. The *Public Health Act* may also be used as a legal tool where a lack of action by water suppliers, building owners, or others may contribute to a health hazard.

Successful reduction of lead in tap water depends on a multi-barrier approach with participation and actions of all parties as it is difficult to achieve lead reduction through centralized mitigation alone. The following table lays out high level expectations of roles and responsibilities of each stakeholder in this process. More specific roles and responsibilities related to each stakeholder are discussed below.

Table 1. Stakeholder Responsibility for Lead in Drinking Water

Responsibility	***Responsible Stakeholders***		
	Drinking Water Supply systems	***Schools/Child Care Facilities***	***Private Buildings***
Screening & Prioritizing	*HA* + Water supplier*	*HA + SD + IS + CF*	*Building owner*
Planning to Test	*HA + Water supplier*	*HA + SD + IS + CF*	*Building owner*
Testing	*Water supplier* *Building owner***	*SD + IS + CF*	*Building owner*
Interpretation	*HA*	*HA*	*HA upon request*
Planning to Mitigate	*Water supplier + HA review & permitting*	*SD + IS + CF + HA review*	*Building owner*
Implementing Mitigation	*Water supplier*	*SD + IS +CF*	*Building owner*
Verification of Mitigation	*Water supplier + HA review*	*SD +IS +CF + HA review*	*Building owner*
Communication/ Education	*Water Supplier (system specific)* *HA (community level)*	*SD + IS +CF (facility specific)* *HA (community level)*	*Building owner (building specific)* *HA (community level)*

** HA- Health Authorities; SD – School Districts; IS – Independent Schools; CF – Care Facilities*
***As lead testing is done at the tap, building owners are key participants in testing programs*

3.a Roles and Responsibilities of Health Authorities

The high level roles of drinking water officers (DWO), medical health officers (MHO), environmental health officers (EHO), public health engineers (PHE) and licensing officers (LO) are to:

- Screen communities to identify those likely to have lead issues, and for those identified;
- work with water suppliers to determine if elevated lead concentrations in community tap water pose an unacceptable risk to end users, and where there is an unacceptable risk; and
- advocate for, or mandate the evaluation and mitigation of lead risks by all stakeholders through appropriate and reasonably achievable mitigation measures.

In communities likely to have lead issues due to corrosion concerns, PHEs and DWOs may need to determine with water suppliers whether concerns are best addressed through centralized mitigation measures at the water supply (e.g., pH and alkalinity adjustment or the addition of corrosion inhibitors at treatment), decentralized measures by users (e.g., flushing, point-of-use treatment devices, leaded plumbing replacement, etc.), or by a combination of both.

The role of the health authority in evaluating and mitigating the risk of lead in a community should include actively working with all stakeholders to ensure they are aware of risks and of the actions they should take to evaluate and reduce risks. Where necessary, health authorities may also need to take progressive enforcement actions with regulated facilities. The priority of any enforcement action should be directed towards large community water systems where the corrosiveness of the water supply contributes to excessive lead levels known to exist in public and private buildings.

As infants and children are more susceptible to health effects from lead, schools and care facilities where children may be exposed to elevated lead concentrations in drinking water should be the focus of health authority efforts. Health authorities should include evaluation of risks for lead in drinking water as part of their engagement with schools and child care facilities and re-assess the frequency of monitoring in areas where lead has been found to be a problem. Drinking water officers should work with licensing officers to introduce testing for lead and ensure appropriate mitigation measures are in place as part of inspections and licensing requirements for child care facilities.

Details of specific roles and responsibilities of health authorities in relation to stakeholders are outlined below. Technical information on assessing risks and sampling are in the appendices of this document.

3.b Roles and Responsibilities of Water Suppliers

The *Drinking Water Protection Act* requires water suppliers to deliver potable water to users, but does not directly compel water suppliers to ensure potability after delivery to customers. However, where it is probable that the nature of the water is likely to pose a potential health risk to users after delivery, the DWO may be justified in requiring the water supplier, through conditions on the operating permit, to take steps to assess whether corrosivity of the water, and/or resulting water lead concentrations in buildings presents a risk to the population, and if necessary, to take steps to reduce risks.

To assess corrosion risks in community water supplies, water suppliers, in collaboration with the local health authority, should develop plans to conduct surveys, tests, inventories or studies to:

- Screen water for indicators of corrosivity;
- survey the prevalence of lead service lines in communities;
- survey the prevalence of buildings with plumbing and fixtures with elevated lead content; and
- implement testing, including surveys of representative samples taken at consumers' taps to evaluate impact of the corrosivity of the water supply in the community.

Results of assessment programs should be reviewed with health authorities. Where the corrosive nature of water quality is determined to contribute to lead exposure from interaction with plumbing at the community level, building owners and the water supplier may need to take steps to reduce risks as described later in the document. For water suppliers, these risk mitigation steps may be done informally through agreement, or may be formalized by the health authority through conditions on its operating permit.

Table 2. Health authority and water supplier roles

Health Authority	Water Supplier
• Liaise with water supplier and advise them as necessary to conduct community risk assessment for corrosion and typical lead exposure. • If necessary, in consultation with the Water Supplier, place conditions on the operating permit, to ensure that an adequate assessment of population health risks from lead in drinking water is undertaken. • Provide direction and advice to water supplier on sampling protocols.	• Liaise with health authority on the necessity to conduct a community risk assessment for corrosion. • Design and implement a residential testing strategy to evaluate lead exposure burden from drinking water in the community, if necessary. • Conduct sampling, tests and surveys in the community. • Report any potential health hazards associated with water supply to end

Health Authority	Water Supplier
• Interpret surveys and studies to advise water suppliers on the risks that the water supply system poses. • Advise water suppliers on public education messaging and provide information on risks. • Follow up on complaints or concerns regarding potential health hazards in the community. • Provide progressive enforcement to mitigate health hazards under the *Public Health Act* and/or DWPA.	users of water supplies related to the corrosivity of water. Provide messaging and information to the public regarding what is being done to mitigate hazards by the water supplier, and what the public can do to protect itself. • Minimize leaching impacts through planning and implementing corrosion control programs.

3.c Roles and Responsibilities of School Districts and Independent Schools

Schools districts and independent schools are responsible for operating schools in a manner that does not adversely affect the health of their students. School districts and independent schools should work with heath authorities to establish a plan to identify where lead risks might occur, as well as to mitigate any identified risks. Details on developing a plan are found in Section 4.

Table 3: Health authority and water supplier roles relative roles of school districts, independent schools, health authorities, and the provincial government in determining risk and actions that should be taken to identify and reduce lead risks in schools.

School Districts / Independent Schools	Health Authority	Ministry of Health and Ministry of Education and Child Care
• Inventory and characterize schools and identify whether they are on a community water supply or school district operated water supply. • Plan and carry out screening/testing programs in consultation with the health authority.	• Work with water suppliers to identify where schools are at increased risk. • Assist school officials to develop plans to evaluate lead risks in schools. Provide advice on sampling protocols.	• Provide policy and guideline direction. • The Minister of Health under the School Act can require the school medical officer to conduct inspections of schools and can require the MHO to provide a report.

School Districts / Independent Schools	Health Authority	Ministry of Health and Ministry of Education and Child Care
• Plan and implement lead mitigation programs for school buildings. • Communicate risks to parents and students. • Send annual reminders to school maintenance staff regarding flushing or other mitigation measures that might be necessary. • Maintain records and report findings to HAs including a summary of the mitigation strategy that identifies flushing schedules and the locations being flushed.	• Interpret results and provide information on mitigation options. • Review the effectiveness of mitigation options. • Advise school officials on risk messaging for the schools. • Engage with schools to verify lead mitigation programs are adhered to, and follow up on complaints or concerns. • Provide progressive enforcement where necessary if health hazard remains unabated.	

3.d Roles and Responsibilities of Licensed Child Care Facilities

Licensed child care facilities are responsible for operating in a manner that will promote the health, safety and dignity of persons in care. Licensed child care facilities should work with heath authorities to evaluate lead risks in their facility, as well as mitigation planning to identify and mitigate the risks.

Table 4: Relative roles of licensed child care facilities and health authorities in determining the actions that should be taken to identify and reduce the risks of lead in drinking water.

Child Care Facilities	Health Authority	Ministry of Health and Director of Licensing
• Plan and carry out screening/testing programs in consultation with health authority where there is a risk of lead in drinking water. • Plan and implement lead mitigation programs for their facilities. • Communicate risks and mitigation steps to parents. May consider sharing with parents new to a facility upon child enrollment, and include in parents handbook. • Send annual reminders to staff regarding flushing, alternate sources of water, or other mitigation measures necessary.	• Provide education materials relating to lead in drinking water. Work with water suppliers to identify where conditions might exist that put facilities at increased risk. • Assist affected facilities to develop plans to evaluate lead risks. Provide advice on sampling protocols. Interpret results and provide information on mitigation options. • Review the effectiveness of mitigation options. • Work with child care facilities to develop messaging to users and their families on lead risks in the child care facilities. • Include lead education in inspections. Verify lead mitigation programs are adhered to and effective. Follow up on complaints or concerns regarding lead in child care facilities. • Provide progressive enforcement where necessary if health hazard remains unabated.	• Provide policy direction • Develop educational materials on lead in drinking water. • Recommend or require testing for lead in high risk child care facilities.

3.e Roles and Responsibilities of the Owners of Homes and Other Buildings

The BC Building Code provides plumbing standards within buildings; however this statute is only applied at the time of construction. As a result, it can be assumed that most homes and other buildings constructed or altered prior to the 1989 revisions of the BC Building Code have a higher risk of lead leaching into drinking water from their plumbing. Under the *Public Health Act*, the owners of these properties are responsible for ensuring that the plumbing does not create a drinking water health hazard for those who consume the water.

While there are no specific regulations that require lead to be tested and mitigated in individual homes and buildings, owners are required to provide tenants with potable water that is fit to drink without further treatment. Owners are responsible for testing their own water and taking mitigation steps (e.g. flushing, service line/plumbing fixture replacement), and health authorities may provide reference information on the best practices for doing so.

Table 5: Relative roles of building owners and health authorities in determining risk and actions that should be taken to identify and reduce the risks of lead in drinking water.

Building/Home Owners	Health Authority
• Provide potable water to rental units intended to be living accommodations. • Learn about the risks of corrosion from communications from the water supplier (system specific info) and/or the health authority (general info). • Plan and carry out testing on building water. • Provide information and communications to tenants and/or employees. • Develop and implement a mitigation strategy for lead in their buildings.	• Work with water suppliers to ensure that risks are communicated to users. • Provide information to the public on the risks of lead in drinking water, lead testing, the interpretation of test results, and mitigation options.

3.f Role of Provincial Government

Ministry of Health is the main agency for provincial drinking water policy development. The Ministry will work with Health Canada, BC's health authorities, the Ministry of Education and Childcare and other stakeholders to provide advice and policy on best practices for assessing lead risks from drinking water, to develop educational material, and to advocate for the reduction of lead exposure to the public from drinking water.

4. Assessment and Mitigation of Lead Risks in Drinking Water

4.a Water Supply System/Community Level

Evaluate and Prioritize

Screening water supply systems for high risk of corrosion:
Health authorities should work with water suppliers to screen water supply systems for characteristics that suggest potential corrosion risks, and/or the prevalence of buildings at risk. These systems may be prioritized for further investigation of the potential for unacceptable lead concentrations in water for consumers.

The chemistry of corrosivity is complex, typically involving many different factors (chemical, physical or microbiological), which can make it challenging to predict how it will impact leaching when it comes into contact with leaded components.

Many indexes such as the Langelier Saturation Index (LSI), the Ryzner Index, the Aggressiveness Index, the Momentary Excess and the Calcium Carbonate Precipitation Potential, were developed to assess the calcium carbonate–bicarbonate equilibrium, and were historically used as an indicator of the corrosivity of water. However, Health Canada's *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* and Ontario's *Guidance Document for Preparing Corrosion Control Plans for Drinking Water Systems*, report significant empirical evidence contradicting the presumed connection between corrosion and the most common of the corrosion indices, the Langelier Index. The American Water Works Association Research Foundation recommends that the use of corrosion indices for corrosion control practices be abandoned. Because of these limitations, these authorities recommend lead and/or other metal sampling at the tap as the most reliable indicator of corrosive water. This is critical, because corrosivity of the water is under control of the water supplier, whereas the lead content in the plumbing is largely under control of the building/home owner. Because the most reliable indicator of corrosive water is actual corrosion as detected in sampling at the tap, water suppliers should not conclude that their water is not corrosive until that is confirmed by sampling inside buildings and homes.

This being said, the chemistry of the water in water supply systems can be proactively evaluated for risk factors that indicate a higher probability that it will be corrosive. Water supplies with one or more of the following water chemistry characteristics should be *prioritized* for further evaluation of potential lead risks from corrosion of plumbing in the community:

- Lower pH (<7)
- Low alkalinity (<30 mg/L)

- Low hardness, i.e., "soft water" (<60 mg/L as calcium carbonate $CaCO_3$)[2]

Other drinking water quality parameters that might impact corrosivity may also be considered such as: higher temperatures, fluctuations in free chlorine residual, chloramines, chloride, sulphate, natural organic matter (NOM), oxidation-reduction potential (ORP), and chloride-sulphate mass ratio (CSMR) (see Table 6).

Table 6. Water Quality Factors Affecting Corrosion.

Factor	**Effect**
pH	Low pH causes iron, lead, and copper corrode rapidly.
Alkalinity and Dissolved Inorganic Carbonate (DIC)	Neutralize strong acids and provide buffering capacity against a pH drop. Affect many reactions in corrosion chemistry.
Hardness	In combination with alkalinity, promote the formation of a protective passivating film.
Disinfectant Residual	Gaseous chlorine lowers pH. Higher chlorine residuals (2 mg/L) may cause protective lead scales.
Dissolved Oxygen	Increases corrosion of copper; effect on lead less certain.
Oxidation Reduction Potential, Redox Potential (ORP, Eh)	High ORP and high pH promote protective lead scales.
Ammonia	Interfere with the formation of passivating films. Oxidation of ammonia (nitrification) lowers alkalinity and pH, increasing corrosion.
Chloride and Sulphate	Chloride (Cl^-) and sulphate (SO_4^{2-}) cause dissolved metals to remain soluble. Increase the salinity (TDS) and electrical conductivity of water. High chloride-to-sulphate-mass ratios (CSMRs) increase corrosion rates for lead solder connected to copper pipe.
Salinity (TDS)	The higher the TDS, the higher the ionic strength and electrical conductivity.
Natural Colour and Organic Matter	May form a protective film and reduce corrosion. May react with the corrosion products to increase corrosion. Food for microorganisms growing in biofilms in the pipes.

[2] According to Health Canada's Guideline Technical Document for Hardness, soft water can lead to corrosion of pipes. The degree to which this occurs is also a function of pH, alkalinity and dissolved oxygen content. According to the Water Research Centre, in water that is soft, corrosion occurs because of the lack of dissolved cations, such as calcium or magnesium in the water. In scale forming water (hard water), a precipitate or coating of calcium or magnesium carbonate forms on the inside of the piping called scale. This scale coating can inhibit the corrosion of the pipe by acting as a barrier, but it can also clog the pipe (i.e., incrustation). Health Canada recommends hardness levels between 80 and 100 mg/L (as $CaCO_3$), which are generally considered to provide an acceptable balance between corrosion and incrustation from scale. (Source: http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/water-hardness-durete-eau/index-eng.php)

Factor	**Effect**
Corrosion Indices	Langelier Saturation Index (LSI) measures calcium carbonate ($CaCO_3$) scale-forming tendency. LSI does not correlate well with actual corrosion, so LSI is less reliable than sampling at taps for corrosion products.
Temperature	For every 10°C rise in temperature, chemical reaction rates, including corrosion, typically tend to double.
Flow velocity	High velocity: increases the supply of dissolved oxygen; erodes pipe walls if abrasive suspended solids are present. Zero velocity: Stagnation may cause pitting and tuberculation, especially in iron pipes, as well as promoting biological growth
Microbiological	Microbiologically induced corrosion (MIC) ≡ localised high corrosion zones (pinholes) sheltered inside biofilms.
Orthophosphate	Corrosion inhibitor added to water to form a passivating film on the pipe surface.

Based on: ON (2009) Guidance Document for Preparing Corrosion Control Plans for Drinking Water Systems. Section 2.3 Water Quality Factors Affecting Corrosion.

To confirm whether corrosion is an issue for a community's water supply system, the most reliable approach is sampling surveys of lead at consumers' taps as described in Health Canada's *Guideline Technical Document on Corrosion Control*, and Appendix C of this document.

Health Authorities may also consider data from lead testing programs in schools, child care facilities or other buildings, which may serve as sentinel information for a community, and help flag the need to further investigate.

Where the initial screening of water chemistry (pH, alkalinity and softness) indicates increased risk factors for corrosive water, a survey of the prevalence of service connections and of the typical age and condition of buildings in the community can also help determine the magnitude of risk. This information can also be used in later steps to assist in determining where to focus lead sampling program from consumers' taps. Communities where a high proportion of buildings were constructed prior to 1989, that have not upgraded their plumbing to lower lead content are likely to be at the highest risk of having lead in their plumbing.

Large communities with older housing stock and buildings as well as a water supply with corrosive characteristics should be targeted for further sampling first. Additionally, communities where there has been a change in water source or water chemistry or treatment processes should also be flagged for testing.

Testing and Evaluating Results

Those drinking water systems identified as being at the highest risk by the screening step should develop and implement lead sampling programs conducted at consumers' taps. The objectives of these sampling programs are to:

- Determine whether community level lead mitigation measures are warranted to reduce corrosion;
- establish base lines to help evaluate the effectiveness of any mitigation measures that are adopted; and
- evaluate if the water typically consumed by customers exceeds the maximum acceptable concentration (MAC) level for lead set out in the *Guidelines for Canadian Drinking Water Quality*.

High level descriptions of sampling protocols for corrosion risks, as well as for determining whether concentrations of lead typically found in the community's water meets the *Guidelines for Canadian Drinking Water Quality* are outlined in Appendix C.

Mitigation

Both centralized and decentralized mitigation measures can be taken to address concerns from lead at user's taps resulting from corrosive water. The most appropriate method will depend on a number of factors. In areas where the nature of the water supply itself is reasonably believed to contribute to a health risk from lead at users' taps, water suppliers should work with health authorities to determine feasible strategies for mitigating lead risk. Reducing risk will usually involve a combination of communicating how consumers can reduce their own risks as well as planning long term corrosion control strategies as follows:

1. Communicate the results of testing programs to consumers and inform them of the appropriate measures that they can take to reduce their exposure to lead. Corrective measures that consumers can take could include any or a combination of the following:
    - flushing the building plumbing system;
    - replacing their portion of the lead service line (if applicable);
    - replacing brass fittings or in-line devices (pre-2012);
    - using drinking water treatment devices certified to reduce lead; and
    - using an alternate water supply for drinking water or food preparation.[3]
2. Implement appropriate corrective measures to control corrosion in the drinking water supply system. Results of sampling should be used to help determine the best corrective measures for the system, which may include any or a combination of the following:
    - replacing lead service lines;

[3] Exposure through bathing and other household purposes is not a health hazard.

- adjusting drinking water pH and alkalinity;
- adding corrosion inhibitors;
- replacing brass fittings or in-line devices containing lead;
- carrying out *ad hoc* or unidirectional flushing, swabbing, or pigging of water mains to reduce accumulated sediment and biofilms; and
- maintaining a disinfectant residual to avoid reducing conditions and to control biofilms.

Corrosion control programs have been shown to significantly reduce leaching, but may not eliminate it. Careful consideration should be given to the potential effectiveness, potential unintended effects on water, public acceptance, and the cost of mitigation measures and programs to determine the most appropriate course of action to follow. Bench-scale and pilot testing should be carried out for any proposed change to distribution water chemistry. No matter what type of mitigation measures are employed, an evaluation of the effectiveness of the mitigation measures should be done after they are implemented. Community level assessment and mitigation steps are outlined in the flow chart set out in Appendix A.

4.b Individual Buildings

Evaluate and Prioritize

Owners and operators of buildings (particularly school boards and child care facilities), particularly those on water systems identified to be at risk from corrosive water, should evaluate their buildings for plumbing components that can leach lead into drinking water. The complexity of the evaluation may vary depending on whether the building in question is a single family home, a multi-family dwelling, an industrial/office building, a school, or a child care facility; however the overlying evaluation principles will be the same. [4]
Evaluations should include:

- Developing a plumbing profile for the building that identifies plumbing components such as service lines, pipes, solder or fixtures that contain lead, and inventories drinking fountains and other points of consumption that might contain lead or brass;
- identifying potential problems and health hazards to users through screening tests and/or more comprehensive testing;

[4] For the purpose of this document:
"buildings" includes private residences and private schools served by a community water system;and
"schools" and "facilities" mean those that are connected to an approved water supplier and are not themselves a water supplier under the DWPA. Schools and other facilities that are their own water supplier may need to also take on roles of water suppliers in this document.

- maintain records and communicate plans and results with stakeholders; and
- taking routine, interim and permanent mitigation measures.

An example of school and child care facility assessment and mitigation steps is outlined in the flow chart set out in Appendix B. The following publication from the Province of Ontario (2009) is an excellent reference for evaluating risks from their plumbing and identifying options to remedy any excess lead in facilities: *A Manual for Operators of Schools, Private Schools and Day Nurseries with Excess Lead in their Drinking Water: A resource guide on how to locate the source and remedy the problem.*

Testing and Evaluating Results

For schools, licensed child care facilities and other buildings that have plumbing containing lead components, or where there is a lack of information about the plumbing that is in place, screening tests and/or more comprehensive testing programs should be planned and implemented in consultation with regional health authorities.

When testing water, it is important to determine the sampling objective, so that the appropriate sampling protocol is used. Sampling protocols differ depending on the desired objective: e.g. whether it is screening of schools for potential lead problems, identifying fixtures/sources of lead for replacement or to estimate health risk from exposure to lead. In order to provide meaningful results, multiple samples are needed. Health authorities can provide advice on what sampling method is appropriate and can help evaluate and interpret the results. Specific results of lead concentrations in sampled water and the method of sampling used should be included in reports to aid in decision making.

A high level description of how, when and where to test buildings is outlined in Appendix C. Health authorities can provide advice on how it should be applied to individual facilities, and can help evaluate and interpret the results against the guidelines.

Subsequent to initial screening and evaluation, schools and child care facilities should develop a plan for long term routine lead monitoring. Annual testing would be ideal, however risk-based decisions on frequency may be warranted from a resource perspective. In general, higher risk facilities where lead has been found as a problem may require more frequent testing than facilities where lead is not known to be an issue or risk. In BC, the Ministry of Education and Child Care has developed policies for schools districts and independent school authorities regarding expectations for lead sampling, reporting and mitigation. These policies (see links below) require regular screening for lead in all schools. This guidance document serves as a guide on how to meet this testing requirement.

BC Ministry of Education (Sept 26, 2016) *Testing Lead Content in Drinking Water of School Facilities*

BC Ministry of Education (January 1, 2017) *Testing Lead Content in Drinking Water of Independent School Facilities*

Mitigation

In buildings where the risk of exposure to lead in drinking water is determined to be unacceptable, mitigation measures should be taken. Owners should communicate results of evaluations, and identify what consumers can do to reduce exposure to lead in the short term, and what building owners can do to reduce exposure in the long term. In situations where the drinking water is at risk of elevated lead and testing to establish water quality has not yet been done, it would be prudent to err on the side of caution and adopt interim measures (flushing, bottled water) to reduce the risks associated with the presence of lead in drinking water while awaiting assessment results.

Options for reducing lead in buildings may include short and long term solutions such as:

- Educating the occupants of the building (e.g., teachers, child care providers, students) and other interested parties (e.g., parents, occupational health and safety committees) on the sampling results and the interim and long-term corrective measures that are being undertaken;
- flushing all water taps used for drinking water or food preparation at the start of each day or after periods of stagnation;
- providing an alternative water supply such as bottled water;
- installing point-of-use (POU) filtration units designed specifically to remove lead;
- installing corrosion control equipment at the point-of-entry (POE) into the building to adjust pH to reduce the likelihood of lead leaching into water (however complexity of maintenance may pose challenges in many situations);
- where lead sample results identify particulate vs dissolved lead, this may help decide whether it is better solved by filtration than conditioning for corrosion control;
- removing drinking water taps from service that contain unacceptable levels of lead;
- posting signs that identify "designated drinking water taps" (DDWTs) and "Do not drink" taps (non-DDWTs);
- replacing lead containing outlets, fixtures, fountains, pipes and fittings with low-lead alternatives;
- replacing old water lines and solder that might contain lead;
- working collaboratively with the water supplier to ensure that the water delivered to the building is not corrosive.

Evaluation of the effectiveness of mitigation measures should be done after they have been implemented, and at regular time intervals afterwards. No matter what type of mitigation measures are employed, re-sampling should be done to verify the effectiveness of the mitigation measures and to ensure that the concentration of lead falls below the GCDWQ maximum acceptable concentration.

Communication

Users of drinking water systems and buildings need to know the risks that exist, if any, and what is being done to mitigate the risks. Users should be advised regularly on lead risks associated with their drinking water and the need for regular testing, and mitigation measures. Communication should be clear and transparent to avoid confusion and ensure the goals, message and actions are understood.
Simple handouts for the public and other stakeholders such as Health Files, as well as those specific to school testing, and daycares may be helpful in communicating key messages.

Table 7: Communication Expectations

Who and What?
Health Authorities
• General messaging about lead and health risks to the public • General technical medical questions • Audience: General public, media, water suppliers, school boards; operators of child care facilities
Water Suppliers
• What is known about water corrosivity • What the drinking water supply system is doing about it • What users need to do to protect themselves • Audience: users of the water supply system
School Boards, Child Care Facilities and Other Building Owners
• What assessments are being done • Results of the assessments • Mitigation measures being taken • Audience: building users, parents of children and students in care
How?
• Written and media communication: Targeted mail outs, flyers in water bills, media releases, annual reports, newsletters, e-mails, websites and social media • Face to face conversations: interviews, public events • Signage: Warning signs on taps. Where flushing is the mitigation measure of choice, signage should be posted by fountains warning users to flush until the water runs cold
When?
• Whenever new, reliable information is available • Prior to and after lead screening and testing programs • Reminders should be done regularly in problem areas

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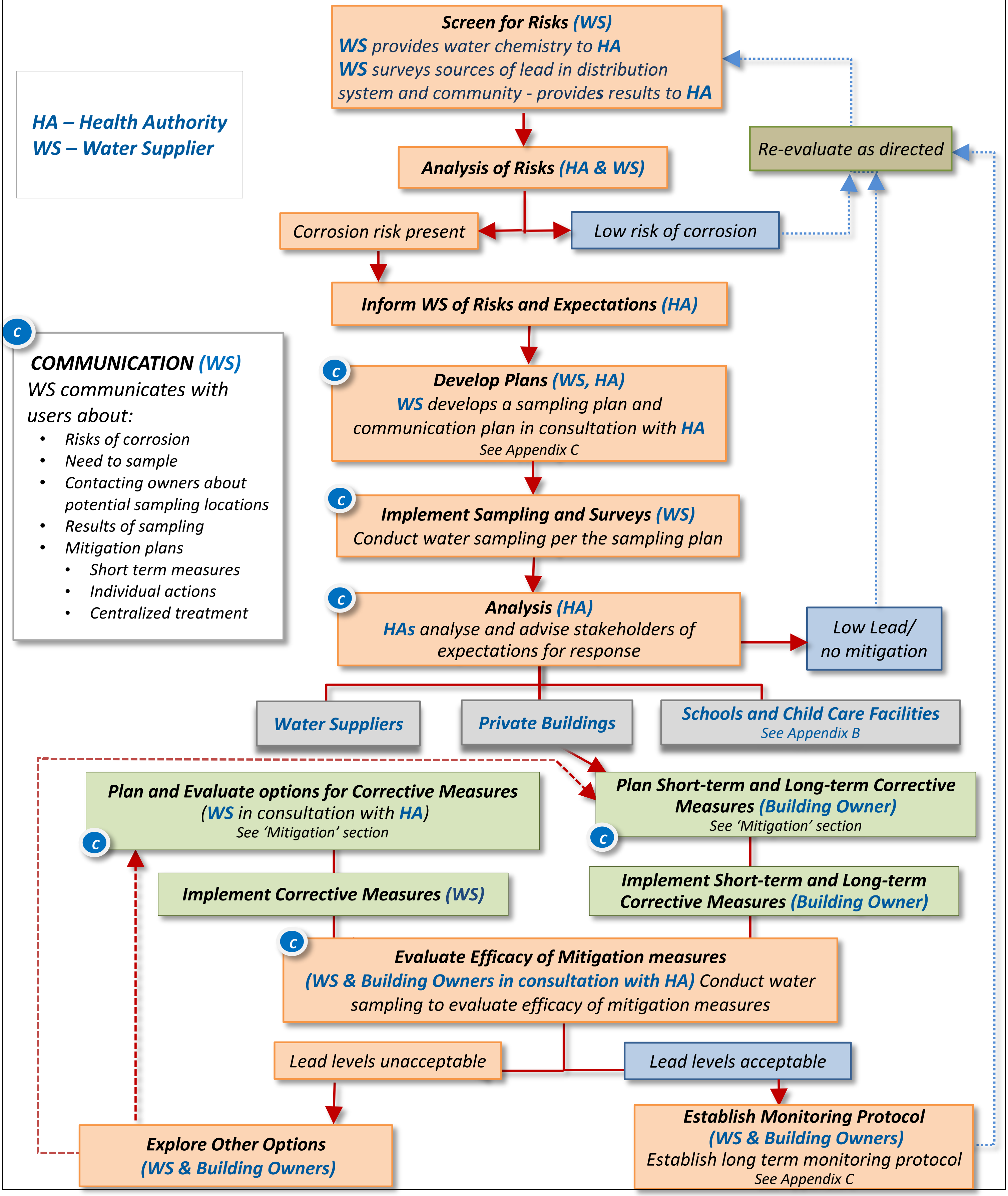
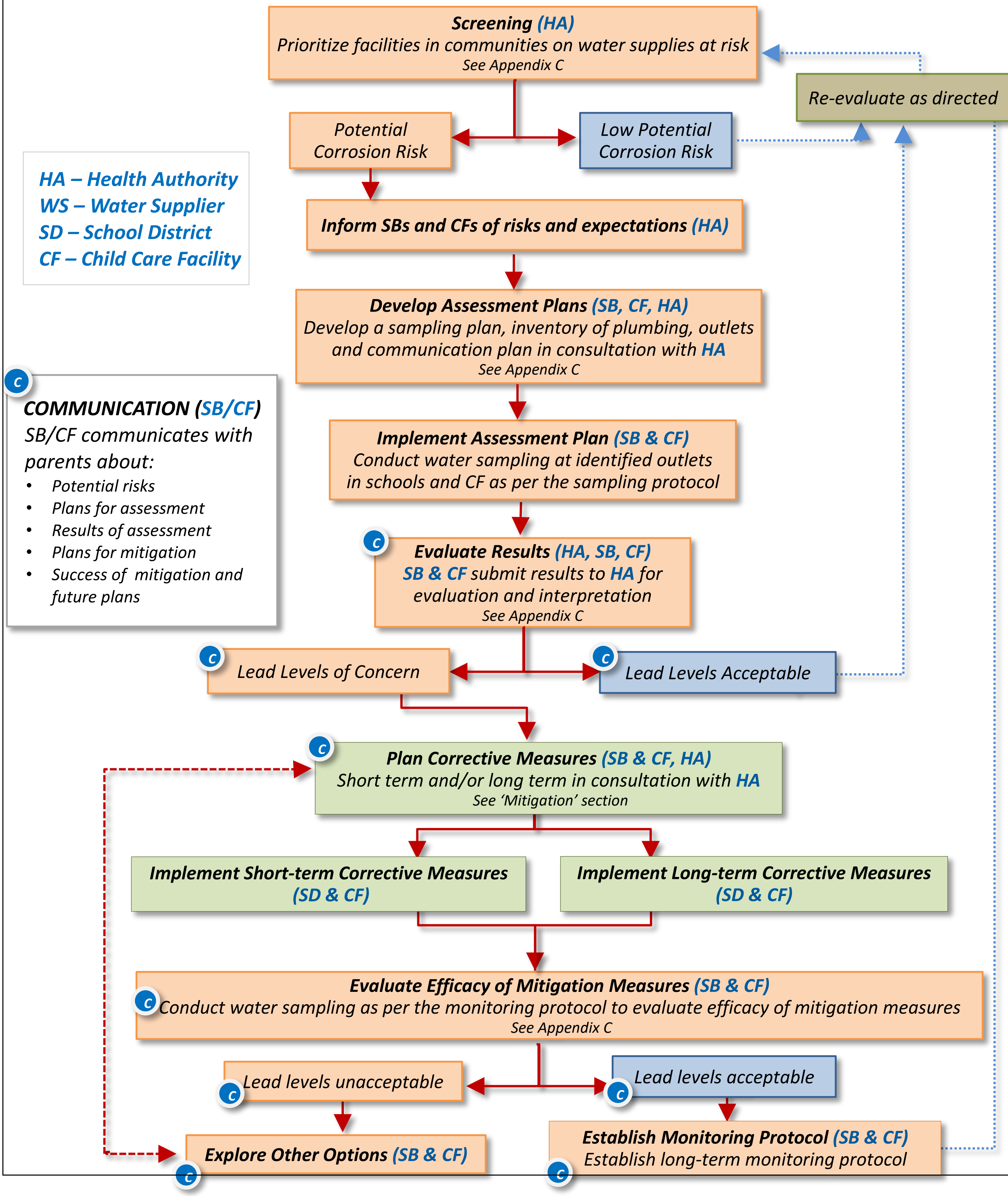
Appendix A – Process Flow for Evaluating Corrosion Risk in Water Supplies



Appendix B - Process Flow for Evaluating Lead in Schools and Child Care Facilities



Appendix C - Evaluating Lead in Drinking Water

Contents:

1. Why are you sampling?

The purpose of this appendix is to provide a reference of best practices for evaluating and sampling lead content in drinking water. As lead concentrations in drinking water vary both spatially and temporally, there are many sampling protocols that have been developed. Therefore consideration should be taken to choose the one that is the most appropriate for the situation.

Prior to embarking on a sampling program, the questions should be asked – what is the objective of sampling and what is it that one would like to demonstrate? Sampling protocols differ depending on the desired objective (e.g. identifying corrosive water, identifying fixtures and potential sources of lead in a building, and estimating if typically consumed lead concentrations in water meets guidelines). It is important that the selected protocol be appropriate to meet the desired objective.

1.1. Evaluating if centralized water system corrosion control is warranted

Depending upon the drinking water supply system and the characteristics of the drinking water produced, it may be necessary to determine whether the drinking water is capable of causing downstream corrosion problems in buildings with leaded plumbing components. Sampling results can be used to make decisions on whether community water system level actions are needed, and to evaluate the effectiveness of corrosion control measures after they are implemented. (See Section 2.1)

1.2. Evaluating sources of lead within a building

Where sources of lead are suspected in buildings, such as schools, child care facilities or other structures, testing should be done to determine if mitigation measures are warranted. This can range from simple screening for potential problems, to comprehensively testing to determine which specific taps/fixtures or other plumbing components within a building are contributors to lead. Results can be used to make decisions on whether building level actions are needed, and to evaluate the effectiveness of control measures after they have been implemented (See Section 2.2).

1.3. Evaluating whether lead concentrations in typically consumed tap water pose a human health risk

The health advice and the Maximum Acceptable Concentration (MAC) for lead in the *Guidelines for Canadian Drinking Water Quality* is based on samples representing typical or average concentrations of lead consumed throughout the day, not best or worst case scenarios. To evaluate whether the guideline for lead is being met, typical lead concentrations in drinking water ingested by users (i.e. representative of normal use) need to be determined. This may be done in the context of a building such as a school, a residence, or an entire community. The results can be used to determine what messaging should be delivered to advise of potential health risks, action plans to mitigate the risks, and to determine if mitigation measures are successful after they have been implemented. (See section 2.3)

Once sampling objectives have been determined, careful planning should be done to get meaningful results, and to ensure that the sampling objectives are met.

2. Sampling Protocols

2.1. To evaluate if centralized water system corrosion control is appropriate

The purpose of this type of monitoring program is to identify drinking water supply systems in which corrosion is an issue, to allow decisions to be made as to whether corrective measures at the water supplier level are warranted, and to determine what measures are likely to be the most effective. These programs can also be used to assess the effectiveness of corrosion control programs after their implementation. Results of this type of protocol do not represent typical concentrations of the lead in drinking water ingested by consumers, therefore, results should not be used for the interpretation of health risks, nor whether the Maximum Acceptable Concentration (MAC) in the Guidelines for Canadian Drinking Water Quality (GCDWQ) is being met.

For the evaluation of the risk of corrosion, "Option 1 (two-tier protocol)" from page 4 of Health Canada's *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* (GCCDWDS) is the preferred protocol. A second option, "Option 2 (lead service line residences)" described in the document can be used as an alternate where the two tier protocol is impractical. A brief overview of the protocol is described below; however, the original document should be referred to for the details.

Investigators will need to determine the number and location of monitoring sites. These sites should include taps within residences. To provide meaningful results, investigators will need to collect between 5 and 100 samples, depending on the size of the drinking water system (i.e., the number of people served). The recommended minimum number of sites to be monitored is shown in Table A. Sampling at individual sites is conducted as follows:

First Tier: Sample to establish whether the community water system has corrosion concerns.

- 6 hour stagnation, then collect 1L of water.

- If more than 10% of the sampled residential sites have a lead concentration greater than the action level of 15 µg/L, go to second tier. Note that this action level is different than the MAC for lead, as this is a measure of corrosion risk, not health risk.

Second Tier: For systems with corrosion concerns, this will provide detailed information about how lead is typically entering the drinking water, and will help plan mitigation measures that most appropriately target the sources found.

- Sampling is conducted at 10% of the sites sampled in Tier 1, specifically, the sites in which the highest lead concentrations were measured.
- Four consecutive 1L samples should be taken at a consumer's cold drinking water tap after a 6 hour stagnation period. This will provide a detailed profile of the sources of lead from within each building (e.g., the faucet, plumbing (lead in solder, brass and bronze fittings, brass water meters, etc.) and the lead service line.
- Each sample should be analysed separately to determine where the highest lead concentrations come from.

Table A: Suggested minimum number of monitoring sites

System Size (number of people served)	Number of Sites (annual Monitoring)	Number of Sites (reduced annual monitoring)
>100 000	**100**	**50**
10 001-100 000	**60**	**30**
3 301-10 000	**40**	**20**
501-3 300	**20**	**10**
101-500	**10**	**5**
≤ 100	**5**	**5**

Adapted from USEPA (1991a)

Interpreting Results

Where the sampling program shows more than 10% of the sampled residential sites have a lead concentration greater than the action level of 15 µg/L the water supply system should consider mitigation programs. This may include any or all of those listed in section 4 of this Guideline. It is recommended that water supply systems considering mitigation options initiate the second tier to help pinpoint typical sources of lead (fixtures vs plumbing vs lead service lines), so that the most effective mitigation measures can be planned to target those sources.

2.2. Screening for and locating sources of lead within a non-residential building (including schools, child care facilities)

This protocol is designed to locate specific lead sources within a building's plumbing and to help identify where and how to proceed with remedial actions. It provides details that help identify specific cold drinking water outlets that have elevated levels of lead following periods of water stagnation.

This is based on Section A.2.5. of Health Canada's *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* be used in conjunction with a systematic plan for lead sampling. While a brief overview of the sampling protocol is described briefly below, the original Health Canada document should be referred to for details.

2.2.1. Screening for lead

- Survey and inventory the building to identify all locations in the building where drinking water is likely to be consumed.
- Take a First Draw (FD) 250ml sample from each location after an 8 hour stagnation period.
- An additional fully flushed (FF) sample should be taken subsequent to the first draw sample.
- If lead concentration exceeds 5 µg/L[5] at any of the monitoring locations, further investigation and remedial action is warranted. This may include short term measures such as flushing programs, and/or long term measures to find and replace source of lead in plumbing (see below).

2.2.2. Pinpointing specific sources of lead in the plumbing for remediation

- To evaluate whether lead may come from other sources within the building, monitoring locations (above) exceeding 5 µg/L*, a subsequent 250 ml sample should be taken at those locations after an 8 hour stagnation period plus 30 seconds of flushing.
- Alternatively, while it may initially require more samples be taken, it may be more cost efficient for investigators to simply take a second sample at all sampling locations 30 seconds after taking the first sample.
- An analysis of results against plumbing plans for the building can be used to pinpoint sources of lead.

Interpreting Results

A comparison of the results can be used to help determine sources of lead, and to plan corrective actions. For example:

- Where the first samples do not exceed the MAC – no further action would be required unless other samples in the building exceed the MAC.
- Where the first samples exceed the MAC, and subsequent samples do not, the fixture is the likely source of contamination and mitigation measures targeted at the fixture should be considered.
- Where the first and subsequent samples exceed the lead action level, mitigation measures targeted to the entire building should be considered.

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[5] *Health Canada's corrosion control guidelines and the USEPA's Lead and Copper Rule refer to an action levels as thresholds beyond the MAC, however these action levels are targeted at optimizing corrosion control, not screening for further investigation of building problems, The Corrosion control document also instructs samplers to inform users where the values exceed the MAC, so using the revised 5 µg/L MAC is a more appropriate trigger for further investigation of building plumbing.*

Successful determination of lead sources within buildings is dependent on developing and implementing a systematic sampling plan to ensure meaningful results. Sampling plans should be tailored to specific situations. Ontario's Manual for Operators of Schools, Private Schools and Day Nurseries with Excess Lead in their Drinking Water published by the Ontario Ministry of the Environment and Climate Change provides an excellent resource for school and other buildings to locate the source of problems and mitigate them. This manual guides users through four key steps:

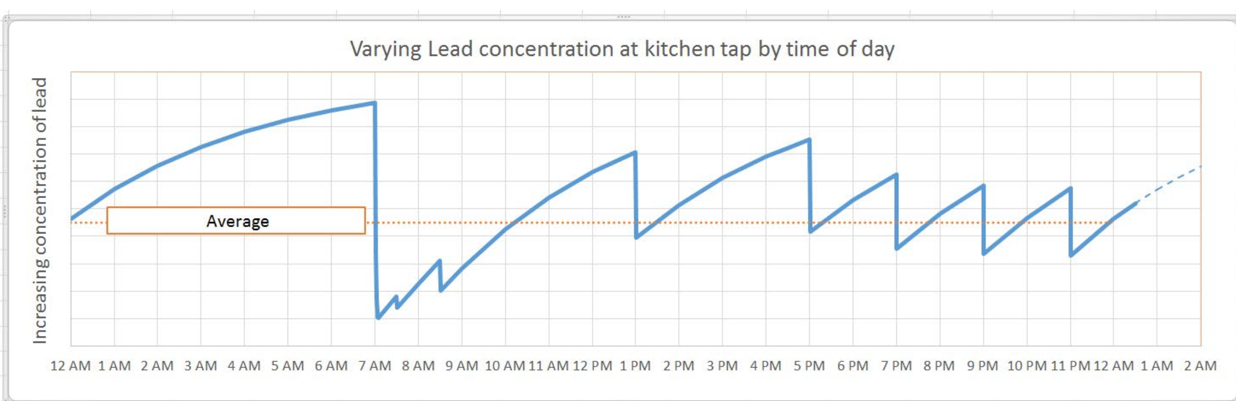
- Assessing plumbing;
- developing a sampling strategy;
- executing the sampling strategy and using the test results to remedy the problem; and
- taking routine, interim and permanent measures.

The manual may describe slightly different sampling protocols and action levels than this document, but its description of the processes for sampling still applies. The general process in this manual could also be applied to non-school settings.

Ideally, schools should be monitored at least once per year with consideration for reductions in the sampling frequency if monitoring shows that the results are acceptable. The BC Ministry of Education and Child Care may recommend alternative frequencies, however the health authority should be consulted in order to help determine an appropriate health-based sampling frequency based on the data available. In circumstances where Ministry of Education and Child Care lead sampling policies require testing at a frequency greater than what a DWO would typically recommend, the frequency set by the Ministry's policy should be followed.

2.3. To evaluate health risks

The Maximum Acceptable Concentration (MAC) published in the *Guidelines for Canadian Drinking Water Quality (GCDWQ)* is intended to apply to the average concentration in the water consumed. This implies that when evaluating health risk, the sampling protocol should be designed to estimate the average or typical exposure to lead in drinking water not the worst possible case scenario. (See conceptual figure A below.)



As water that has remained stagnant in pipes is at highest risk for lead content, it would be expected that concentrations in plumbing will be highest in the morning, and drop over the day with use. Assessing whether or not typical concentrations consumed meet the GCDWQ should therefore be based on sampling at times and places where water is usually consumed, and not a worst or best case scenario.

The following describes specific approaches to estimate typical concentrations in different scenarios, including community risk, and risks with individual dwellings or larger buildings.

2.3.1. Evaluating health risk at the community level:

While it is relatively simple to sample lead concentrations in drinking water as it leaves the treatment plant, it is not representative of what is consumed by users as building plumbing can significantly impact lead content. To establish a typical concentration of lead being consumed by customers, a series of either Random Daytime Samples (RDT) or Thirty Minute Stagnation (30MS) samples should be taken at multiple points of consumption. These samples should be averaged. Details of the pros and cons of each method are discussed in part three of this document.

Sampling plan designs should consider:

- Producing reliable results typically requires 20 or more samples, taken at different consumer locations and at different times of year;
- choosing sampling points from consumer's taps that are balanced between public and private buildings;
- identifying homes with lead service lines for inclusion in the sampling program, as these are likely to have the highest lead concentrations;
- dividing larger distribution networks into neighbourhoods or zones of similar age and evaluating the risk of each community independently may be advisable in some areas; and
- taking samples of the water supplied to the distribution network to establish baselines of the lead concentration of water supplies.

After selection of the taps being sampled, either:

a) For RDT programs, the first 1 litre of water, from each tap is sampled without flushing at random times throughout the day, or
b) for 30MS programs, flush taps for 5 minutes, let stagnate for 30 minutes, then take two consecutive 1-litre samples.

Interpretation

Results should be averaged to determine a typical value for evaluation against the MAC set in the GCDWQ of 5 µg/L. Individual samples that exceed the MAC should not be cause for community concern, however further investigation of the cause might be warranted. Where averaged samples exceed the MAC, the Health Authority should be engaged with the water supplier to further investigate and plan mitigation options.

2.3.2. Evaluating health risks in individual dwellings:

Homeowners, operators of child care facilities in residential settings or occupants of dwellings with older plumbing may wish to investigate whether drinking water from their home meets the requirements of the GCDWQ. This scenario provides a challenge as it is unlikely that a series of samples will be taken and averaged to produce "typical" results. Where only one sample is practical to be taken, a 30MS sample should be done as it is the most reproducible for post mitigation evaluation, and can be done at any time of the day.

Interpretation

Where possible, multiple samples should be taken and averaged, and results evaluated against the MAC of 5 µg/L in the GCDWQ. Where the MAC is exceeded, further investigation should be done to determine the source of lead and/or the mitigation measures that can be implemented.

2.3.3. Evaluating health risks in schools and other larger buildings:

The purpose is to determine if water typically consumed by students in schools or occupants/residents of larger buildings are likely to be at levels that exceed the GCDWQ. This may be done after screening (See Section 2.3). If screening does not show exceedance of action levels, further sampling and calculation of the MAC is likely not warranted. As school plumbing tends to be complex in use patterns, age, and variability, there is typically no single sentinel site that can be established for most schools, thereby requiring the sampling of every drinking water location. Large buildings face similar challenges.

A RDT sampling protocol is recommended to capture typical exposures, including potential exposure to particulate lead. This should be conducted by sampling at all drinking water fountains and cold water taps where water is used for drinking or food preparation. Samples should be taken:

- At random times throughout the school day;
- preferably taken between May and September as leaching increases with higher water temperatures; and
- two consecutive 125 mL samples should be collected at each fountain or tap without a stagnation period and without prior flushing. Note: smaller samples are taken as it can provide valuable data for find and fix options if needed at a later date.

<u>Interpreting Results</u>
Results from a sampling program should be calculated by averaging the results from at least two samples and averaging sampling locations within a building. Averages should not exceed the MAC for lead that is set out in the GCDWQ.

Those schools and buildings with indicators of lead problems should undertake further screening and mitigation as per section 2.3 below. Taking two 125ml samples is preferable to taking a 1L sample as it can help determine if the fixture or the plumbing system is the problem by providing valuable data for further investigation and for determining mitigation options.

3. Definitions

3.1.1. Random Daytime Sampling (RDT):

Purpose: To capture typical exposures at residential sites, assess health risk, and set priorities.

A sample is taken at a random time during a working day directly from the tap in a property without previous flushing. The stagnation of water in a distribution system influences the concentration of lead in a random manner. Health Canada recommends taking a 1L samples for sampling programs conducted at the community level. For schools and other large buildings, Health Canada recommends taking two 125ml samples be taken as the data from smaller volumes can provide valuable data for identifying and mitigating problem fixtures and areas within buildings.

RDT sampling is relatively inexpensive and convenient (per sample), but needs to be repeated numerous times to provide confidence in the results. Results are close to typical use when averaged over many samples. RDT sampling is better suited for determining system wide health risks than for individual sites. It requires 2-5 times more samples that 30MS sampling to provide statistically significant results.

3.1.2. Thirty Minute Stagnation (30MS):

Purpose: To capture typical exposures at residential sites, assess health risk, and set priorities.

A typical 30MS sampling protocol is to flush a tap for 5 minutes, then allow water to stand for 30 minutes. Two consecutive 1L samples are then taken and the results of the two samples are averaged.

30MS samples are more reproducible than RDT samples, and may be the most appropriate for single samples estimating lead risk in individual dwellings. Using two consecutive samples allows the estimation of the relative contribution of the fixture to the lead concentration. 30MS sampling is time consuming and may underestimate typical exposure to lead in drinking water.

3.1.3. First Draw (FD)

Purpose: To capture the highest levels of lead using long stagnation times.

During the stagnation period no water should be drawn from any outlet within the property (this includes the flushing of toilets). If any water is drawn during the stagnation period the result will be invalid.

- 6-8hr stagnation period then the collection of a 250 mL or 1L sample.

First draw gives the "worst case scenario". This may also be useful in conjunction with flushed samples to help determine if a specific fixture is contributing lead to the water. This protocol is not appropriate for assessing health risk based on average exposure to lead in drinking water, unless it confirms samples are below thresholds of concern.

3.1.4. Fully Flushed (FF)

Purpose: To determine lead levels in plumbing after complete flushing of the system, or to infer lead levels from water mains.

Samples are taken after prolonged flushing of the tap in a premise in such way that the stagnation of water in the domestic distribution system does not influence the concentration of lead in the drinking water. In practice a sample is taken after flushing at least three plumbing volumes, a prescribed time, or after an observed temperature drop.

While fully flushed samples provide an indication of lead concentrations in systems that are under heavy use, they are not suitable for assessing average exposure to lead in drinking water, as they are likely to underestimate typical lead exposure. Calculating pipe volumes, flow rates and flushing times may be challenging for some larger buildings with complex plumbing systems.

4. References

Health Canada (2009). Guidance on Controlling Corrosion in Drinking Water Distribution Systems (Catalogue No. H128-1/09-595E). https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidance-controlling-corrosion-drinking-water-distribution-systems.html

Health Canada (1992). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Lead (Catalogue No. H128-1/09-595E). https://www.canada.ca/en/health-canada/services/publications/healthy-living/guidelines-canadian-drinking-water-quality-guideline-technical-document-lead/guidance-document.html

Ontario (2009). A Manual for Operators of Schools, Private Schools and Day Nurseries with Excess Lead in their Drinking Water. Queens Printer for Ontario (Toronto, Ontario). https://dr6j45jk9xcmk.cloudfront.net/documents/2460/pibs-7101e.pdf

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UK Drinking Water Inspectorate (2013). DWI PR14 Guidance – Lead in Drinking Water. http://www.dwi.gov.uk/stakeholders/price-review-process/PR14-guidance-lead.pdf

UK Drinking Water Inspectorate (2010). Lead in Drinking Water. http://www.dwi.gov.uk/consumers/advice-leaflets/lead.pdf

USEPA Office of Water (October 2018). 3Ts for Reducing Lead in Drinking Water in Schools and Child Care Facilities. EPA 815-B-18-007. https://www.epa.gov/sites/production/files/2018-09/documents/final_revised_3ts_manual_508.pdf

Appendix D: Guidance on Flushing for Mitigation

One option for mitigation of lead risks from drinking water in schools, licensed child care facilities, or other buildings is to implement a flushing program. The intention of flushing is to run the tap water until the water from the water main in the street or the water supply from within the well reaches the taps. This has been shown to significantly reduce lead levels in drinking water at the tap. However, the degree to which flushing helps reduce lead levels in drinking water can vary, depending upon the age and condition of a facility's plumbing and the corrosiveness of the water. Regardless of these limitations, flushing is still the quickest and easiest measure to reduce high lead levels in drinking water, especially when contamination is localized in a small area or in a small building.

Circumstances that indicate implementing a flushing program:

Where assessment and/or water sampling of a facility has identified risks for elevated lead in water mitigation actions should be taken. These circumstances include:

- Results of testing for lead in water (see appendix C) exceed the Maximum Acceptable Concentration in the *Guidelines for Canadian Drinking Water Quality or* action levels;
- any part of the plumbing was installed before January 1, 1990 that has not been assessed for lead content, and/or there is no sampling history for the last 24 months;
- it is recommended by the Regional Health Authority.

Mitigation should include implementing a flushing program until permanent measures can be taken to reduce the lead or until testing confirms that lead levels are within acceptable limits. Any additional flushing requirements will be determined by the results of the facility's plumbing profile and risk assessment in consultation with the local Environmental Health Officer.

When to flush:

- Flushing should be conducted daily when the facility or part of the facility is open.
- Flushing should be completed before the facility opens for the day. Where a facility is open for 24 hours on that day (e.g., a building housing student residences within a school property), flushing should be completed as early in the day as possible.

Where and how to flush:

- First, turn on the cold water for at least five minutes at the last tap on each branch or each run of pipe in the plumbing that serves a drinking water tap that is commonly used to provide water for consumption. In many cases, depending on the plumbing configuration, it may be necessary to flush the plumbing for a longer period of time. The actual amount of time that will be needed depends on the type of tap, diameter of pipes, and its location within the building plumbing (i.e. distance from the water main in the street or the distance to the water supply well). For best results, the volume of the plumbing and the flow rate at the tap should be calculated, and the flushing time should be adjusted accordingly – See **Calculating how long to flush** below.

- Then, turn on the cold water for at least 10 seconds at every drinking water fountain and every tap that is commonly used to provide drinking water for human consumption.
- Additional recommendations for flushing specific types of non-end-of-run outlets include:
    - For drinking water fountains without refrigeration units, the water should run for at least 15 seconds, or until the water is cold.
    - For drinking water fountains with refrigeration units, the water should run for at least 15 minutes. If it is not feasible to flush for such a long time, these outlets should be replaced with lead-free, NSF-approved devices.
    - For all kitchen faucets and other faucets where water may be used for drinking (including bathroom faucets where it is possible to obtain cold water), the water should run for at least 10 seconds or until the water is cold.
- Be careful not to flush too many taps at once. This could dislodge sediments that might create further lead problems, or could reduce pressure in the system below safe levels. If the flow from drinking water outlets is reduced noticeably during flushing, too many taps are probably being turned on at once.

Calculating how long to flush:

The amount of time it will take to fully flush a building's plumbing will vary depending on the diameter of the water supply pipe and the water flow rate during flushing. Some of the ways to determine how long to flush include:

- Calculating the pipe volume, in litres, between the outlet and the location in the plumbing being flushed using the formula: 3.14 x pipe radius^2 x pipe length (i.e., $\pi r^2 l$);
- measuring the outlet flow rate in litres per minute;
- dividing the pipe volume in litres by the outlet flow rate in litres per minute.

The following table and information from the 2016 Copper Tube Handbook[6] can assist in calculations.

Table B: Pipe Volume (per unit of pipe length) for different diameters of copper pipe

Pipe diameter	Volume of tube (litres per meter of length) Type L Copper
9.53 (3/8)	0.0938
12.70 (1/2)	0.1505

[6] Copper Development Association Inc.(2016) *Copper Tube Handbook: Industry Standard Guide for the Design and Installation of Copper Piping Systems*; CDA Publication A4015-14/16, NY

15.88 (5/8)	0.2248
19.05 (3/4)	0.3122
25.40 (1)	0.5323
31.75 (1 ¼)	0.8129
38.10 (1 ½)	1.1520
50.80 (2)	1.9974
63.50 (2 ½)	3.0751
76.20 (3)	4.3943

Establishing due diligence – recording and reporting:

- Keep written records of the date and time of every required flushing and the name of the person who performed the flushing. If auto flushers are used, record the name of the person who verified that the automatic flushing took place. Records for auto flushers need to be completed based on the frequency set out in the manufacturer's instructions or at least once a month if no instructions are available.
- Keep the written record on file and available for review by an Environmental Health Officer.

Additional information:

- It is not required to flush any tap or drinking water fountain in a part of a building that is not in use by children or staff during the day as well as in private student residences or in a public washroom (e.g., in a shopping mall).
- If a tap or drinking water fountain has an aerator, the aerator should not be removed when flushing.
- If a tap or drinking water fountain has an individual filter or other water treatment device, the filter should be bypassed when flushing if this can be done easily. A filter or treatment device is not required to be bypassed if it would require removing or dismantling the device to do so.
- To save water, thoroughly flush several designated drinking water outlets daily while taking all others temporarily out of service. Collect the water being flushed and use it for non-consumptive purposes.

References:

Copper Development Association Inc. (2016). Copper Tube Handbook: Industry Standard Guide for the Design and Installation of Copper Piping Systems. CDA Publication A4015-14/16, NY.

Ontario Ministry of the Environment and Climate Change (updated June 23, 2016). Flushing and sampling for lead: Rules for schools, private schools and child care centres to flush plumbing and test drinking water for lead. https://www.ontario.ca/page/flushing-and-sampling-lead

Ontario Ministry of the Environment (2009). A Manual for Operators of Schools, Private Schools and Day Nurseries with Excess Lead in their Drinking Water: A resource guide on how to locate the source and remedy the problem.
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Guidance on Manganese in Drinking Water

Version 1.1 / First Published May 2019

Ministry of Health

1. Introduction

This guidance is intended to provide strategies and resources to assist local governments, health authorities, and water system operators to assess and manage risks related to manganese in drinking water sources used for drinking water purposes, based on revisions to the Guidelines for Canadian Drinking Water Quality (GCDWQ). It provides supplemental guidance for drinking water officers (DWOs) on manganese in drinking water based on the 2019 GCDWQ.

The guidance in this document focuses on three key areas:

- Background information on the health risks of manganese;
- Communication strategies for drinking water systems with elevated concentrations of manganese in treated water; and
- Manganese treatment options.

2. Background and Regulatory Framework

The 2019 GCDWQ Guideline Technical Document for Manganese is what B.C.'s water supply systems should refer to when evaluating water from both aesthetic and health considerations. From an aesthetic perspective, elevated concentrations of manganese in drinking water are known to result in discoloured water, staining of laundry and/or plumbing fixtures. The previous GCDWQ for manganese addressed these concerns with an aesthetic objective (AO) of 0.05 mg/L, and did not consider manganese to pose any risk to human health. In the new GCDWQ, the AO has been revised to 0.02 mg/L to reduce complaints regarding discoloured water.

Based on emerging health research, the GCDWQ for manganese now also sets out a maximum acceptable concentration (MAC). The MAC has been set at 0.12 mg/L, and is based on being protective of ongoing consumption of tap water by infants, especially infants consuming formula made with tap water. Risk to other users is not as well established and likely not as significant.

Concentrations of manganese in drinking water should be compared to both the revised AO and the MAC. Exceedances of the AO which are less than the MAC can be addressed as aesthetic concerns; however, consumption of water with manganese concentrations greater than the MAC of 0.12 mg/L should be evaluated from a health perspective.

2.1 Background Manganese Concentrations

Background levels of manganese in untreated water typically range from 0.001 to 0.2 mg/L, but can be much higher in groundwater depending on the geology. A monitoring program by Health Canada from 1991 to 2014 found manganese concentrations in water from British Columbia were greater than 0.2 mg/L in 13% of samples and greater than 10 mg/L in 4% of samples. Manganese can be present as dissolved Mn(II), manganese(II) sulfate, particulate manganese oxides and hydroxides, and Mn (IV) carbonates.

In British Columbia, the Ministry of Environment & Climate Change Strategy reported that manganese was monitored at various locations including both surface and groundwater supplies between 1991 and 2014 (British Columbia Ministry of Health, 2014). Results of monitoring are presented below in Table 1.

Table 1. Historical concentrations of manganese in British Columbia water supplies (1991-2014)

Parameter	Median Concentration (mg/L)	Maximum Concentration (mg/L)	Concentration Range (mg/L)	Number of Samples (percentage)
Total Manganese	**0.008**	**139**	**>0.2**	413 of 3,593 (11.5%)
			>10	6 of 3,593 (0.2%)
Dissolved Manganese	**0.008**	**26.2**	**>0.2**	20 of 160(12.5%)
			>10	1 of 160(0.6%)

BC Ministry of Health (2014)

2.2 Manganese Exposure and Toxicity

The primary target of manganese toxicity is the central nervous system, followed by the reproductive system. Several epidemiological studies on manganese exposure via drinking water were reviewed by Health Canada in the development of the guidelines. The majority of the studies:

- were based on environments with elevated manganese concentrations;

- had significant confounding variables or were not sufficiently powerful to establish a dose-response relationship at low concentrations;
- were unable to confidently establish a lower threshold based on the available data.

The significant limitations of the human studies prevented their use in quantitative risk assessment, and they were instead used to select neurotoxicity as the key endpoint to use from animal studies.

A lowest observed adverse effect limit (LOAEL) of 25 mg Mn/kg-bw/d was established based on two studies of neurological effects in rats. A tolerable daily intake of 0.025 mg/kg-bw/d was then calculated for humans using an uncertainty factor of 1000 [for interspecies variation (x10), intraspecies variation (x10), and use of a LOAEL rather than a NOAEL (x10)]. Neurological effects in laboratory animals were found in other studies at concentrations as low as 0.106 mg/kg-bw/d, but these endpoints were not selected due to study limitations. There are additional limitations when extrapolating to infant human exposure associated with Health Canada's assumption that half of manganese exposure is from drinking water, as well as differences in bioavailability between different age groups and species. These uncertainties are reflected in the differences in other international health-based limits for manganese in drinking water, which range from 0.1 mg/L (Minnesota) to 0.5 mg/L (Australia).

While there is no evidence to conclude that detectable differences in health will be present at concentrations less than the MAC, the available evidence does suggests that measurable neurological impacts may be possible when infants and children are chronically exposed to manganese concentrations greater than the MAC. Based on the precautionary approach adopted by Health Canada and the high degree of uncertainty and limitations of the available information, the guideline of 0.12 mg/L should be interpreted as being protective of ongoing exposure to all infants relying solely on formula made with tap water. Health impacts in other human groups with decreased exposure or sensitivity to manganese might not be significant until drinking water concentrations are much higher. The amount of manganese transferred from an expecting mother to her baby is not fully understood, however, it is expected that manganese absorption and excretion would be managed by the mother's body.

2.3 Previous Recommendations

In areas of BC with naturally elevated concentrations of manganese, there is the potential for regular or seasonal occurrences of elevated manganese in water. Based on the previous recommendations from Health Canada, manganese was not believed to be toxic at palatable concentrations in drinking water. For small water systems with limitations on the ability to remove manganese, many communities were advised in the past that water with manganese levels above the AO was safe to drink.

This approach may no longer be appropriate based on the current understanding of manganese toxicity. For existing drinking water systems that have elevated concentrations of manganese in their water, the following sections contain options for evaluating and communicating risk.

2.4 Evaluating Risk

In determining whether increased manganese in drinking water is a health hazard and the need to advise on mitigation, drinking water officers should look at:

The magnitude of the exceedance above the MAC - Marginal short-term exceedances indicate a need for further evaluation, but may not require any immediate actions. Chronic exceedances slightly above the MAC likely require, at a minimum, notification that infants should not consume formula made with tap water and consideration of options for mitigating manganese concentrations. Concentrations exceeding 0.3 mg/L warrant consideration of risks to a broader population and may require short-term mitigation. Concentrations in this magnitude would also exceed less conservative international guidelines from the US EPA and WHO which would indicate further potential health risks to other groups in addition to bottle-fed infants.

Trends in manganese concentration - Whether there is a single occurrence, periodic/seasonal occurrence, a persistent problem, or an increasing trend. Manganese concentrations can be significantly influenced by environmental conditions. Since the drinking water guideline is based on chronic exposure, individual isolated short term exceedances are not likely to require action. Ongoing elevated trends in manganese concentration may indicate a change in source water or watershed conditions and could be associated with changes to water chemistry or the presence of co-contaminants and warrant significant consideration.

Who the users of the systems are – The MAC is based on toxicity to bottle-fed infants. Water systems supplying sensitive populations, such as schools, hospitals, or daycares should be considered at greater risk than communities comprised of adults or those that have access to other sources of drinking water.

What potential actions can be taken to mitigate risks – Risks can be mitigated by using various treatment technologies to reduce the concentration of manganese in the water. Boiling water is not an effective form of treatment for manganese reduction. Boiling water can increase the concentration of dissolved, and therefore absorbable, manganese in drinking water. Switching to an alternate source or bottled water is also an option.

3. Communicating Risk

The type and extent of communication of risks to human health from manganese depend on the degree of human exposure and the severity of the health risk. A template for messaging is included as an Appendix to this document, however individual water supply systems may have unique challenges and therefore it may be appropriate to create community specific messaging for systems that do not meet the MAC.

The goal of health authority communication with the water supplier is to ensure that the supplier understands health authority expectations regarding:

- risk communication to the public, and
- drinking water system plans to meet the MAC

Water suppliers should consult with health authorities on appropriate messaging. Communication between the water supplier and the users of drinking water from the water supply system should:

- Describe the situation and the reason for the message:
  - what the source of water is and why it is at risk
  - whether an aesthetic objective (AO) or a maximum acceptable concentration (MAC) was not met
  - the risks associated with consuming drinking water that does not meet the standards or guidelines
  - actions that consumers can take to reduce the risk (e.g. use alternate water supplies, support water system improvements)
- Identify the area(s) and population(s) affected
- Explain what the water system is doing to address the risks and to resolve the situation:
  - where the water system is in the process of resolving the situation
  - what the plans and timelines are for meeting the treatment standards
- Identify a central point of contact for information and where updates can be found as they become available

Further messaging may be considered, such as identifying:

- subpopulations that might be particularly vulnerable such as infants
- reference to the appropriate HealthLinkBC - #49g – Manganese in Drinking Water
- How individuals can help share the notice with others such as communicating with neighbours, and isolated or vulnerable individuals, etc.

Communication with the general public can range from informational notices intended to educate the water user, to an advisory to take some action either to reduce or prevent exposure as in the case of "Do Not Consume" messaging.

Messaging should be specific to the situation and to the water supply system, and should use plain, non-technical language that is clear and easy to understand by the general public. Messaging should include multiple channels of communication to ensure all users, including transient users, are apprised of the situation, as well as ensuring susceptible sub-populations receive guidance as appropriate. Examples include but are not limited to website updates, annual reports, signage, and leaflets with water bills.

4. Example Messaging for Public Notice

4.1 Background Information on Manganese for Consumers

Emphasis should be placed on the fact that manganese is generally naturally occurring in the source water, and may be reduced to acceptable levels through water treatment. Key points for communication:

- Manganese is a naturally occurring element that is present throughout the environment and can normally be found in many water sources.
- British Columbians can be exposed to manganese through air, food, soil, consumer products, and drinking water. The main source for most people is their diet as manganese is present in nuts, beans, fruits, and leafy green vegetables, and some types of infant formula.
- Manganese is an essential nutrient- and consuming a small amount of manganese is necessary to maintain your overall health.
- High levels of manganese can make water appear, brown, purple or black at concentrations less than the MAC.
- Water that is high in manganese can pose a risk to infants when it is used to prepare formula.

4.2 Why did the guideline change?

Messaging regarding the change made to the manganese guideline should indicate that the understanding of manganese toxicity has changed over time, and that the new guideline is based on studies that have been completed since the previous manganese guideline was established. Key points for communication:

- Until recently, elevated levels of manganese in drinking water were not considered to be a health concern.
- Manganese from drinking water is now believed to be a greater health risk than previously thought. New evidence has shown that consuming drinking water with high levels of manganese may impact the memory, attention, motor function, and the overall intellectual development of infants and young children.

4.3 Did drinking manganese in the past impact my health?

For communities with historical issues related to elevated levels of manganese in their drinking water, there may be concern regarding potential health impacts, particularly if infants have been relying on tap water. Key points for communication:

- Exposure to manganese through skin contact is not harmful. Exposure through hand washing, showering, or bathing from water with manganese is unlikely to be significant. While inhalation of manganese aerosols during showering has not been directly evaluated it is not expected to pose any risk to human health.
- The MAC is based on animal studies and includes safety factors to ensure even sensitive individuals are protected. Concentrations approaching, but remaining less than, the MAC are not associated with increased health risks in any individuals.
- Health Canada calculated the MAC assuming that people would be constantly exposed to elevated levels of manganese for long periods of time. Occasionally consuming water with manganese concentrations slightly greater than the MAC is unlikely to cause any health issues.
- Health Canada has adopted a precautionary approach due to the limitations on the available information. Manganese concentrations greater than the guideline are only representative of a potential risk to health, but do not represent measurable health impacts.
- The health effects from manganese exposure are related to neurological function, and related symptoms could include changes in behaviour, poor memory, or reduced motor function. If you have been consuming water with elevated levels of manganese and are experiencing, or have concerns regarding these issues, you should consult your family physician.

4.4 What should I do if there are high levels of manganese in my drinking water?

If you have drinking water with high levels of manganese, the following actions are recommended:

- Water with high levels of manganese can have a purple, brown, or blackish colour; however, a better indicator is discolouration of fixtures such as kettles or toilet tanks. Manganese may also facilitate the growth of manganese bacteria which may form black-brown (manganese) slime and produce a foul odor that may be mistaken for sewage contamination. Testing for manganese should be considered as a first step if the above properties are observed. Manganese can cause discoloured water at concentrations that are still safe to drink. Regardless, as a precaution, it is recommended that you avoid drinking discoloured water, or using it to prepare food or infant formula.
- Infants should not consume tap water or formula prepared with tap water if the manganese concentrations are greater than the MAC of 0.12 mg/L. An alternate source such as bottled water should be used.
- Children and adults are less sensitive to manganese than infants, and may be able to safely consume drinking water with concentrations of manganese slightly above the MAC for short periods of time.

- If you have concerns regarding high levels of manganese in your drinking water, you can switch to other sources of drinking water, such as bottled water until such time that mitigation measures are in place for your water supply system.

4.5 Can our treatment system be upgraded to remove manganese?

Water suppliers may wish to consider sharing information on why upgrades are required, the types of upgrades being considered, the capital and operating costs of the upgrades and expected timelines for construction. In areas where it is known that manganese can exceed the MAC based on naturally occurring conditions, it may be appropriate to discuss options for treatment plant upgrades over an extended period of time because *the infrastructure of many water supply systems predates current treatment expectations.* Health Authorities have been engaging water suppliers to make continuous improvements to meet treatment expectations; however improvements to infrastructure often take considerable time to complete due to financial, technical and logistical challenges.

5. Technical Treatment Details

5.1 Manganese Chemistry

Selection of an appropriate treatment system for manganese is dependent on the chemistry of the source water and water within the drinking water system. Treatment for manganese removal is often done in conjunction with treatment for iron removal, however, it is more difficult to remove manganese than iron.

Manganese can exist in several oxidation states: Mn(II) is soluble and appears clear in water, Mn(III) and Mn(IV) are insoluble oxides, and Mn(VII) is a soluble ion that appears purple. The species of manganese present is controlled by the oxidation/reduction potential and pH of the source water, as well as the presence of other parameters that can form manganese compounds.

Treatment of manganese is generally accomplished by reducing the solubility of manganese, typically by oxidizing the highly soluble Mn(II) species to the Mn(III) or Mn(IV) species which precipitate as solid oxides (referred to as MnOx). The oxidation process is influenced by the amount of iron present in the treatment system, as iron is preferentially oxidized under most conditions. Adsorption/desorption processes can also occur in treatment systems as negatively charged MnOx compounds can adsorb Mn(II) and catalyze further oxidation of Mn(II).

5.2 Municipal Scale Treatment

Selection of an appropriate treatment system for manganese depends on the form of manganese present in the source water. Mn(II) is often the most common form in source water that requires treatment; however, the levels of pH and dissolved oxygen (DO) in the source water could result in a combination of dissolved and solid manganese being present.

Dissolved manganese can be removed through source water control, oxidation/physical separation, absorption/oxidation, biological filtration, and precipitative softening (Health Canada, 2019). Manganese oxides can exist as both particulate (large solids) and colloidal (small particle) forms. While particulate can be more easily removed through sedimentation or filtration, the colloidal particles may require the addition of a coagulant (Health Canada, 2019).

5.2.1 Source Water Control

Manganese concentrations can vary significantly between different groundwater intake wells, and altering intake flow rates (blending) from multiple wells is a method that can be used to optimize concentrations of manganese entering a treatment plant (Health Canada, 2019). A similar option for surface water would be the use of a variable depth intake.

Manganese in groundwater sources can also be oxidized by raising the redox potential in the aquifer by injecting aerated water into the aquifer through recharge wells. However, this option can raise concerns about altering the natural aquifer geochemistry and permeability.

Aeration to increase levels of DO in surface waters can be beneficial to reduce the concentration of Mn(II). There are several physical and chemical aeration options, and the amount of DO required will depend on the volume of water, existing DO levels, and oxygen demand of the underlying sediment (Health Canada, 2019). Control is needed to avoid destratification of the water body which can cause other water quality issues.

5.2.2 Chemical Oxidation

If dissolved Mn(II) is the primary form of manganese present in source water, direct oxidation to precipitate manganese as MnOx followed by physical separation is an effective treatment strategy. The effectiveness of this treatment is based on several factors, including pH, reduction potential, temperature, reaction time, alkalinity, and total oxidant demand in the source water. Oxidation can also be influenced by the presence of other compounds such as iron, sulphide, nitrate, ammonia, and organic compounds (Brandhuber et al., 2013).

Different combinations of oxidants and physical separation methods are available. Typical chemical oxidants include permanganate ($MnO4^-$), chlorine dioxide (ClO2), and ozone (O3). Chlorine and oxygen can also be used under high pH conditions. Oxidant doses generally must be greater than stoichiometric ratios in order to meet source water oxidant demand and to achieve an adequate oxidation of manganese (Knocke et al., 1990a). Iron is easier to oxidize than manganese and oxidant demand from iron must be satisfied before oxidation of manganese will occur at any pH.

When using permanganate, chlorine dioxide, and ozone to oxidize Mn(II), colloidal particles less than 1 µm can be created. This occurs more often under low hardness conditions as calcium and manganese ions help to destabilize and aggregate colloids. It is recommended that oxidants be added prior to coagulation/flocculation processes so that colloidal particles can be removed thorough conventional sedimentation and filtration processes.

Oxidation/filtration methods typically remove between 80 to 99% of manganese and are able to achieve treated water concentrations less than 0.04 mg/L (Health Canada, 2019).

5.2.2.1 Permanganate

Permanganate is supplied as either sodium permanganate (NaMnO4) or potassium permanganate (KMnO4). NaMnO4 is being used at an increasing number of facilities as it can be purchased as a concentrated solution rather than a dry product (Health Canada, 2019). Oxidation of Mn(II) occurs rapidly under a wide range of temperature and pH conditions in water with low (<3 mg/L) dissolved organic carbon (DOC). The stoichiometric dosage is 1.9 mg KMnO4 per mg Mn(II) but the required dosage will increase based on the source water oxidant demand. Permanganate is not as effective under conditions less than 5 °C and pH less than 5.5. Under ideal conditions permanganate can reduce concentrations by greater than 80% resulting in concentrations less than 0.045 mg/L (Health Canada, 2019).

Oxidation with permanganate requires precise optimization otherwise there may be remaining permanganate in the treated water, resulting in consumer complaints about the water colour. Optimization requires oxidation/reduction potential measurements to determine the necessary permanganate feed.

5.2.2.2 Chlorine Dioxide

Chlorine dioxide can oxidize Mn(II) to Mn(IV), and is best suited for source waters that do not have a high oxidant demand (Tobiason et al., 2008). Chlorine dioxide oxidation has reduced efficiency at low temperatures (less than 5°C) and pH levels (less than 5.5) (Knocke et al., 1990a). Kohl and Medlar (2006) reported removal efficiencies of 81-95%, achieving treated water concentrations as low as 0.001 mg/L.

The stoichiometric dosage is 2.45 mg ClO2 per mg Mn(II); however, during the oxidation reaction chlorine dioxide is not completely reduced to Cl^- and instead forms chlorite ($ClO2^-$). Chlorite will react with free chlorine to form chlorate, which is difficult to remove. As chlorate and chlorite have health based drinking water quality guidelines, it is recommended that the chlorine dioxide feed be limited to less than 1.2 mg/L (Health Canada, 2019).

5.2.2.3 Ozone

Ozone can oxidize Mn(II) but is less effective for achieving treated water concentrations less than 0.02 mg/L (Brandhuber et al., 2013; Tobiason et al., 2008). The stoichiometric dosage requirement for oxidation is 0.87 mg O3 per mg Mn(II), but the actual dosage required may be 2 to 5 times greater depending on the alkalinity and DOC of the source water (Knocke et al., 1990a). Increasing alkalinity promotes direct oxidation of Mn(II) by O3 and can reduce the effect of higher DOC concentrations.

While ozone can be effective under certain conditions, a high natural oxidant demand can result in a required dose sufficient to oxidize manganese to Mn(VII), which can discolour water (Gregory and Carlson, 2003).

5.2.2.4 Chlorine and Oxygen

Direct chemical oxidation of Mn(II) by chlorine and oxygen can also be used; however, this treatment is only effective under alkaline (pH between 8 and 9) conditions, due to slow reaction kinetics and high dosage requirements (Brandhuber et al., 2013).

5.2.3 Physical Separation

Physical separation methods include: coagulation/flocculation, sedimentation, dissolved air flotation, granular media filtration, and low pressure membrane filtration (Health Canada, 2019). The effectiveness of the selected physical separation method is dependent on: conversion of manganese to a particulate form, particle size and location in the treatment system where they are generated, and if the manganese oxides are present as particulate or colloidal solids (Health Canada, 2019).

5.2.4 Oxidation/Physical Separation

MnOx is capable of adsorbing and retaining Mn(II) due to its negative charge. The MnOx surface also acts as a catalyst for oxidation of Mn(II) (Health Canada, 2019). Filter media which can adsorb Mn(II) include: manganese greensand, pyrolusite, and conventional filters with MnOx coatings (Health Canada, 2019). Dosing with an oxidant is still required prior to contact with the filter media in order to maintain MnOx adsorption sites. These processes can achieve concentrations less than 0.015 mg/L (Brandhuber et al., 2013).

5.2.4.1 Manganese Greensand

Traditional manganese greensand is processed from glauconite and coated with a manganese base material (Sommerfeld, 1999). Greensand has an effective size of 0.03 to 0.35 mm and is effective at capturing small particles (Health Canada, 2019); however, it often requires pressure filtration due to higher head loss compared to silica. Greensand filters are suited to groundwater systems with iron and manganese concentrations less than 5 mg/L (Kohl and Medlar, 2006). Groundwater treatment plants using greensand have been able to achieve 86 to 100% manganese removal from source water concentrations between 0.35 and 0.52 mg/L, with treated water concentrations less than 0.020 mg/L (Kohl and Medlar, 2006).

Potassium permanganate or chlorine is typically used as the oxidant, and is applied to the raw water prior to contact with the greensand filter. Potassium permanganate oxidizes Mn(II) so it can be physically removed with the remaining Mn(II) adsorbed onto the filter media, with excess oxidant to regenerate adsorption sites. Lower doses of permanganate with chlorine (0.5 to 1.0 mg/L) are then used to regenerate the filter media and avoid discolouration of treated water from permanganate (Health Canada, 2019).

5.2.4.2 Pyrolusite

Pyrolusite is the mineral form of MnO_2, and filters are typically a blend of pyrolusite and sand (Health Canada, 2019). Chlorine is typically added prior to treatment to continuously regenerate the pyrolusite media (Health Canada 2019). Limited information is available on pyrolusite filtration; however, a review by Kohl and Medlar (2006) determined that treated water could achieve concentrations ranging from 0.001 to 0.024 mg/L.

5.2.4.3 MnOx on Conventional Filter Media

MnOx coatings on anthracite coal or silica sand media can adsorb Mn(II) in the presence of free chlorine or permanganate (Knocke et al., 1990b). Oxidation of Mn(II) across the filter continuously regenerates the MnOx adsorption sites and these filter systems are able to sustain themselves without operator intervention (Brandhuber et al., 2013). The effectiveness of these methods depends on the number of oxidation sites, pH (6 or higher), and concentration of free chlorine (0.5 to 1.0 mg/L). Under ideal conditions MnOx coated conventional filters can treat manganese concentrations as low as 0.015 mg/L and can be achieved from pre-filter concentrations up to 0.5 mg/L (Health Canada, 2019).

In comparison to post-filter chlorination, addition of pre-filter chlorination can result in a 10 to 50% increase in disinfection byproducts (Tobiason et al., 2008). The potential for formation of disinfection byproducts should be evaluated before consideration of this treatment method.

5.2.5 Biological Filtration

Manganese can be removed by naturally occurring bacteria present in biofilms or on filter media, which can oxidize Mn(II) to Mn(IV). The solid MnOx compounds are then removed by filter backwashing. The performance of biological filters is influenced by the: presence of oxidizing bacteria in the source water, ability to form an active biofilm under operating conditions, acclimation period of the bacteria (14 to 100 days), and ability to maintain biological activity during stresses to the filter (Health Canada, 2019). Physical-chemical factors include: DO levels (minimum 5 mg/L), pH (equal or greater than 6.3), redox potential of the source water (300 to 400 mV), and the initial Mn(II) concentration and filter loading rates (Kohl and Dixon, 2012). The presence of ammonia, nitrate, and sulphide in the source water can significantly reduce the effectiveness of biological filters (Health Canada, 2019).

Biological filtration is best suited to groundwater sources with consistent Mn(II) concentrations and physical chemical characteristics (Brandhuber et al., 2013). Biological filtration and softening can achieve treated water manganese concentrations less than 0.03 mg/L (Health Canada, 2019).

5.2.6 Softening and Ion Exchange

Lime or soda ash softening treatments can also remove manganese by raising the pH above the solubility limit (9.5) of manganese hydroxides and carbonates (Health Canada, 2019). The elevated pH will also increase the oxidation rate of Mn(II) in the presence of DO. This is generally not a cost effective treatment method, but it can be effective if chemical softening of the source water is already being undertaken.

Mn(II) can also be removed by cation exchange in zeolite softening processes (Health Canada, 2019). Backwashing the zeolite with a brine solution will remove manganese, iron, calcium, and magnesium accumulated on the resin (Health Canada, 2019).

5.2.7 Sequestration

Chemical sequestration can be used to control aesthetic water quality problems associated with the oxidation of dissolved Mn(II) to MnOx by binding dissolved Mn(II) so that it is not available for oxidation or precipitation. The addition of polyphosphates alone or in conjunction with chlorine is the most commonly reported method used to sequester manganese (Sommerfeld, 1999; Kohl and Medlar, 2006). Sequestration does not remove manganese from water, therefore, it should not be considered as a treatment option for drinking water systems that have manganese concentrations that are greater than the MAC.

When sequestration is used to reduce the potential for discoloured water, the potential for manganese accumulation and subsequent release in the distribution system should always be considered.

5.2.8 Other Manganese Sources and Residuals Management

Chemical addition and treatment plant processes can add manganese to water through: manganese impurities in coagulants, resolubilization of Mn(II) under anoxic conditions in sedimentation basins, and presence of dissolved manganese in recycle streams from solids processing (Tobiason et al., 2008). In cases where a treatment plant uses enhanced coagulation, manganese contamination of the ferric chloride can result in soluble manganese concentrations of up to 0.5 mg/L, with typical levels of manganese attributable to coagulant addition in surface water treatment plants ranging from 0.025 to 0.055 mg/L (Health Canada, 2019). Release from solids in sedimentation basins typically ranges from 0.01 to 0.10 mg/L with variations observed seasonally. Manganese in residuals recycle streams can range from 0.01 to 1 mg/L (Tobiason et al., 2008). Thus, while the total flow from residual processing side streams can be relatively small in comparison to the influent flow to the treatment plant the total mass loading of dissolved Mn(II) from such side streams can be quite significant. Careful sampling of dissolved Mn(II) concentrations in residuals processing side streams is strongly recommended.

5.2.9 Distribution System Considerations

Manganese in the distribution system can accumulate as solid deposits, periodically releasing manganese into the distribution system as a result of physical or chemical disturbances (Health Canada, 2019). The initial deposition of manganese oxides can occur at treated water concentrations as low as 0.02 mg/L, and a treated water manganese concentration of <0.015 mg/L is recommended to prevent the formation of manganese deposits (Brandhuber et al., 2013). Manganese deposits are a concern as they can scavenge and become sinks for heavy metals (Dong et al., 2003), that are released during disturbances to the system at much higher concentrations.

Key distribution system management options include:

- maintaining stable water chemistry;
- minimizing the amount of manganese entering the distribution system; and
- minimizing the potential for physical/hydraulic disturbances of the system (Brandhuber et al., 2015).

5.3 Small Water Systems

Direct oxidation and MnOx coated filters can be used effectively in small water systems and can achieve very low manganese concentrations through ongoing optimization of source water and treatment system conditions. It is expected that most small water systems will use greensand filters to reduce manganese concentrations in drinking water to acceptable levels.

5.4 Residential Scale Treatment

Residential drinking water treatment devices are also an option for reducing high levels of manganese. Appropriate treatment methods for removal of manganese on a residential scale include reverse osmosis, ion exchange/water softeners, and oxidizing filters. These systems are typically installed at the point-of-entry into the home, but can also be used at the point-of-use (taps or faucets). It should be noted that boiling water may increase the concentration of dissolved manganese in drinking water and is not recommended.

Selection of a water treatment device will depend on a variety of factors, including the concentration and form of manganese, and other water related parameters such as water hardness, iron content, alkalinity, and sulphide, ammonia and dissolved organic carbon concentrations.

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Appendix

Water Quality Advisory: Elevated Manganese in Drinking Water

Do Not Use Water for Reconstituting/Preparing Infant Formula.

Key Points:

- This notice is being issued because elevated levels of manganese have been measured in the drinking water supply that serves ________________.
- Manganese in the water supply has been measured at _____ mg/L, which exceeds Health Canada's - Maximum Acceptable Concentration (MAC) of 0.12 mg/L.
- According to Health Canada, increased levels of manganese may contribute to adverse health effects on the nervous system, especially in infants. The MAC is protective of this most vulnerable population (infants and young children).
- To reduce risks, the Drinking Water Officer/ Medical Health Officer advises:
  - Water from this water supply system should not be fed to infants nor used for preparing/reconstituting infant formula.
  - Older children and adults should consider in-home water filtration or reverse osmosis systems to reduce the levels of manganese in drinking water used for drinking and cooking.
  - Water may be used for showering, bathing and other household uses without concern.

Background Information on Manganese

- Most manganese intake comes from food; however water can also be a significant contributor in our diet. Manganese is an essential nutrient, and some manganese is required for proper bodily function, however high levels of manganese in drinking water have been associated with effects on neurological development. Infants are at highest risk, particularly those who consume powdered baby formula reconstituted from water that is high in manganese.
- Because of infants' increased water consumption relative to body weight, rapid brain development, an increased ability to absorb manganese and a decreased ability to remove manganese from their bodies, another suitable source of drinking water (e.g., bottled water) should be used to reconstitute and prepare powdered infant formula. Breastfeeding is not likely to be a route of significant exposure.
- Short-term ingestion of manganese in drinking water by older children and adults at levels slightly above the MAC is not expected to result in adverse effects, however, if there are concerns, an alternate source of water should be considered.
- It is not possible to quantify health effects of past exposure to manganese in individuals, however future exposure can be managed to reduce risks of neurological effects.

- Link to HealthFile #49g – Manganese in Drinking Water, at https://www.healthlinkbc.ca/services-and-resources/healthlinkbc-files
- For further information contact: ____________________

Guidance for Treatment of Rainwater Harvested for Potable Use

Version 1.1 / First Published August 2020

Ministry of Health

1. Objective

This guidance document provides a general overview of assessing risks and treatment of rainwater for potable use in British Columbia. It characterizes harvested rainwater as a type of surface water, meaning water from a source which is open to the atmosphere and includes streams, lakes, rivers, creeks and springs, as defined in the Drinking Water Protection Regulation (DWPR). This document is intended to supplement but not replace the existing surface water treatment objectives found in the Ministry of Health's Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (referred to herein as the BC Surface Water Treatment Objectives).

2. Background and Regulatory Framework

Two documents serve as the primary reference materials for treatment objectives for harvested rainwater: the BC Surface Water Treatment Objectives, and the Rainwater Harvesting Systems standard CSA B805-ICC 805 (produced by the CSA Group and the International Code Council, Inc. and referred to herein as the CSA/ICC Rainwater Standard).

In this guidance document, *rainwater* means: water collected from natural precipitation. Any system used to collect, convey, store, treat and distribute rainwater for use is a *rainwater harvesting system.* This definition is consistent with the CSA/ICC Rainwater Standard.

The British Columbia Building Code and local bylaws may have additional regulatory requirements for the use of harvested rainwater, including its use within single-family dwellings and other buildings. These are not included in this guidance document but should be consulted for reference.

Domestic water systems that serve only one single family residence are exempt from these guidelines, though owners may use them to develop safe systems that protect the health of household water users. The owner of any drinking water supply system servicing more than a single-family residence[1] who wishes to harvest rainwater for domestic use is required as a water supplier under the *Drinking Water Protection Act* (DWPA) and the DWPR to obtain the necessary permits from the local health authority (HA). A water use licence under the *Water Sustainability Act* (WSA) is not required for rainwater harvesting.

Under the DWPA, water suppliers have the responsibility to provide potable water to all users of their systems. As such, rainwater harvested for use as potable water in any drinking water supply system must be disinfected.[2] Schedule A of the DWPR specifies bacteriological water quality standards for potable water for the protection of human health. The DWPA and the DWPR give *Drinking Water Officers*[3] (DWOs) in each health authority the flexibility to address further microbiological, chemical and physical risks through applying site-specific treatment requirements to construction and operating permits. The Drinking Water Officers' Guide (DWOG) contains drinking water policies that must be considered by DWOs when making these statutory decisions, and DWOs must be consulted prior to planning or upgrading drinking water supply systems in the province. The DWOG further suggests best management practices which align with and/or further build on those detailed in the Guidelines for Canadian Drinking Water Quality (GCDWQ) as developed and updated regularly by Health Canada.

Reliability of water volume and quality should be a key consideration during all phases of development, including during the subdivision of land parcels. Given seasonal variations in precipitation, a water supply that relies solely on rainwater may face significant challenges with sufficient storage volume and capacity to cover extended drought periods. Additionally, the costs of using materials that comply with standards for potable water, of implementing sufficient treatment for potable rainwater systems, and of supplementing low volumes with bulk water can be significant. When these factors are considered, in many situations, harvested rainwater may be best suited for non-potable use only, or as a supplementary source to existing water supplies for the purposes of reducing stresses related to water quality and/or quantity.

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[1] The term "single-family residence" is not defined in the DWPA. As such, according to the Drinking Water Officers' Guide, it should be given its plain meaning and taken to mean any single residence; i.e., a domestic house. For example, seasonal accommodation for labourers, residences with guest houses and outbuildings would likely fall outside the term "single-family residence" as they are not a single domestic home. Rainwater may be used as a source of drinking water by commercial operations and by owners who rent out their single family residences, so long as it is made potable. A landlord must not rent a domestic accommodation rental unit that is not connected to a water supply system unless the landlord can provide the tenant with a supply of potable water for domestic purposes, according to Section 7 of the *Public Health Act*'s Health Hazards Regulation.

[2] See section 5 of the Drinking Water Protection Regulation: http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/200_2003#section5.

[3] Drinking Water Officer (DWO) is defined in the DWPA as a drinking water officer under Section 3 of the DWPA.

3. Purpose and Scope

3.1. Purpose

The intent of this guideline is to assist water suppliers and DWOs in ensuring harvested rainwater is made potable.

3.2 Scope

The focus of this guide is on the assessment of risks and appropriate treatment of harvested rainwater for potable use in drinking water supply systems.

This document does not address:

- Non-potable uses of rainwater.
- Stormwater runoff[4] harvested rainwater.
- Assessing collection capacity, storage volumes, reliability nor sustainability of rainwater as a source of domestic water. Annex C of the CSA/ICC Rainwater Standard recommends tank sizing and capacity methodologies.
- Instructions for how to design a rainwater system. Guidance is limited to high level outcomes related to processes for mitigating human health risks and contributing to potability.
- The appropriateness of rainwater sources as basis for subdivision approval.
- Standards for chemical contaminants. As with other sources, rainwater chemical parameters should be reviewed against the GCDWQ.

4. Rainwater Harvesting System Design

This section provides an approach to hazard identification, risk assessment and mitigation through system design, as well as determining appropriate treatment objectives to achieve potability.

Application must be made to the local health authority for the issuance of construction and operating permits under the DWPA prior to commencing construction of any system falling under the scope of this document. This process will look at how the water supplier plans to mitigate the risks identified for the proposed system. Treatment systems may be of a complexity that water suppliers might want to consider employing contracted consultants familiar with rainwater as a drinking water source, rainwater catchment and treatment objectives to assist with this process.

The process of designing a rainwater harvesting system should follow a risk assessment and mitigation strategy similar to any other potable water source in British Columbia. The Comprehensive

[4] Stormwater runoff, as per Section 3.1 of the CSA/ICC Rainwater Standard, is rainwater that is not roof runoff. This includes precipitation runoff from rain or snowmelt that flows over land and/or impervious surfaces (e.g. streets, parking lots, vegetative/green roofs, and roofs with public access).

Drinking Water Source-To-Tap Assessment Guideline, Drinking Water Source-To-Tap Screening Tool and the Water System Assessment User's Guide provide risk assessment and mitigation strategies suitable to a harvested rainwater water supply.[5]

4.1 Rainwater Harvesting Risks

Harvested rainwater can become contaminated through numerous pathways of exposure including via airborne particles, animal fecal matter, tree litter, and by the materials used to collect and store rainwater.

Harvested rainwater is at risk of contamination prior to reaching a collection point. This can occur through contact with air pollutants that are either regularly occurring or associated with specific events (e.g. forest fire). As these risks will vary between locations and over time, all existing and potential risk should be considered as part of a risk mitigation approach.

At the collection stage, rainwater passes over surfaces (often a roof) which are likely to harbour residual matter, namely airborne contaminants such as dust, fecal matter from birds or mammals, chemical contaminants or other organic matter (Fewtree & Kay 2008). The source and concentration of contamination may vary depending on conditions, and in some cases with seasons (Zhang et al. 2014).

4.2 Materials

Materials used to make collection surfaces and conveyancing systems may have a negative impact on harvested rainwater quality (Ward et al. 2010; Bae et al. 2019). Some roof surface materials are not recommended for potable water applications including those containing asbestos, copper or cedar, since these materials have components capable of leaching into the rainwater. There are some coatings and materials that are NSF/ANSI 61 compliant for potable water applications and components certified for potable water should be used in all conveyancing materials. In some environments, metal roofs, concrete tile and cool roofs (reflective roofs) produce a higher quality of harvested rainwater with lower dissolved organic carbon than shingle and green roofs.

Green roofs may produce discoloured water, as well as high concentrations of dissolved organic carbon which can lead to the formation of disinfection by-products that are harmful to human health if not adequately treated (Mendez et al. 2010; Zhang et al. 2014). The growing medium used in some green roofs is further correlated with a higher concentration of metals (such as arsenic) (Mendez et al. 2010). Green roofs may incur higher costs due to a need for more substantial treatment or costly testing for disinfection by-products. Given that green roofs may also produce a lower volume of water, these factors make green roofs not generally suitable for rainwater harvesting.

[5] All three documents are available, along with others, at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators

4.3 Storage

The quality of a harvested rainwater supply is impacted by storage time (stagnation), the environment and the materials in which water is being stored (Crabtree et al. 1996; Ahmed et al. 2010a; 2010b). These factors further interact depending on the quality of harvested rainwater as described in the previous paragraph. Primary filtration should take place before the water storage stage to prevent excessive buildup of organics in the tank. Storage tanks should be completely opaque to prevent algae growth. Thermal-resistant materials are ideal for storage tanks. Lighter colours will reflect sunlight, keeping water cooler on hot days than dark-coloured tanks. In general, storage tanks made of a dark coloured polyethylene are associated with creating a warmer environment for harvested rainwater and may impact microbial contamination of rainwater (Struck 2011).

The risk of opportunistic pathogens (e.g. Legionella) exists where water temperatures will be stored at a temperature at above 25 degrees Celsius. Therefore, tanks should be stored out of direct sunlight, and storage should be in-ground if there is a risk of temperatures exceeding 25 degrees Celsius. Best practice for the location of a storage tank recommends it not be located directly under sanitary, waste or storm drain pipes or in any other location that may increase the risk of contamination or microbial growth, such as a location subject to direct mid-day sun or above an onsite sewage disposal system (see the CSA/ICC Rainwater Standard). For systems without another potable source of water, it should be possible for storage tanks to be filled by bulk water haulers during drought periods. However, water collection, conveyancing and storage areas should not be accessible to the public.

Tanks and all associated components, including but not limited to sealants, fittings and linings contacting collected water, should comply with NSF/ANSI 61 and have a weighted average lead content of 0.25% or less when evaluated in accordance with NSF/ANSI 372. Solders and fluxes used in potable use rainwater harvesting systems should not exceed lead content greater than 0.2% by mass (see the CSA/ICC Rainwater Standard).

4.4 Risk Identification and Assessment

Identifying hazards and implementing control measures to mitigate potential health hazards is an essential aspect of any potable water supply system. A risk assessment process, such as the one outlined in Figure 1 below, serves as a tool for water systems to develop a more comprehensive understanding of the risks to drinking water safety and availability, designing risk mitigation measures, operating more effectively, and ensuring the best possible water quality. Understanding threats and vulnerabilities to drinking water supplies and the interdependency of their components equips water suppliers with the ability to make informed decisions about reducing or mitigating risks.

Figure 1: Flow Diagram for Rainwater Harvesting Risk Assessment Process

Site Visit

Identify potential off-site source contaminants that could impact catchment area such as:

- Air pollutants, agricultural chemicals and land use practices
- Waste disposal sites, industrial complexes or farming practices
- Local zoning, historical and current property use
- Rural vs urban landscapes

Hazard Identification

Identify potential on-site contaminants that could impact water quality such as:

- Fecal pathogens from animals or natural reservoirs of disease
- Chemical contamination from on-site air pollutants
- Leaching from roofing, conveyance or storage materials
- Debris or pests
- Pathogen proliferation caused by water stagnation or storage siting in direct sun
- Human activities or access

Source Water Quality Study

Assess the proposed treatment technology's effectiveness in providing potable water:

- Collect and analyze raw water samples to determine baseline water quality
- Identify constituents that can adversely affect treatment technologies
- Collect samples during initial portion of a storm event following arid conditions
- DWOs can require suppliers to complete a source assessment

A thorough evaluation should be done on land use in vicinity of the collection surface for both human and natural activity. Hazards identified should be documented to inform risk analysis, application of risk mitigation measures, and for measuring successes over time. The process may include surveys of potential sources of contamination and the frequency of occurrence of contamination events. A period of sampling for microbiological and/or chemical quality to characterize typical nature of the water quality may be valuable to ensuring that the design and treatment objectives (see section 5 in this guideline) applied are appropriate. It may be appropriate to sample in different seasons to obtain a robust representation of water quality throughout the year. Existing studies of raw rainwater collected directly from the air in close proximity to the site may be considered as a source of information for risk assessment at the discretion of the DWO; this can be helpful for systems that have not been constructed yet. For systems that will be using components that are already installed, baseline studies should involve sampling water that has come in contact with the existing components where possible.

Several tools exist to assist with the above-described process. The Comprehensive Drinking Water Source-To-Tap Assessment Guideline, Drinking Water Source-To-Tap Screening Tool and the Water System Assessment User's Guide are intended to help water suppliers develop a better understanding of the risks to drinking water safety and availability. Ongoing assessment and evaluation of potential offsite and onsite sources of contamination, as well as water quality, will be important in mitigating risks over the long term.

4.5 Design Considerations

Central to the risk assessment process is the implementation of control measures to ensure appropriate and effective risk mitigation. Table 1 below identifies some of the essential design considerations that can be administered in a rainwater harvesting system.

Table 1: Rainwater Harvesting Water System Design Considerations

Design Consideration	Reasoning
Collection Potential	Amount of available precipitation in the area
Output Demand	Required storage volume for intended use
NSF/ANSI 61, NSF/ANSI 372 and NSF P151 Materials (or third party certification)	Ensures materials adhere to minimum established health effects requirements for any chemical contaminants or impurities that are imparted to the water[6]
Air Gap or Backflow Preventer	Prevent potential cross contamination with other water supply system(s)[7]
Inlet Pre-Filter and Inlet Cover	Prevent entry of debris, roof contaminants and pests into water supply
First Flush Diverter[8]	Reduce contaminants in the harvested water supply
Food-Grade Plastic Storage	Retains acidic nature of harvested rainwater which can inhibit microbial growth
Covered or Shaded Storage	Retains cool temperatures of stored water which can slow microbial growth
Calmed Inlet	Brings oxygenated water to lower levels of tank, preventing stagnation and disturbance of debris at bottom of tank
Floating Intake	Extracts water from the tank where it is cleanest, just below the surface

[6] USEPA (2002) *Permeation and Leaching. Distribution System Issue Paper.* https://www.epa.gov/sites/production/files/2015-09/documents/permeationandleaching.pdf

[7] The DWPR prohibits the mixing of potable and non-potable water systems to protect human health.

[8] First flush diverter, as per Section 3.1 of the CSA/ICC Rainwater Standard, is a device or method for removal of sediment and debris from collection surface by diverting initial rainfall from entry into the storage tank. NSF/ANSI 61 provides further guidance on how to perform an effective flush. First flush diverters must be installed correctly and maintained regularly to work properly.

Alarm Systems	Systems to monitor, alert or shut-off supply when intake or output water quality standards not being achieved due to power failure or other incident
Secured Access	Prevents unauthorized access to water supply

5. Treatment Objectives

Drinking water treatment objectives provide a minimum performance target for water suppliers to treat water to produce potable water from harvested rainwater. The actual amount of treatment required will depend on the risks identified (see Section 4.1 and 4.2) and may require levels of treatment over and above those outlined below.

5.1 Treatment Objectives (Microbiological)

As this document has categorized rainwater as a surface water supply, most of the treatment objectives and the supporting reference material for this section can be found in the BC Surface Water Treatment Objectives. Further reasoning and explanation is provided when necessary within each sub-section where the treatment objectives differ or expand in the BC Surface Water Treatment Objectives.

This section outlines the following treatment objectives for the following pathogenic microbes: enteric viruses, bacteria, enteric protozoa in harvested rainwater for potable use:

- 4-log reduction or inactivation of viruses.
- 4-log reduction or inactivation of *Giardia* and *Cryptosporidium*.
- Two methods of treatment (dual treatment) for harvested rainwater.
- Less than or equal to (≤) one nephelometric turbidity unit (NTU) of turbidity.
- No detectable *E. coli*, fecal coliforms and total coliform.

5.1.1. 4-log Inactivation of Viruses

A minimum 4-log reduction of enteric viruses is recommended for all potable rainwater harvested systems. This is consistent with requirements for surface water in the BC Surface Water Treatment Objectives. Depending on the results of testing and ongoing monitoring, a greater than 4-log reduction may be necessary, as per the Surface Water Treatment Objectives.

While the CSA/ICC Rainwater Standard assumes that elevated collection surfaces are unlikely to become contaminated with human viruses and recommends this level of reduction only where a water supply system includes a below-ground tank (where there is potential for sewage contamination), this guideline takes a more precautionary approach to ensure air transported human viruses, or viruses that are capable of cross-species transfer are inactivated.

5.1.2. 4-log Inactivation of *Giardia* and *Cryptosporidium*

Protozoa such as *Giardia* and *Cryptosporidium* can be responsible for severe and, in some cases, fatal gastrointestinal illness. Local climate, the rate of pathogen occurrence, and the potential for higher pathogen concentrations increase the risks to human health associated with harvested rainwater for potable use (Ahmed et al. 2013; Schoen et al. 2017). As reliable and ongoing monitoring remains a challenge with a water supply such as harvested rainwater, the measures in place to ensure protection should aim to reduce the level of risk as much as possible.

A minimum 4-log reduction of enteric protozoa is recommended for all potable rainwater harvested systems. This is a higher level of reduction than recommended in the BC Surface Water Treatment Objectives but is aligned with the CSA/ICC Rainwater Standard (see Table 8.1). The 4-log reduction is based on the United States Environmental Protection Agency (USEPA) health based target of an annual risk of less than 1/10,000 persons per year (10^{-4} ppy) (USEPA 1989). The higher level of reduction is recommended based on the potential for rainwater harvested systems to harbour significantly higher concentrations of protozoa, as well as the potential for such water sources to experience an unpredictable rate of pathogen occurrence, when compared to other surface water sources.

5.1.3. Two Methods of Treatment (Dual Treatment)

To provide the most effective protection, the GCDWQ and the BC Surface Water Treatment Objectives recommend that filtration and one form of disinfection be used to meet the treatment objectives. The CSA/ICC Rainwater Standard also supports dual treatment and recommends filtration and disinfection of harvested rainwater supplies used for potable purposes. It is possible that a water supply system may be permitted to operate without filtration if certain conditions are met, as described in the BC Surface Water Treatment Objectives.

It is recommended that dual treatment should be applied to all rainwater harvested potable water supply systems. This is consistent with requirements for surface water in the BC Surface Water Treatment Objectives.

5.1.4. ≤1 NTU in Turbidity

Turbidity of treated harvested rainwater should be maintained at less than 1 NTU. Turbidity levels should comply with the GCDWQ on turbidity, as referenced in the BC Surface Water Treatment Objectives, and the same exceptions apply (see section 4.4).

5.1.5. No Detectable *E. Coli*, Fecal Coliform and Total Coliform

Schedule A of the DWPR requires that the treatment target for all potable water systems is to contain no detectable *E. coli* or fecal coliform per 100 ml. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of the samples should have no detectable total coliform bacteria per 100 ml and no sample should have more than 10 total coliform bacteria per 100 ml. The DWO may require increase the frequency of testing within the operating permit if deemed necessary.

5.2. Treatment Objectives (Physical and Chemical)

This document does not outline the required treatment mechanisms or equipment to remove chemical/physical contaminants but recognizes that such contaminants can reduce the effectiveness of disinfection methods (e.g., by increasing the chlorine demand or by blocking/absorbing UV irradiation). Where the risk assessment or subsequent monitoring identifies potential concerns due to the presence of chemicals or turbidity, appropriate treatment technologies should be applied. The GCDWQ should be consulted for further guidance.

6. Operation, Monitoring, Maintenance and Training

Operational monitoring is critical for ensuring the treatment objectives and control measures in place are effective, and that a system is supplying potable water. Identifying and monitoring critical control points in a water system allows opportunities for corrective actions to be taken. As part of any operation, maintenance plans, monitoring and record keeping are required.

Water quality should be monitored for all parameters identified in the risk assessment, which may be over and above the minimum required by the DWPA. If there is uncertainty about how water quality from a new supply may vary over time, the DWO may establish different sampling frequencies and parameters than those specified in section 8 of the DWPR. Additional parameters could include a comprehensive combination of microbial indicators (e.g., heterotrophic plate count (HPC) bacteria, Pseudomonas and Aeromonas). Testing and monitoring protocols should take into account that different rainwater collection surfaces in close proximity to each other can have vastly different bacteriological counts.

Rainwater harvesting systems require ongoing maintenance and cleaning. Maintenance activities could include: cleaning and sanitizing the collection, conveyance and storage systems; inspecting and verifying inlet pre-filters and first flush diverters are in working order; and removing overgrown foliage, accumulated debris and pest harborage locations.

Water system operators need to ensure sufficiently trained and qualified people are available to maintain the system. In B.C., the level of training and certification required for operators is tied to the size of the system and classification level assigned to a drinking water system by the [Environmental Operator's Certification Program]() (EOCP) or as required by the DWO through conditions on the operating permit. Many small water systems are exempt from training as per the DWPR, however a DWO may impose training requirements through conditions on permit when deemed necessary. Training specific to rainwater harvesting systems are listed (based on availability) on the EOCP Customer Relationship Management System, under the Career Management tab. The EOCP website and training guides are available to and recommended for anyone in the water industry.

Unforeseen circumstances that fall outside of an owner/operators' control will always pose a risk to the quality of water produced within any drinking water system. Water suppliers are required, as per

Section 10 of the DWPA with requirements outlined under Section 13 of the DWPR, to have an Emergency Response Plan (ERP). The Ministry of Health's Guide to Emergency Response and Contingency Plans for Water Supply Systems and Emergency Response and Contingency Planning for Small Water Systems documents are useful tools for developing an ERP. Water suppliers are encouraged to engage with their local DWO on ERP planning.

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Guidelines for Pathogen Log Reduction Credit Assignment

Version 1.0 / First Published January 2022

Ministry of Health

Table of Contents

1. Objective

To provide guidance on pathogen log reduction credit[1] assignment for the production of microbiologically safe[2] drinking water based on the type of treatment processes used and the applicable pathogen log reduction credit assignment criteria being met.

2. Background and Regulatory Framework

The *Drinking Water Protection Act* (DWPA) (2001) and Drinking Water Protection Regulation (DWPR) (2003) specify water quality standards[3], monitoring schedules and recommended treatment aimed at reducing the risks from pathogens in drinking water. There are three main types of pathogens in drinking water that pose risks to human health in BC: viruses, protozoa, and bacteria. The ingestion of these pathogens can result in short term illness and in some instances, serious long-lasting illnesses or even death.

To ensure the provision of clean, safe, and reliable drinking water in British Columbia, the multi-barrier approach is used. The multi-barrier approach is a system of procedures, processes and tools that collectively prevents or reduces the risk of contamination of drinking water from source-to-tap to reduce risks to human health[4]. Drinking water treatment is one component of the multi-barrier approach. Other components include source protection, operator training, water system maintenance, water quality monitoring and emergency response planning.

Section 5 of the DWPR requires that drinking water from a water supply system must be disinfected if the water originates from surface water, or groundwater that in the opinion of a Drinking Water Officer is at risk of containing pathogens. As "disinfection" is not defined in the DWPA or DWPR, technical guidance on disinfection is provided in this document, the Design Guidelines for Drinking Water Systems in British Columbia, the Guidelines for Ultraviolet Disinfection of Drinking Water and in provincial drinking water treatment objectives.

Provincial drinking water treatment objectives are set out in the following guidance documents, which are included in Part B to the Drinking Water Officers' Guide:

[1] A pathogen log reduction credit is a value assigned to a specific drinking water treatment process, expressed in log units, for the removal or inactivation of a specific microorganism or a group of microorganisms. A 1-log credit equals 90% reduction, a 2-log credit equals 99% reduction, a 3-log credit equals 99.9% reduction, and a 4-log credit equals 99.99% reduction.

[2] Health risks posed from chemical, physical, or radiological parameters are beyond the scope of this document. Secondary disinfection to maintain a chemical residual in the distribution system is also beyond the scope of this document. Information on secondary disinfection can be found in the British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems.

[3] Schedule A of the Drinking Water Protection Regulation.

[4] B.C. Office of the Provincial Health Officer (2019). Clean, Safe, and Reliable Drinking Water.

- Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia which provides a general overview of microbiological drinking water treatment objectives for surface water supplies; and

- Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia which specifies guidance on the treatment necessary to address microbiological contamination of groundwater sources and the assignment of subsurface filtration treatment credits.

Provincial drinking water treatment objectives for harvested rainwater are set out in the following guidance document, which supplements the existing provincial treatment objectives for surface water supplies:

- Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia which provides a general overview of assessing the risks and treatment of rainwater for potable use.

All surface water supplies require disinfection; however, the requirement to disinfect groundwater supplies only applies to groundwater sources at risk of microbiological contamination. The Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP) was developed to assist Health Authorities and water suppliers determine if a particular groundwater source requires disinfection. Risk factors that are discussed in the guideline include well construction, well location, aquifer characteristics and water quality results.

Minimum performance targets for surface water and groundwater at risk of containing pathogens are set out in the provincial drinking water treatment objectives.

Surface Water

The provincial drinking water treatment objectives for surface water supplies establish a minimum performance target for water suppliers to treat water to produce microbiologically safe drinking water. These objectives are often referred to as the "4-3-2-1-0 objectives" and are as follows:

- 4-log (99.99 percent) reduction of enteric viruses.
- 3-log (99.9 percent) reduction of *Giardia* and *Cryptosporidium* (both protozoa).
- 2 forms of treatment for pathogen log reduction - *see next paragraph.*
- 1-Less than or equal to 1 nephelometric turbidity unit (NTU) of turbidity.
- 0 detectable *E. coli,* total coliform, and fecal coliform (bacteria indicative of fecal presence – this objective is prescribed in the Regulation).

The provincial treatment objectives for surface water call for two forms of treatment. Filtration (as described in Section 6 of this document) followed by disinfection are the two forms of treatment recommended by Health Canada[5].

Groundwater

The provincial drinking water treatment objectives for groundwater supplies specify treatment objectives for groundwater at risk of containing pathogens (GARP), groundwater at risk of containing viruses only ('GARP-viruses only') and groundwater at low risk of containing pathogens.

Drinking water systems that draw water from sources determined to be GARP or 'GARP-viruses only' must employ disinfection. As a minimum, GARP water sources require disinfection by treatment methods that are equivalent to surface water supplies (i.e. 4-log reduction of enteric viruses, 3-log reduction of *Giardia* and *Cryptosporidium*, 2 forms of treatment for pathogen log reduction, less than 1 NTU turbidity, and 0 detectable *E. coli,* total coliform, and fecal coliform in delivered water). Water sources that are determined to be 'GARP-viruses only', require treatment for virus reduction only. Two forms of treatment are not required for 'GARP-viruses only' raw water sources.

Groundwater sources determined to be at low risk of containing pathogens do not require disinfection unless specified by a Drinking Water Officer per the DWPA.

3. Purpose and Scope

Under the DWPA, water suppliers are responsible for providing potable water to all users of their systems. This guideline provides provincial guidance[6] on the assignment of pathogen log reduction credits for drinking water systems using filtration, chemical disinfection and/or ultraviolet (UV) disinfection. The information in this document should be used by issuing officials during the approvals process, particularly with respect to the issuance of construction permits and operating permits under the *Drinking Water Protection Act* and the Drinking Water Protection Regulation. The information in this document can also be used by water suppliers, designers, and any other person or persons responsible for the planning and design of new water supply systems and when considering changes to existing systems.

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[5] Provincial treatment objectives allow a surface water or GARP water supply system to operate without filtration if conditions for filtration exemption are met, or a timetable to implement filtration has been agreed to by a Drinking Water Officer (see Section 6.11). The filtration exemption should be supported by a continuous assessment of water supply conditions to ensure that source water quality does not deteriorate due to changes in the surrounding watershed.

[6] The guidance in this document is not legally binding. In the event of an inconsistency between the guidance in this document and the DWPA, DWPR, a drinking water operating permit or construction permit, or any direction of a Drinking Water Officer, the guidance in this document gives way to legally binding requirements.

More detailed information on the design and operation of filtration, chemical disinfection and/or UV disinfection systems can be found in the Design Guidelines for Drinking Water Systems in British Columbia and the Guidelines for Ultraviolet Disinfection of Drinking Water.

4. Standards and Treatment Objectives

One of the goals of drinking water treatment is to reduce the presence of pathogens (disease-causing organisms) and associated health risks to an acceptable or tolerable level. Bacterial indicator water quality standards for potable water are specified in Schedule A to the DWPR as:

- No detectable fecal coliform bacteria per 100 mL of water.
- No detectable *Escherichia coli (E. coli)* per 100 mL of water.
- No detectable total coliform bacteria per 100 mL of water when 1 sample is collected in a 30 day period. Where more than 1 sample is collected in a 30 day period, at least 90% of samples have no detectable total coliform bacteria per 100 mL of water and no sample has more than 10 total coliform bacteria per 100 mL of water.

Provincial drinking water treatment objectives recommend minimum pathogen log reduction for protozoa and viruses based on source water type (see Table 1).

Table 1: Recommended Minimum Pathogen Log Reduction for Different Source Water Types

Source Water Type	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Surface Water	3	3	4
Rainwater	4	4	4
GARP	3	3	4
GARP – viruses only	0	0	4
Groundwater at low risk of containing pathogens	0	0	0

Depending upon site-specific considerations, the actual amount of treatment required will depend on the risks identified and may require higher levels of pathogen log reduction and therefore greater levels of treatment. Pathogen log reduction requirements should be determined by an issuing official in consultation with the water supply system owner based on the type of source water and any site-specific considerations.

5. Pathogen Log Reduction Credits

There are many different treatment technologies available to produce microbiologically safe drinking water. These technologies are assigned pathogen log reduction credits by issuing officials for *Cryptosporidium*, *Giardia,* and viruses.

Recommended pathogen log reduction credit assignment is based on the following guidance documents:

- Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ)
  1. Guideline Technical Document – Enteric Protozoa: *Giardia* and *Cryptosporidium* (2019)
  2. Guideline Technical Document – Enteric Viruses (2019)
  3. Guideline Technical Document – Turbidity (2012)

- United States Environmental Protection Agency
  4. Membrane Filtration Guidance Manual (2005)
  5. Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule (2006)

- British Columbia Ministry of Health
  6. Design Guidelines for Drinking Water Systems in British Columbia (2023)
  7. Guidelines for Ultraviolet Disinfection of Drinking Water (2022)

By combining the pathogen log reduction credits assigned for each treatment technology in a treatment train, the combined total can be used to meet the recommended minimum pathogen log reduction listed in Table 1 for the specified source water type and specified pathogen. Pathogen log reduction credit assignment is based on the treatment processes being fully operational and the applicable recommended pathogen log reduction credit assignment criteria being met. The recommended pathogen log reduction credit assignment criteria are specific to each treatment technology, and include design, operational, and monitoring criteria which are important for treatment performance. The Drinking Water Officer may include additional operational and monitoring requirements in terms and conditions to an operating permit.

Sections 6, 7 and 8 of this guidance document discuss the treatment technologies that are available for producing microbiologically safe drinking water and include the recommended pathogen log reduction credits that should be assigned based on treatment process type, and the criteria that should be met for credit assignment. Filtration technologies are discussed in Section 6, UV disinfection is discussed in Section 7 and chemical disinfection is discussed in Section 8. It should be noted that pathogen log reduction capabilities vary depending upon the type of filtration or disinfection technology being applied.

6. Filtration

Table 2 sets out maximum pathogen log reduction credit assignment for filtration systems. Pathogen log reduction credit assignment is based on filtration systems meeting operational and design criteria and consistently meeting filter effluent turbidity objectives.

Table 2: Maximum Pathogen Log Reduction Credit Assignment for Filtration Systems

Maximum Pathogen Log Reduction Credits Assigned [a]	***Cryptosporidium* Oocysts**	***Giardia* Cysts**	**Viruses**
Conventional Filtration	3	3	2
Direct Filtration	2.5	2.5	1
Slow Sand Filtration	3	3	2
Diatomaceous Earth Filtration	3	3	1
Microfiltration	4 [b]	4 [b]	0 [c]
Ultrafiltration	4 [b]	4 [b]	0 [c]
Nanofiltration	4 [b]	4 [b]	0 [c]
Reverse Osmosis	4 [b]	4 [b]	0 [c]
Cartridge Filtration, single unit (1 micron absolute)	2 [d]	2 [d]	0
Cartridge Filtration, two units in series (1 micron absolute)	2.5 [d]	2.5 [d]	0
Subsurface Filtration [e] (Well/Surface Water Separation)	1	1	0
Subsurface Filtration [e] (Subsurface Filtration Study)	3	3	0
Subsurface Filtration [e] (Demonstration of Performance)	3	3	4
Filtration Exemption	0	0	0

[a] Pathogen log reduction credit assignment is based on the specified filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Removal efficiency is demonstrated using challenge testing and verified by daily direct integrity testing in accordance with the guidance set out in the Membrane Filtration Guidance Manual (USEPA, 2005), or another method deemed acceptable by an issuing official.

[c] Pathogen log reduction credits for viruses are not assigned for membranes as direct integrity tests to verify virus-sized leaks are not commercially available.

[d] Challenge testing should demonstrate at least 3-log reduction of *Cryptosporidium* oocysts and *Giardia* cysts for each unit. However, the recommended maximum pathogen log reduction credit assignment for each protozoa is 2-log for a single unit and 2.5-log (total) for two units in series, providing a safety factor to account for the lack of daily direct integrity testing.

[e] Subsurface filtration is only considered as one of the two required treatment processes if it has been awarded greater than 1-log removal credit each for *Cryptosporidium* oocysts and *Giardia* cysts and the second treatment process achieves the remainder of the recommended minimum pathogen log reduction.

Filtration Overview

Filtration systems remove particulate matter from water by passage through porous or non-porous media. The Guidelines for Canadian Drinking Water Quality state that the combination of physical removal (e.g. filtration) and inactivation barriers is the most effective way to reduce protozoa in drinking water[7].

Filtration systems should be designed, operated, and appropriately optimized to reduce turbidity levels as low as reasonably achievable. Turbidity objectives are specified in the recommended pathogen log reduction credit assignment criteria for different filtration types (see Sections 6.1 – 6.9); however, all filtration systems should strive to achieve a treated water turbidity target from individual filters of < 0.1 NTU at all times[8].

Filtration that is considered to be 'pre-treatment' is not eligible for pathogen log reduction credit assignment. This includes:

- pressure filtration
- media filtration for chemical-specific removal (ion exchange resin, greensand, and engineered media e.g. for iron/manganese removal) and
- conventional or direct filtration without chemically-assisted coagulation.

Bag filters are also not eligible for pathogen log reduction credits because they have shown variable performance for turbidity reduction (especially when raw water turbidity exceeds 1 NTU) and poor *Cryptosporidium* oocyst removal. Bag filters have also been known to fail due to:

- improper installation
- filter leaks or tears due to the fragility of the filter material
- bursting due to clogging and subsequent over-pressurizing and
- pressure transients causing damage to filter seams (Hung *et al.*, 2007).

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[7] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Protozoa: *Giardia* and *Cryptosporidium*.

[8] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

Clarification (sedimentation or DAF) without subsequent filtration is not eligible for pathogen log reduction credits. Without filtration, clarification may not provide adequate protection or process flexibility to manage adverse water quality events and may cause downstream issues with treatment or water chemistry.

6.1 Conventional Filtration

Conventional Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Conventional Filtration	3	3	2

[a] Pathogen log reduction credit assignment is based on the conventional filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. A chemical coagulant is used at all times when the treatment process is in operation. 2. Chemical dosages are monitored and adjusted in response to variations in raw water quality. 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure during filter ripening to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from each filter[9] and from combined filter effluent where there are multiple filters[10]. 5. For each filter, filter effluent turbidity is less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95% of the measurements either per filter cycle or per month. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[9] Continuous monitoring of filter effluent turbidity from each individual filter is necessary to (1) ensure that each filter is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual filters should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[10] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

Conventional Filtration Overview

Conventional filtration uses chemical coagulation, rapid mixing, flocculation, solids separation and rapid rate gravity filtration to remove pathogens, dissolved organic carbon and particulate matter from the raw water supply.

Chemical coagulation involves the addition of chemical coagulants to promote the aggregation of dissolved and suspended particles in water into larger particles called floc, initiating faster settling and water clarification. Rapid mixing is used to introduce and uniformly disperse chemical coagulants into the raw water supply. The coagulant chemicals typically used for water treatment include aluminum salts (e.g. aluminum sulphate), iron salts, and organic and inorganic polymers.

Following coagulation, flocculation is used to facilitate larger floc formation by using gentle mixing to bring floc into contact with each other. Larger floc can then be removed by a sedimentation process in which floc settle out of solution, or by dissolved air flotation (DAF) where tiny air bubbles are used to float contaminants to the water surface where they can be removed by mechanical skimming. Rapid rate gravity filtration is used to physically remove additional particulate matter and pathogens from the raw water supply by passing the water through porous media (e.g. sand, anthracite and/or granular activated carbon).

Conventional filtration is primarily used for the treatment of raw water supplies (or influent water after pre-treatment) with turbidity values of less than 3,000 NTU, total coliform counts of less than 20,000 per 100 mL, and colour measurements of less than 75 true colour units (TCU)[11].

[11] Washington State Department of Health (2019). Water System Design Manual.

6.2 Direct Filtration

Direct Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Direct Filtration	2.5	2.5	1

[a] Pathogen log reduction credit assignment is based on the direct filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. A chemical coagulant is used at all times when the treatment process is in operation. 2. Chemical dosages are monitored and adjusted in response to variations in raw water quality. 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure during filter ripening to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from each filter[12] and from combined filter effluent where there are multiple filters[13]. 5. For each filter, filter effluent turbidity is less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95% of the measurements either per filter cycle or per month. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[12] Continuous monitoring of filter effluent turbidity from each individual filter is necessary to (1) ensure that each filter is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual filters should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[13] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

Direct Filtration Overview

Direct filtration uses chemical coagulation, rapid mixing, flocculation, and rapid rate gravity filtration. It is very similar to conventional filtration (see Section 6.1) but without the solids separation step prior to the filtration process. Direct filtration is primarily used for the treatment of raw water supplies (or influent water after pre-treatment) with turbidity values of less than 15 NTU, total coliform counts of less than 500 per 100 mL, colour measurements of less than 40 true colour units (TCU)[14], and low concentrations of algae, iron, and manganese. Pre-treatment processes can allow for greater levels of raw water turbidity, total coliform, or colour to be managed by direct filtration, and pilot testing may demonstrate that a direct filtration system has the ability to process higher levels of influent turbidity based on the system design parameters.

In-line filtration – coagulation with in-line mixing but no dedicated flocculation stage – may be acceptable for high quality raw water supplies (i.e. turbidity values of less than 5 NTU, total coliform counts of less than 500 per 100 mL, and colour measurements of less than 5 TCU) at the discretion of the Drinking Water Officer.

Compared to conventional filtration, the advantages of direct filtration include lower capital costs because there is no solids separation step, lower operating and maintenance costs, and potentially lower chemical costs due to lower coagulant usage. The disadvantages include shorter response times to address changes in raw water quality and a shorter detention time for controlling seasonal taste and odour problems.

[14] Washington State Department of Health (2019). Water System Design Manual.

6.3 Slow Sand Filtration

Slow Sand Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Slow Sand Filtration	3	3	2

[a] Pathogen log reduction credit assignment is based on the slow sand filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. An active biological layer is maintained. 2. Effective filter cleaning procedures are regularly carried out. 3. Filter-to-waste or an equivalent procedure is used during filter ripening periods. 4. Filter effluent turbidity is continuously monitored and recorded from each filter[15] and from combined filter effluent where there are multiple filters[16]. 5. For each filter, filter effluent turbidity is less than or equal to 1.0 nephelometric turbidity unit (NTU) in at least 95% of the measurements either per filter cycle or per month. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 3.0 NTU.

[15] Continuous monitoring of filter effluent turbidity from each individual filter is necessary to (1) ensure that each filter is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual filters should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity). For facilities needing monitoring equipment upgrades, daily grab samples for turbidity monitoring may be considered an acceptable interim measure at the discretion of the Drinking Water Officer.

[16] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

Slow Sand Filtration Overview

Slow sand filtration is a process involving the passage of raw water through a bed of sand at low velocity (generally less than 0.4 m/h) resulting in substantial particulate removal by physical and biological mechanisms[17]. Filter effectiveness depends on the formation of the schmutzdecke — a layer of bacteria, algae, and other microorganisms on the surface of the sand — and the formation of a biological population within the sand bed[18].

Slow sand filtration is generally limited to raw water supplies (or influent water after pre-treatment) with applied filter turbidity values of less than 10 NTU, total coliform counts of less than 800 per 100 mL, and colour measurements of less than 5 true colour units (TCU). The treatment process can handle higher source water turbidity, coliforms, and colour if additional pre-treatment is provided[19]. Process efficiency depends upon water turbidity, nutrient levels, and temperature.

[17] 40 CFR Ch. 1, s 141.2.

[18] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

[19] Washington State Department of Health (2019). Water System Design Manual.

6.4 Diatomaceous Earth Filtration

Diatomaceous Earth Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Diatomaceous Earth Filtration	3	3	1

[a] Pathogen log reduction credit assignment is based on the diatomaceous earth filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. A minimum 3.175 mm (1/8") thickness of pre-coat is maintained. 2. Effective filter cleaning procedures are maintained. 3. Full recycle or partial discharge to waste of water flow during filter pre-coat is maintained until recycle stream turbidity falls below 1.0 nephelometric turbidity unit (NTU)[20]. 4. Filter effluent turbidity is continuously monitored and recorded from each filter[21] and from combined filter effluent where there are multiple filters[22]. 5. For each filter, filter effluent turbidity is less than or equal to 1.0 NTU in at least 95% of the measurements either per filter cycle or per month. 6. The diatomaceous earth filtration process is specifically tested and confirmed by an independent testing agency for the removal of *Cryptosporidium* oocysts or removal of surrogate particles. 7. For each filter, the maximum level of filter effluent turbidity is less than or equal to 3.0 NTU.

[20] Recycle stream turbidity can be monitored continuously or via grab sampling.

[21] Continuous monitoring of filter effluent turbidity from each individual filter is necessary to (1) ensure that each filter is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual filters should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[22] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

Diatomaceous Earth Filtration Overview

Diatomaceous earth filtration is a process resulting in substantial particulate removal in which (1) a pre-coat cake of diatomaceous earth filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake[23].

Diatomaceous earth filtration is generally limited to raw water supplies (or influent water after pre-treatment) with turbidity values of less than 5 NTU, total coliform counts of less than 50 per 100 mL, and colour measurements of less than 5 true colour units (TCU)[24].

[23] 40 CFR Ch. 1, s 141.2.

[24] Washington State Department of Health (2019). Water System Design Manual.

6.5 Microfiltration

Microfiltration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Microfiltration	4 [b]	4 [b]	0 [c]

[a] Pathogen log reduction credit assignment is based on the microfiltration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Removal efficiency is demonstrated using challenge testing and verified by direct integrity testing.

[c] Pathogen log reduction credits for viruses are not assigned for membranes as direct integrity tests to verify virus-sized leaks are not commercially available.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. *Cryptosporidium* and *Giardia* removal efficiency is demonstrated using challenge testing and verified by daily direct integrity testing in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005) or ANSI/NSF Standard 419. 2. Membrane integrity is monitored using continuous indirect integrity monitoring in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from individual membrane units in each filter[25] and from combined filter effluent where there are multiple filters[26]. 5. For each filter, filter effluent turbidity is less than or equal to 0.1 nephelometric turbidity units (NTU) in at least 99% of the measurements per operational filter period or per month[27]. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

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[25] Continuous monitoring of filter effluent turbidity from individual membrane units is necessary to (1) ensure that each unit is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual membrane units should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[26] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

[27] Measurements greater than 0.1 NTU for a period of greater than 15 minutes from an individual membrane unit should immediately trigger an investigation of the membrane unit integrity.

Microfiltration Overview

Microfiltration is a low operating pressure membrane process with a relatively low feed water operating pressure of approximately 100 to 400 kPa that is used to remove particles, sediment, algae, protozoa, and bacteria. Microfiltration membranes typically have a pore size range of 0.1 to 10 μm. Water is filtered through a thin wall of porous material.

The main mechanism for removal of particulate matter is through straining or size exclusion, and the types of contaminants that are removed depend partially on the pore size or molecular weight cut-off of the membrane[28]. Pre-treatment with coagulation can be applied to improve contaminant removal; however, fouling may affect membrane performance.

[28] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

6.6 Ultrafiltration

Ultrafiltration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Ultrafiltration	4 [b]	4 [b]	0 [c]

[a] Pathogen log reduction credit assignment is based on the ultrafiltration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Removal efficiency is demonstrated using challenge testing and verified by direct integrity testing.

[c] Pathogen log reduction credits for viruses are not assigned for membranes as direct integrity tests to verify virus-sized leaks are not commercially available.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. *Cryptosporidium* and *Giardia* removal efficiency is demonstrated using challenge testing and verified by daily direct integrity testing in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005) or ANSI/NSF Standard 419. 2. Membrane integrity is monitored using continuous indirect integrity monitoring in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from individual membrane units in each filter[29] and from combined filter effluent where there are multiple filters[30]. 5. For each filter, filter effluent turbidity is less than or equal to 0.1 nephelometric turbidity units (NTU) in at least 99% of the measurements per operational period or per month[31]. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[29] Continuous monitoring of filter effluent turbidity from individual membrane units is necessary to (1) ensure that each unit is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual membrane units should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[30] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

[31] Measurements greater than 0.1 NTU for a period of greater than 15 minutes from an individual membrane unit should immediately trigger an investigation of the membrane unit integrity.

Ultrafiltration Overview

Ultrafiltration is a lower pressure membrane process characterized by a wide band of molecular weight cut-off and pore sizes for the removal of small colloids, particulates and, in some cases, viruses. Ultrafiltration membranes typically have a pore size range of 0.01 to 0.1 µm. Similar to microfiltration, water is filtered through a thin wall of porous material.

The main mechanism for removal of particulate matter is through straining or size exclusion, and the types of contaminants that are removed depend partially on the pore size or molecular weight cut-off of the membrane[32]. Pre-treatment with coagulation can be applied to improve contaminant removal; however, fouling may affect membrane performance.

It is recognized that challenge testing has demonstrated that ultrafiltration membranes are capable of providing significant virus reduction. However, given the lack of viable direct integrity tests to detect virus-sized fiber breaks, virus log reduction credit assignment is not recommended.

[32] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

6.7 Nanofiltration

Nanofiltration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Nanofiltration	4 [b]	4 [b]	0 [c]

[a] Pathogen log reduction credit assignment is based on the nanofiltration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Removal efficiency is demonstrated using challenge testing and verified by direct integrity testing.

[c] Pathogen log reduction credits for viruses are not assigned for membranes as direct integrity tests to verify virus-sized leaks are not commercially available.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. *Cryptosporidium* and *Giardia* removal efficiency is demonstrated using challenge testing and verified by daily direct integrity testing in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 2. Membrane integrity is monitored using continuous indirect integrity monitoring in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 3. Filter effluent turbidity is continuously monitored and recorded from individual membrane units in each filter[33] and from combined filter effluent where there are multiple filters[34]. 4. For each filter, filter effluent turbidity is less than or equal to 0.1 nephelometric turbidity units (NTU) in at least 99% of the measurements per operational filter period or per month[35]. 5. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[33] Continuous monitoring of filter effluent turbidity from individual membrane units is necessary to (1) ensure that each unit is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual membrane units should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[34] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

[35] Measurements greater than 0.1 NTU for a period of greater than 15 minutes from an individual membrane unit should immediately trigger an investigation of the membrane unit integrity.

Nanofiltration Overview

Nanofiltration is a low-pressure reverse osmosis process for the removal of larger cations (e.g., calcium and magnesium ions) and organic molecules. Nanofiltration membranes are typically considered non-porous and are reported to reject particles in the size range of 0.5-2 nm. Nanofiltration is based on preferential diffusion to achieve separation of dissolved solutes from water. Nanofiltration can also remove particulate matter, although it is not intended specifically for this purpose as high particulate loadings can cause the membrane to foul rapidly[36].

[36] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

6.8 Reverse Osmosis

Reverse Osmosis Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Reverse Osmosis	4 [b]	4 [b]	0 [c]

[a] Pathogen log reduction credit assignment is based on the reverse osmosis treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Removal efficiency is demonstrated using challenge testing and verified by direct integrity testing.

[c] Pathogen log reduction credits for viruses are not assigned for membranes as direct integrity tests to verify virus-sized leaks are not commercially available.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. *Cryptosporidium* and *Giardia* removal efficiency is demonstrated using challenge testing and verified by daily direct integrity testing in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 2. Membrane integrity is monitored using continuous indirect integrity monitoring in accordance with the guidance set out in the Membrane Filtration Guidance Manual (2005). 3. Filter effluent turbidity is continuously monitored and recorded from individual membrane units in each filter[37] and from combined filter effluent where there are multiple filters[38]. 4. For each filter, filter effluent turbidity is less than or equal to 0.1 nephelometric turbidity units (NTU) in at least 99% of the measurements per operational filter period or per month[39]. 5. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[37] Continuous monitoring of filter effluent turbidity from individual membrane units is necessary to (1) ensure that each unit is functioning properly; (2) help determine when to end filter runs; and (3) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual membrane units should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity).

[38] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

[39] Measurements greater than 0.1 NTU for a period of greater than 15 minutes from an individual membrane unit should immediately trigger an investigation of the membrane unit integrity.

Reverse Osmosis Overview

Reverse osmosis is a high-pressure membrane process based on diffusion of water through a semi-permeable membrane as a result of a concentration gradient. Reverse osmosis membranes are considered to be non-porous and are used to remove dissolved solids, such as sodium, chloride, and nitrate, from water. Similar to nanofiltration, reverse osmosis is based on preferential diffusion to achieve separation of dissolved solutes from water. Reverse osmosis can also remove particulate matter, although it is not intended specifically for this purpose as high particulate loadings can cause the membrane to foul rapidly[40].

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[40] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

6.9 Cartridge Filtration

Cartridge Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Cartridge Filtration, one unit [1 micron absolute pore size]	2 [b]	2 [b]	0
Cartridge Filtration, two units in series [1 micron absolute pore size]	2.5 [b]	2.5 [b]	0

[a] Pathogen log reduction credit assignment is based on the cartridge filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[b] Challenge testing should demonstrate at least 3-log reduction of *Cryptosporidium* oocysts and *Giardia* cysts for each unit. However, the recommended maximum pathogen log reduction credit assignment for each protozoa is 2-log for a single unit and 2.5-log (total) for two units in series, providing a safety factor to account for the lack of daily direct integrity testing.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. Materials coming into contact with water conform to ANSI/NSF Standard 61.   2. The cartridge filtration process is specifically tested and confirmed by an independent testing agency for at least 3-log removal of *Cryptosporidium* oocysts or surrogate particles (e.g. conforming to ANSI/NSF Standard 53 would satisfy this criterion for low flow systems)   3. Differential pressure across the filter medium is continuously measured and does not exceed the manufacturer's rating.   4. Filter effluent turbidity is continuously monitored and recorded[41] from each filter and from combined filter effluent where there are multiple filters[42].   5. For each filter, filter effluent turbidity is less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95% of the measurements per month.   6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.

[41] Continuous monitoring of filter effluent turbidity from each individual filter is necessary to (1) ensure that each filter is functioning properly and (2) detect any short-term or rapid increases in turbidity that represent a process failure and a potential health risk. Filter effluent turbidity levels from individual filters should be continuously measured (with an online turbidimeter) and recorded at intervals no longer than five minutes apart at a point in each individual filter effluent line (see the Health Canada Guideline Technical Document for Turbidity). For facilities needing monitoring equipment upgrades, daily grab samples for turbidity monitoring may be considered an acceptable approach at the discretion of the Drinking Water Officer.

[42] The combined filter effluent should also be monitored at some point downstream of the combined filter effluent line or the clearwell or tank. Continuous monitoring of combined filter effluent turbidity will help ensure that the quality of water entering the distribution system has not deteriorated following filtration (see the Health Canada Guideline Technical Document for Turbidity).

Cartridge Filtration Overview

Cartridge filtration is a pressure-driven physical separation process that removes particles greater than 1 μm using a porous filtration medium. Cartridge filters are typically made of a semi-rigid or rigid wound filament that is housed in a pressure vessel in which water flows from the outside of the cartridge to the inside. Cartridge filtration systems can be constructed with either single or multiple filters within one pressure vessel[43].

Cartridge filters effectively remove particles from water in the size range of *Cryptosporidium* oocysts (2-5 microns) and *Giardia* cysts (5-10 microns). Cartridge filters do not significantly remove viruses[44]. Challenge testing should demonstrate at least 3-log reduction of *Cryptosporidium* and *Giardia* for individual cartridge filters; however, credit assignment for each protozoa should be 2-log reduction as cartridge filters lack daily direct integrity tests to confirm ongoing performance. For two cartridge filters in series, the total credit assignment for each protozoa should be 2.5-log reduction.

Cartridge filtration is generally limited to raw water supplies with applied filter turbidity values of less than 5 NTU. Cartridge filters can handle higher source water turbidity if additional pre-treatment is provided. Special studies are required to determine equipment-specific total coliform and colour limitations[45]. To reduce the frequency of filter replacement, cartridge filters are typically used in series with decreasing pore sizes.

Cartridge filters with filters and/or housings that are not certified by an approved testing agency are not eligible for pathogen log reduction credit assignment.

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[43] Health Canada (2012). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Turbidity.

[44] Government of Ontario (2006). Procedure for Disinfection of Drinking Water in Ontario.

[45] Washington State Department of Health (2019). Water System Design Manual.

6.10 Subsurface Filtration

Subsurface Filtration Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Subsurface Filtration (Well/Surface Water Separation)	1	1	0
Subsurface Filtration (Subsurface Filtration Study)	3	3	0
Subsurface Filtration (Demonstration of Performance)	3	3	4

[a] Subsurface filtration is only considered as one of the two required treatment processes if it has been awarded greater than 1-log removal credit each for *Cryptosporidium* oocysts and *Giardia* cysts and the second treatment process achieves the remainder of the recommended minimum pathogen log reduction.

Recommended Pathogen Log Reduction Credit Assignment Criteria

1. Groundwater wells are properly constructed, have a satisfactory well protection plan in place, and draw from an unconsolidated and granular aquifer (e.g., sand and gravel). Aquifers have interconnected pores without substantial cementation which might indicate preferential flow pathways.
2. Subsurface filtration effectiveness is demonstrated by either well/surface water separation, a subsurface filtration study or by demonstration of performance.
3. If Microscopic Particulate Analysis (MPA) testing has been conducted, the groundwater source is not considered 'high risk'. Wells drawing from MPA high risk sources are ineligible for subsurface filtration credits.
4. Well water turbidity is monitored and recorded for each groundwater well at equal intervals (at least every four hours) immediately prior to where disinfection occurs. Different sampling requirements and intervals may be specified by a DWO.
5. For each well, well water turbidity is around 1.0 nephelometric turbidity unit (NTU)[46] in at least 95% of the measurements per month.
6. For each well, the maximum level of well water turbidity is less than or equal to 3.0 NTU.

[46] To ensure effectiveness of disinfection and for good operation of the distribution system, it is recommended that water entering the distribution system have turbidity levels of 1.0 NTU or less. For systems that use groundwater, turbidity should generally be below 1.0 NTU (Health Canada (2020). Guidelines for Canadian Drinking Water Quality – Summary Table).

Subsurface Filtration Overview

Subsurface filtration (also called riverbank filtration) is a naturally occurring process that filters surface water as it passes through river or lakebed sediments, lake/riverbank substrate, and into an aquifer before being drawn up by a well. Engineered filtration structures, such as infiltration galleries, are not naturally occurring and therefore are not considered equivalent to subsurface filtration treatment[47].

The effectiveness of subsurface filtration is site-specific and can depend on many factors such as surface water quality, water temperature, groundwater flow conditions, dilution rates, surface water-groundwater interface characteristics (such as pH, specific surface area of substrate particles, and organic matter content), and aquifer material (Wang et al., 2002). Further, subsurface filtration can vary seasonally and in response to extreme climatic events (Hrudey and Hrudey, 2004).

Subsurface filtration effectiveness should be demonstrated by either well/surface water separation, a subsurface filtration study or by demonstration of performance. Groundwater wells drawing from groundwater sources identified as 'high risk' by Microscopic Particulate Analysis (MPA) testing are <u>ineligible</u> for any subsurface filtration credits.

Subsurface Filtration Demonstration Methods

Well/Surface Water Separation

For well/surface water separation, wells that meet the following criteria are eligible for a 1-log credit for *Cryptosporidium* and *Giardia*:

- The wells are located at least 15 m from a surface water source (i.e., high water mark for horizontal separation, riverbed for vertical separation) through the shortest flow path.
- The wells have core samples collected along at least 85% of the well screen depth with composite samples that:
  - are collected at intervals of no greater than 60 cm (2 feet) in length and have more than 10% of particles passing through a 1.5 mm screen; or
  - in the absence of continuous core samples, a DWO may consider wells screened in sand with a grain size of 1 mm[48] or finer where well log information is provided, supplemented by field review and aquifer mapping (if available).

A 1-log credit based on well/surface water separation cannot be assigned **in addition to** log credits associated with other subsurface treatment credit demonstration methods (i.e. subsurface filtration study or demonstration of performance).

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[47] B.C. Ministry of Health (2017). Drinking Water Officers' Guide.

[48] Sand with a diameter of 1 mm is considered medium sand according to the Unified Soil Classification System (ASTM, 2006) and coarse sand according to the Canadian System of Soil Classification (SCWG, 1998).

Subsurface Filtration Study

Treatment credits for subsurface filtration may also be obtained through the completion of a subsurface filtration study. Hydrogeological conditions should be determined by a qualified professional[49] to characterize the subsurface filtration in question and should include the collection of a minimum of two paired (surface water and groundwater) MPA samples; one MPA sample pair must be collected annually under or close to worst-case conditions to establish and maintain this treatment credit. Alternatives to MPA testing (including analysis of surrogates for *Cryptosporidium* and *Giardia*) may be considered at the discretion of the DWO. The scope of the subsurface filtration study, including water quality sample timing and proposed analyses, should be established by the qualified professional, and submitted to the DWO for consideration prior to the start of the study, and should consider the following factors[50]:

Surface Water Conditions

- Historic flow patterns
- Seasonal variations
- 50, 100, and 200-year flood levels (considering diking, where applicable)
- High water mark
- Likelihood of extreme precipitation events and the impact on surface water quality
- Assessment of potential for riverbank or lakebed scour and flow rates that may cause scour
- Expected flooding frequency
- Clogging potential

Aquifer Conditions

- British Columbia Aquifer Classification System ranking
- Grain size and porosity
- Aquifer stratigraphy and lithology
- Hydraulic conductivity
- Storativity and transmissivity (in confined aquifers)
- Groundwater dilution rate (related to the pumping rate)
- Groundwater flow directions and gradients (under both natural and pumping conditions)
- Groundwater flow rate or velocity

Well Conditions

- The location and construction of a well should be consistent with legislated construction standards
- Time of travel from high water mark to well under various pumping and water level conditions

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[49] A qualified professional is an individual who is registered with Engineers and Geoscientists BC with competency in the field of hydrogeology and experience in evaluating sources of groundwater supply.

[50] Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia (2015).

- Water level readings to capture seasonal fluctuations and recharge events (monthly readings should be completed at a minimum, however, continuous monitoring is ideal); sampling frequency can be reduced if aquifer does not show significant variation
- Pumping test data
- Well capture zone
- Summary of hydrogeological cross sections showing stratigraphy, aquifers, confining layers, well capture zones under high pumping and high surface water stage conditions

Groundwater and Surface Water Quality

- Paired MPA sampling results
- Total coliforms, *E. coli*, level and nature (organic vs inorganic) of turbidity
- Field measurements of temperature, pH, electrical conductivity
- Observed variations between groundwater and surface water quality with time
- Correlation between variations in surface water and groundwater quality employing statistical methods

Demonstration of Performance

Demonstration of Performance is based on the completion of a Subsurface Filtration Study but with a far more rigorous testing protocol. For an eligible well drawing from a GARP source, subsurface filtration may be considered for up to 3-log removal credit for *Cryptosporidium* oocysts and *Giardia* cysts and, in some cases, up to 4-log removal credit for viruses where proven by a Demonstration of Performance Study.

To maintain a treatment credit obtained as a result of a subsurface filtration study or demonstration of performance, water suppliers should collect and submit for analysis at least one pair (groundwater and surface water) of MPA samples (and virus surrogate samples, if virus credit was obtained) annually or at a frequency agreed upon by the Drinking Water Officer. The timing of the sample should coincide with the reasonable worst-case conditions, as identified during the initial MPA sampling[51].

Subsurface filtration should only be considered as one of the two required treatment processes if it has been awarded greater than 1-log removal credit each for *Cryptosporidium* oocysts and *Giardia* cysts and the second treatment process achieves the remainder of the recommended minimum pathogen log reduction.

Detailed information on subsurface filtration including pathogen log reduction credit maintenance can be found in Appendix A to the Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia.

[51] Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia (2015).

6.11 Filtration Exemption

Filtration Exemption Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Filtration Exemption	0	0	0

Recommended Filtration Exemption Criteria
1. Overall pathogen inactivation is met using a minimum of two types of disinfection providing at a minimum 3-log reduction of *Cryptosporidium* and *Giardia*, and 4-log reduction of viruses. 2. The number of *E. coli* in raw water does not exceed 20/100 mL (or if *E. coli* data are not available, less than 100/100 mL of total coliform) in at least 90% of the weekly samples from the previous six months[52]. 3. For all water systems, treated water is to contain no detectable *E. coli* or fecal coliform per 100 mL. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of samples have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL. **For Surface Water Supplies:** 4. Average daily turbidity levels measured at equal intervals (at least every four hours) immediately before the disinfectant is applied are around 1 nephelometric turbidity unit (NTU)[53] and do not exceed 5 NTU for more than two days in a 12-month period. 5. A watershed control program[54] is maintained that minimizes the potential for fecal contamination in the source water. **For Groundwater Supplies:** 6. Average daily turbidity levels measured at equal intervals (every four hours or at an interval acceptable to the Drinking Water Officer) immediately prior to any disinfection process are around 1 NTU[53] and do not exceed 5 NTU for more than two days in a 12-month period.

[52] A longer monitoring period may be required at the discretion of the DWO to capture seasonal variations and annual trends in raw water quality. For UV equipment design, two years of data (including UVT) is recommended (B.C. Guidelines for Ultraviolet Disinfection of Drinking Water, 2021).

[53] To ensure the effectiveness of disinfection and for good operation of the distribution system, it is recommended that water entering the distribution system have turbidity levels of 1.0 NTU or less. (Health Canada (2020). Guidelines for Canadian Drinking Water Quality – Summary Table).

[54] Watershed control program requirements are not set out in the Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia (2012). The Comprehensive Drinking Water Source-to-Tap Assessment Guideline, Modules 1, 2, 7 & 8 could be considered for this purpose or another method deemed acceptable by a DWO.

Recommended Filtration Exemption Criteria
7. The well is properly constructed and protected to minimize the potential for fecal or other pathogenic-related contamination in the source water, and a Well Protection Plan (or equivalent satisfactory to the DWO) is in place.

Filtration Exemption Overview

Provincial treatment objectives allow a surface water or GARP water supply system to operate without filtration if conditions for filtration exemption are met, or a timetable to implement filtration has been agreed to by a Drinking Water Officer. To assist in the filtration exemption process, the Drinking Water Officer has the discretion to rely on additional sample types to account for local water quality influences and contaminants that could affect treatment. Even though there are no pathogen log reduction credits assigned, the filtration exemption should be recorded pursuant to Section 10 of these guidelines to facilitate open and transparent communication on how the drinking water system is meeting the provincial drinking water treatment objectives.

If a water supply system is permitted to operate without filtration, it does not mean that filtration will not be required in the future. Changes in raw water source quality and increased threats to the watershed or aquifer might necessitate the installation of a filtration system.

7. Ultraviolet Disinfection

Ultraviolet Disinfection Pathogen Log Reduction Credits and Assignment Criteria

Validation Protocol or Certification Standard	**Minimum UV Dosage [a]**	**Maximum Pathogen Log Reduction Credits Assigned [b, c]**		
		***Cryptosporidium* Oocysts**	***Giardia* Cysts**	**Viruses [d]**
DVGW W294	RED = 40 mJ/cm^2	3	3	0.5 or 2
NSF Standard 55 (Class A Systems only)	40 mJ/cm^2	3	3	0.5 or 2
ÖNORM M 5873	RED = 40 mJ/cm^2	3	3	0.5 or 2
UVDGM	Validated dose ≥ required dose for target pathogen log inactivation	Determined on a case by case basis	Determined on a case by case basis	Determined on a case by case basis

RED = Reduction Equivalent Dose. May also be called the REF (Reduction Equivalent Fluence).

[a] Validated reactors establish a RED for a specific organism (e.g. an MS2 RED or a *B. subtilis* RED). Similarly, NSF Standard 55 Class A certified systems are designed to deliver a UV dose that is at least equivalent to the MS2 bacteriophage dose-response at 40 mJ/cm^2 when the systems are tested in accordance with the Standard.

[b] Pathogen log reduction credit assignment is based on post-filter applications of UV equipment, or application of UV equipment to drinking water systems that use a groundwater source at low risk of containing pathogens; a 'GARP-viruses only' water source; or a water source that has been granted a filtration exemption by a Drinking Water Officer.

[c] Pathogen log reduction credit assignment is based on UV equipment being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

[d] For drinking water sources that a Drinking Water Officer considers to be at risk from human fecal contamination, a 0.5-log reduction credit should be assigned because of the high level of resistance of adenovirus to UV treatment. For drinking water sources that a Drinking Water Officer does not consider to be at risk from human fecal contamination[55], a 2-log reduction credit should be assigned based on rotavirus inactivation.

[55] The DWO may use their discretion to determine whether a drinking water source is at risk of fecal contamination, based on a source water assessment from the water supplier, or other studies conducted by the water supplier and provided to the DWO. Key considerations could include hydraulic connection to a known human sewage source and elevated presence of fecal indicators (i.e. *E. coli* > 20 colony forming units/100 mL).

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. UV equipment is validated or certified based on a validation protocol or certification standard recognized by the Province of British Columbia. 2. UV equipment is operated within its validated or certified operating conditions. 3. UV equipment is operated such that a continuous UV dose is maintained throughout the lifetime of the UV lamp(s) that is at least the minimum continuous UV dose used in the validation protocol or certification standard for the targeted pathogen log reduction credit. 4. For UV equipment using the UV intensity set point control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours: - Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated or certified operating conditions) - Lamp status - UV intensity 5. For UV equipment using the calculated dose control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours: - Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated operating conditions) - Lamp status - UV intensity - UV transmittance (UVT)[56] 6. When UV equipment components are installed or replaced, they are the same as the components used for equipment validation and/or certification unless the UV equipment was revalidated or recertified. 7. Within 30 days following the end of a calendar month, a monthly summary report is prepared which sets out the time, date, and duration of each major or critical UV equipment alarm that occurred during the month, the reason for the alarm, the volume of water treated during each alarm period and the actions taken by the water supplier to correct the alarm situation.

[56] UVT may not be required for some calculated dose monitoring approaches. See USEPA (2020) "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems".

Ultraviolet Disinfection Overview

UV disinfection is an effective treatment process for the inactivation of protozoa, bacteria, and viruses, depending on the UV dose applied. UV light inactivates pathogens by damaging their nucleic acids (DNA and RNA) so that they cannot replicate and infect humans. One of the advantages of using UV disinfection is that the disinfection by-products typically associated with the use of chemical disinfectants are not formed. Unlike chlorine which can be used for both primary and residual disinfection, UV light can only be used for primary disinfection because it does not have any residual disinfection capability.

Provincial guidance on the reduction of pathogenic microorganisms in drinking water using UV disinfection is set out in the Guidelines for Ultraviolet Disinfection of Drinking Water.

8. Chemical Disinfection

Chemical Disinfection Pathogen Log Reduction Credits and Assignment Criteria

Maximum Pathogen Log Reduction Credits Assigned [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Chemical disinfection	Determined through CT calculations	Determined through CT calculations	Determined through CT calculations

[a] Pathogen log reduction credit assignment is based on the chemical disinfection process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Recommended Pathogen Log Reduction Credit Assignment Criteria
1. Chemical disinfectant dosages are adjusted in response to variations in raw water quality. 2. At all times, $CT_{Calculated}$ is greater than or equal to the $CT_{Required}$ to achieve the pathogen log reduction credits assigned. **For Large Water Systems** 3. Sampling and testing for disinfectant residual are carried out by continuous monitoring equipment at or near a location where the intended contact time has been achieved. **For Small Water Systems** 4. Sampling and testing for disinfectant residual are carried out: a. at a minimum frequency of once every 24 hours or on a more frequent basis at the discretion of the Drinking Water Officer; b. at or near a location where the intended contact time has been achieved.

Chemical Disinfection Overview

Chemical disinfection is used to inactivate pathogens in water by direct contact with chlorine, chloramine, chlorine dioxide or ozone.

The selection of an appropriate disinfectant should consider the efficacy of the chemical and the potential for the generation of disinfection by-products (DBPs). DBPs are formed when chemical disinfectants react with natural organic matter in source water or a drinking water distribution system. There are several factors that influence the formation of disinfection by-products including the presence of organic and inorganic precursors, the disinfectant type and dose, water temperature, pH, and water age. Disinfection is typically applied after filtration so that the formation of DBPs is minimized because of the removal of organic and inorganic matter[57]. The health risks from disinfection by-products are generally much lower than the risks from consuming water that has not been disinfected[58].

Disinfection chemicals are discussed below.

Chlorine

Chlorination is the process of adding chlorine or chlorine-containing compounds (e.g. sodium hypochlorite or calcium hypochlorite) to water. Chlorine is the most common chemical used for drinking water disinfection because it is widely available, relatively inexpensive and produces a free chlorine residual[59] that can be used to maintain water quality in the distribution system[60]. Chlorine effectively inactivates enteric viruses, but the inactivation of protozoa is less effective due to their resistance to chlorine (*Cryptosporidium* is more resistant to chlorine than *Giardia*). Chlorine may form undesirable DBPs in water, including trihalomethanes (THMs) and haloacetic acids (HAAs).

Chloramine

Chloramination is the process of adding chlorine and ammonia to water to produce a combined chlorine residual predominantly in the form of monochloramine. A combined chlorine residual is defined as the concentration of residual chlorine that is combined with ammonia, organic nitrogen, or both in water that is available to oxidize organic matter and act as a disinfectant. Monochloramine is a weak disinfectant that is best suited for maintaining a more persistent chlorine residual in the water distribution system. Chloramine forms a significantly lower amount of most DBPs than chlorine but may produce more N-nitrosodimethylamine (NDMA).

Chlorine Dioxide

Chlorine dioxide is a highly effective disinfectant that is generally more rapidly effective than chlorine, but less so than ozone. Chlorine dioxide is explosive under pressure and is usually manufactured onsite. The use of chlorine dioxide can result in the formation of DBPs such as chlorite and chlorate.

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[57] To ensure the effectiveness of disinfection and for good operation of the distribution system, it is recommended that water entering the distribution system have turbidity levels of 1.0 NTU or less (Health Canada (2020). Guidelines for Canadian Drinking Water Quality – Summary Table).

[58] Health Canada (2006). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Trihalomethanes.

[59] A free chlorine residual is defined as the amount of chlorine available as dissolved gas (Cl_2), hypochlorous acid (HOCl) and hypochlorite ion (OCl^-) that is not combined with ammonia or other compounds in water (see the Health Canada Guideline Technical Document for Chlorine).

[60] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses.

Ozone

Ozone is a strong oxidant and virucide. It is significantly more effective than chlorine at inactivating pathogens in water; however, it is more expensive than chlorine and does not produce a persistent residual that can be used for maintaining drinking water quality in the distribution system. The use of ozone results in the formation of fewer THMs and HAAs than chlorination but can also form other DBPs such as bromate.

The efficacy of chemical disinfectants can be predicted based on knowledge of the residual concentration of the disinfectant, temperature, pH, and contact time. This relationship is commonly referred to as the CT concept, where CT is the product of the residual concentration of the disinfectant (C) measured in mg/L and the disinfectant contact time (T) measured in minutes[61].

CT = C x T
= Concentration (mg/L) x Time (minutes)

To account for disinfectant decay, the residual concentration "C" is usually determined at the exit of the chemical contact chamber rather than using the applied dose or initial concentration. The contact time "T" is typically calculated using a T_{10} value, which is defined as the length of time during which 10% of the influent water passes through the contact chamber[62]. Using T_{10} in CT calculations ensures that 90% of the treated water meets or exceeds the contact time.

Ideally, hydraulic tracer tests can be used to determine the actual contact time under plant flow conditions[63]. However, it is often impractical or cost prohibitive to conduct tracer studies. Accordingly, the T_{10} value is usually estimated based on the geometry and flow conditions of the contact chamber or basin.

As ozone reactions occur quickly in water, T_{10} calculations are not always appropriate to assess contact time when ozone is used as the disinfectant. The U.S. EPA Long Term 2 Enhanced Surface Water Treatment Rule: Toolbox Guidance Manual (2010) describes the CSTR method, Extended T_{10} method and Extended CSTR method for calculating CT in an ozone contactor.

Other methods may be used to determine contact time with the approval of a DWO: for example, segregated flow analysis[64] (also referred to as segregated flow modelling) or partially segregated

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[61] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses.

[62] Government of Ontario (2006). Procedure for Disinfection of Drinking Water in Ontario.

[63] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses.

[64] USEPA (1991). Guidance Manual for Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

modelling (also referred to as N-CSTR or tanks-in-series modelling)[65] of high-resolution tracer studies, or the use of site-specific computational fluid dynamics (CFD) modelling.

For the purpose of pathogen log reduction credit assignment, worst-case operating conditions should be considered when determining whether a drinking water treatment facility has the ability to achieve the recommended minimum pathogen log reduction for the chemical disinfection component of the larger drinking water treatment process.

Worst-case operating conditions reflect the most challenging conditions under which the drinking water treatment facility would operate and typically comprise minimum water depth or operating level in clearwells or reservoirs, minimum temperature, maximum pH, maximum flowrate, and minimum disinfectant residual.

Where appropriate, CT values can be calculated for each process step of the treatment train and the values summed. Calculations should be based on the residual concentration of disinfectant at the end of each process step.

Section 9 discusses the steps to calculate CT based on T_{10} and worst-case operating conditions.

9. Calculating CT based on T_{10} and Worst-Case Operating Conditions

Determining Contact Volume

The first step in calculating CT using T_{10} is to determine the volume of water (V) in the unit process, measured in cubic metres (m^3). Clearwells, reservoirs and contact pipes are typically used to provide disinfectant contact time and different formula are used to calculate contact volume depending upon the physical configuration of the contact chamber. For rectangular and cylindrical contact chambers, minimum water depth is based on the lowest allowable depth for the unit process (e.g. the low level alarm for finished water).

For <u>rectangular contact chambers</u> (e.g. a clearwell or reservoir), the volume of water (m^3) is calculated by multiplying together the chamber internal length (l) and width (w), and the minimum water depth (d).

Volume (V) = l x w x d
= length (m) x width (m) x minimum water depth (m)

For <u>cylindrical contact chambers</u> (e.g. a clearwell or reservoir), the volume of water (m^3) is calculated by multiplying together the constant Pi (π), the square of the cylindrical contact chamber internal radius (r), and the minimum water depth (d).

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[65] Pfeiffer and Barbeau (2014). Validation of a simple method for predicting disinfection performance in a flow-through contactor. Water Research 49: 144-156.

Volume (V) = π x r^2 x d
= pi x radius squared (m^2) x minimum water depth (m)

For contact pipes (e.g. designated contact piping or distribution pipes prior to the first customer), the volume of water (m^3) is calculated by multiplying together the constant Pi (π), the square of the contact pipe internal radius (r), and the length of the pipe (l).

Volume (V) = π x r^2 x l
= pi x radius squared (m^2) x length (m)

Determining T_{10}

T_{10} is estimated using the theoretical detention time (T) and a baffling factor. Baffling factors describe the degree of short circuiting that occurs within a contact chamber.

The theoretical detention time (T) measured in minutes, is calculated as the volume (V) of water in the contact chamber measured in m^3 divided by the flowrate (Q) of water through the chamber measured in m^3/minute. For the purpose of calculating CT under worst-case operating conditions, the peak hourly flowrate should be used.

T = V/Q
= Volume (m^3) / Flowrate (m^3/minute)

T_{10} is calculated as the theoretical detention time (T) of water in the contact chamber measured in minutes, multiplied by the baffling factor (T_{10}/T) based on the hydraulic characteristics of the chamber.

T_{10} = T x BF
= Theoretical Detention Time (minutes) x Baffling Factor (T_{10}/T)

The baffling factor for a particular contact chamber can be estimated based on the configuration of the chamber and the degree of short-circuiting. Typical baffling factors are set out in Table 3.

Table 3: Baffling Factors[66]

Baffling Factor (T_{10}/T)	Baffling Condition	Baffling Description
0.1	Unbaffled	No baffles, agitated basin, very low length-to-width ratio, high inlet and outlet flow velocities, inlet and outlet at the same level
0.2	Unbaffled	No baffles, agitated basin, very low length-to-width ratio, high inlet and outlet flow velocities, inlet high and outlet low or vice versa
0.3	Poor	Single or multiple unbaffled inlets and outlets, no intra-basin baffles, vertical perforated pipe for an inlet and/or outlet
0.5	Average	Baffled inlet or outlet, vertical perforated pipe for an inlet or outlet, with some intra-basin baffles
0.7	Superior	Perforated inlet baffle, perforated intra-basin baffles, outlet weirs or perforated launders
0.9	Excellent	Serpentine baffling throughout
1.0	Perfect	Pipeline flow, very high length-to-width ratio (≥160:1) with turbulent flow

Determining $CT_{Calculated}$

$CT_{Calculated}$ is used to estimate the CT that is being achieved with the use of the disinfectant. $CT_{Calculated}$ is measured in minutes·mg/L and is determined by multiplying together the disinfectant residual concentration (C) measured in mg/L and the contact time T_{10} measured in minutes.

$$CT_{Calculated} = C \times T$$
$$= \text{Concentration (mg/L)} \times \text{Time (minutes)}$$

The disinfectant residual concentration is usually measured at the outlet of the contact chamber (clearwell, reservoir, or contact pipe) before the treated water reaches the first consumer. For the purposes of determining C, the minimum design disinfectant residual concentration (for example, the low chlorine alarm level) should be used for a conservative estimate.

If historical field data is available, the minimum recorded disinfectant concentration can be used as C. Alternative values for C, such as the C_{10} (the 10^{th} percentile of recorded disinfectant concentrations,

[66] Government of Ontario (2006). Procedure for Disinfection of Drinking Water in Ontario; Colorado Department of Public Health and Environment (2014). Baffling Factor Guidance Manual.

such that 90% of the treated water meets or exceeds that concentration) or estimates from models (see Section 8) may be used with the approval of a DWO.

In some cases, $CT_{Calculated}$ may be determined for multiple disinfection segments. This is often implemented for ozone, which has a short decay period in water. Refer to the U.S. EPA Guidance Manual for Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources (1991) for detailed guidance.

Determining $CT_{Required}$

$CT_{Required}$ is used to determine the level of disinfection that is required in the chemical disinfection part of the drinking water treatment process based on the CT tables that are included in the Appendix to this guidelines document. The Appendix comprises 14 CT tables:

- Tables A1 through A6 set out CT values for the inactivation of *Giardia* cysts by free chlorine.
- Table A7 sets out CT values for the inactivation of viruses by free chlorine.
- Tables A8 and A9 set out CT values for the inactivation of *Giardia* and viruses by chlorine dioxide.
- Tables A10, A11 and A12 set out CT values for the inactivation of *Cryptosporidium*, *Giardia,* and viruses by ozone.
- Tables A13 and A14 set out CT values for the inactivation of *Giardia* and viruses by chloramine.

Where applicable, the CT tables set out the $CT_{Required}$ values based on:

- Pathogen type (*Cryptosporidium*, *Giardia,* or viruses)
- Disinfectant type (free chlorine, chlorine dioxide, ozone, or chloramine)
- Water temperature (°C)
  - If water temperature falls between temperature values in Tables A1 through A14, the lower temperature value should be used.
- Water pH
  - If water pH falls between pH values in Tables A1 through A7, the higher pH value should be used.
- Target pathogen log inactivation
- Free chlorine concentration (mg/L)

If $CT_{Required}$ is less than $CT_{Calculated}$, then no additional disinfectant contact time is required.

If $CT_{Required}$ is greater than $CT_{Calculated}$, then additional disinfectant contact time is needed to achieve the required pathogen log inactivation.

9.1 CT Calculation Examples

The following two examples set out CT calculations for a chlorine contact pipe and a chlorine contact chamber.

CT Calculation for a Chlorine Contact Pipe

The following example is for a drinking water treatment facility that has a design capacity of 1,090 m^3/day, and a 300 m long chlorine contact pipe (300 mm internal diameter) that is being used to provide chlorine contact time for 2-log inactivation of viruses. The treatment facility is targeting a minimum free chlorine residual of 0.4 mg/L (low residual alarm setting). The CT calculation is based on worst-case operating conditions (e.g., minimum water temperature, maximum pH, maximum flowrate, and minimum free chlorine residual).

For the ABC Water Treatment Plant, and for 2-log inactivation of viruses by free chlorine under worst-case operating conditions:

Minimum water temperature = 0.5 degrees Celsius
Maximum pH = 8.0
Minimum free chlorine residual = 0.4 mg/L (based on the low residual alarm setting for finished water)

$CT_{Required}$ = 6 min·mg/L (for 2-log inactivation of viruses by free chlorine based on the CT values in Table A7 of the British Columbia Guidelines for Pathogen Log Reduction Credit Assignment)

Maximum flow rate (Q) = 1,090 m^3/day = 0.757 m^3/min (based on plant design capacity)

Contact Pipe Length = 300 m
Contact Pipe (D) = 300 mm

Contact Pipe Radius = D/2 = 300 mm/2 = 150 mm = 0.15 m
Contact Pipe Volume (V) = $\pi \times r^2 \times l = \pi \times (0.15\ m)^2 \times 300\ m = 21.21\ m^3$

Theoretical Detention Time (T) = V/Q = (21.21 m^3) / (0.757 m^3/min) = 28 min
Baffle Factor (B.F.) = 1.0 (based on very high length to width ratio – pipeline flow)

T_{10} = T x B.F. = 28 min x 1.0 = 28 min

$CT_{Calculated}$ = Concentration X T_{10}
= 0.4 mg/L x 28 min
= 11.2 min·mg/L

Based on the above calculations, under worst-case operating conditions, $CT_{Calculated}$ is greater than $CT_{Required}$, and no additional chlorine contact time is required to achieve 2-log inactivation of viruses by free chlorine.

CT Calculation for a Chlorine Contact Chamber

The following example is for a drinking water treatment facility that has a design capacity of 30,000 m^3/day, and two rectangular clearwells in series that are being used to provide chlorine contact time for 0.5-log inactivation of *Giardia* cysts. Each clearwell is 30 metres long and 25 metres wide (internal dimensions). The minimum water depth in each clearwell is 1.5 metres based on the low water alarm setting. The facility is targeting a minimum free chlorine residual of 0.4 mg/L, based on the low residual alarm setting for finished water.

The CT calculation below is based on worst-case operating conditions (e.g., minimum water temperature, maximum pH, maximum flowrate, minimum clearwell volume, and minimum free chlorine residual).

For the ABC Water Treatment Plant under worst-case operating conditions:

Minimum water temperature = 0.5 degrees Celsius
Maximum pH = 8.5
Minimum free chlorine residual = 0.4 mg/L (based on the low residual alarm setting for finished water)

$CT_{Required}$ = 55 min·mg/L (for 0.5-log inactivation of *Giardia* cysts by free chlorine based on the CT values in Table A1 of the Guidelines for Pathogen Log Reduction Credit Assignment)

Maximum flow rate (Q) = 30,000 m^3/day = 20.83 m^3/min (based on plant design capacity)

Minimum Clearwell Level = 1.5 m (based on the low alarm)
Minimum Clearwell Volume (V) = l x w x d = (30 m x 25 m x 1.5 m) + (30 m x 25 m x 1.5 m) = 2,250 m^3

Theoretical Detention Time (T) = V/Q = (2,250 m^3) / (20.83 m^3/min) = 108 min
Baffle Factor (B.F.) = 0.5 (based on baffled inlet or outlet with some intra-basin baffles)

T_{10} = T x B.F. = 108 min x 0.5 = 54 min

$CT_{Calculated}$ = Concentration X T_{10}
= 0.4 mg/L x 54 min
= 21.6 min·mg/L

Based on the above calculations, under worst-case operating conditions at maximum flow rate with the low water alarm for the clearwells set at 1.5 m, $CT_{Calculated}$ is less than $CT_{Required}$. Additional chlorine contact time is required to achieve 0.5-log inactivation of *Giardia* cysts by free chlorine.

10. Pathogen Log Reduction Credit Assignment

Pathogen log reduction credit assignment can be used to determine whether drinking water treatment facilities have the necessary infrastructure in place to meet provincial drinking water treatment objectives and where necessary, to prioritize facilities for infrastructure improvements.

The pathogen log reduction credit assignment examples below illustrate how pathogen log reduction credits can be documented in a clear, succinct way that identifies how the credits are assigned based on source water type, the treatment processes used for disinfection, and the criteria that should be met for pathogen log reduction credit assignment. The pathogen log reduction credit assignment criteria are customized for each treatment facility based on the treatment processes used at the facility.

Where multiple raw water sources are combined and treated in a common treatment facility, recommended minimum pathogen log reduction would be based on the most demanding source water type: for example, for a surface water supply with supplemental groundwater supply (GARP – viruses only), the recommended minimum pathogen log reduction would be based on the surface water supply (i.e., 3-log reduction of both *Cryptosporidium* oocysts and *Giardia* cysts, and 4-log reduction of viruses).

The following examples set out pathogen log reduction credit assignment for:

a) One treatment facility with one raw water source
b) One treatment facility with multiple raw water sources
c) Two treatment facilities with multiple raw water sources and a common distribution system

Pathogen Log Reduction Credit Assignment Example #1
(One Treatment Facility with One Raw Water Source)

ABC Water Treatment Plant

Source Water Information			
Source Water Name	Source Water Type	Water Licence Number	Well Tag/ID Number (if applicable)
ABC Lake	Surface Water	*[Insert Number]*	N/A
Recommended Minimum Pathogen Log Reduction			
Treatment Facility Name	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
ABC Water Treatment Plant	3	3	4
Pathogen Log Reduction Credits Assigned			
Treatment Technology Applied [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Filtration Exemption	0	0	0
UV Disinfection	3	3	2
Chlorination	0	0	2
Total Pathogen Log Reduction Credits	**3**	**3**	**4**

[a] Pathogen log reduction credit assignment is based on each treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Pathogen Log Reduction Credit Assignment Criteria	
Filtration Exemption	1. Overall pathogen inactivation is met using a minimum of two types of disinfection providing at a minimum 3-log reduction of *Cryptosporidium* and *Giardia*, and 4-log reduction of viruses. 2. The number of *E. coli* in raw water does not exceed 20/100 mL (or if *E. coli* data are not available, less than 100/100 mL of total coliform) in at least 90% of the weekly samples from the previous six months. 3. For all water systems, treated water is to contain no detectable *E. coli* or fecal coliform per 100 mL. Total coliform objectives are also zero based on one sample in a 30-day period. For more than one sample in a 30-day period, at least 90% of samples have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL. 4. Average daily turbidity levels measured at equal intervals (at least every four hours) immediately before the disinfectant is applied are around 1 nephelometric turbidity unit (NTU) and do not exceed 5 NTU for more than two days in a 12-month period. 5. A watershed control program is maintained that minimizes the potential for fecal contamination in the source water.

UV Disinfection	1. UV equipment is validated or certified based on a validation protocol or certification standard recognized by the Province of British Columbia. 2. UV equipment is operated within its validated or certified operating conditions. 3. UV equipment is operated such that a continuous UV dose is maintained throughout the lifetime of the UV lamp(s) that is at least the minimum continuous UV dose used in the validation protocol or certification standard for the targeted pathogen log reduction credit. 4. For UV equipment using the UV intensity set point control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours: – Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated or certified operating conditions) – Lamp status – UV intensity 5. For UV equipment using the calculated dose control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours: – Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated operating conditions) – Lamp status – UV intensity – UV transmittance (UVT) 6. When UV equipment components are installed or replaced, they are the same as the components used for equipment validation and/or certification unless the UV equipment was revalidated or recertified. 7. Within 30 days following the end of a calendar month, a monthly summary report is prepared which sets out the time, date, and duration of each major or critical UV equipment alarm that occurred during the month, the reason for the alarm, the volume of water treated during each alarm period and the actions taken by the water supplier to correct the alarm situation.
Chlorination	1. Chemical disinfectant dosages are adjusted in response to variations in raw water quality. 2. At all times, $CT_{Calculated}$ is greater than or equal to the $CT_{Required}$ to achieve the pathogen log reduction credits assigned. 3. Sampling and testing for disinfectant residual are carried out by continuous monitoring equipment at or near a location where the intended contact time has been achieved.

Pathogen Log Reduction Credit Assignment Example #2

(Example for One Treatment Facility with Multiple Raw Water Sources)

ABC Water Treatment Plant

Source Water Information			
Source Water Name	Source Water Type	Water Licence Number	Well Tag/ID Number (if applicable)
ABC Lake	Surface Water	*[Insert Number]*	N/A
Well #1 (backup water supply)	GARP	*[Insert Number]*	*[Insert Number]*
Well #2 (backup water supply)	GARP-viruses only	*[Insert Number]*	*[Insert Number]*
Recommended Minimum Pathogen Log Reduction			
Treatment Facility Name	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
ABC Water Treatment Plant	3	3	4
Pathogen Log Reduction Credits Assigned			
Treatment Technology Applied [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Conventional Filtration	3	3	2
Chlorination	0	0	2
Total Pathogen Log Reduction Credits	**3**	**3**	**4**

[a] Pathogen log reduction credit assignment is based on each treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Pathogen Log Reduction Credit Assignment Criteria	
Conventional Filtration	1. A chemical coagulant is used at all times when the treatment process is in operation. 2. Chemical dosages are monitored and adjusted in response to variations in raw water quality. 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure during filter ripening to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from each filter and from combined filter effluent where there are multiple filters. 5. For each filter, filter effluent turbidity is less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95% of the measurements either per filter cycle or per month. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.
Chlorination	1. Chemical disinfectant dosages are adjusted in response to variations in raw water quality. 2. At all times, $CT_{Calculated}$ is greater than or equal to the $CT_{Required}$ to achieve the pathogen log reduction credits assigned. 3. Sampling and testing for disinfectant residual are carried out by continuous monitoring equipment at or near a location where the intended contact time has been achieved.

Pathogen Log Reduction Credit Assignment Example #3

(Two Treatment Facilities with Multiple Raw Water Sources and a Common Distribution System)

ABC Pump House

Source Water Information			
Source Water Name	Source Water Type	Water Licence Number	Well Tag/ID Number (if applicable)
Well #1	Groundwater at low risk of containing pathogens	*[Insert Number]*	*[Insert Number]*
Well #2	Groundwater at low risk of containing pathogens	*[Insert Number]*	*[Insert Number]*
Recommended Minimum Pathogen Log Reduction			
Treatment Facility Name	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
ABC Pump House	0	0	0
Pathogen Log Reduction Credits Assigned			
Treatment Technology Applied [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
No Treatment Required	0	0	0
[a] Pathogen log reduction credit assignment is based on each treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.			
Pathogen Log Reduction Credit Assignment Criteria			
Not Applicable	Not Applicable		

Continued on next page …

ABC Water Treatment Plant

Source Water Information			
Source Water Name	Source Water Type	Water Licence Number	Well Tag/ID Number (if applicable)
ABC Lake	Surface Water	*[Insert Number]*	N/A
Recommended Minimum Pathogen Log Reduction			
Treatment Facility Name	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
ABC Water Treatment Plant	3	3	4
Pathogen Log Reduction Credits Assigned			
Treatment Technology Applied [a]	*Cryptosporidium* Oocysts	*Giardia* Cysts	Viruses
Direct Filtration	2.5	2.5	1
UV Disinfection	3	3	2
Chlorination	0	0	1
Total Pathogen Log Reduction Credits	**5.5**	**5.5**	**4**

[a] Pathogen log reduction credit assignment is based on each treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met.

Pathogen Log Reduction Credit Assignment Criteria	
Direct Filtration	1. A chemical coagulant is used at all times when the treatment process is in operation. 2. Chemical dosages are monitored and adjusted in response to variations in raw water quality. 3. Effective backwash procedures are maintained including filter-to-waste or an equivalent procedure during filter ripening to ensure that filter effluent turbidity objectives are met at all times. 4. Filter effluent turbidity is continuously monitored and recorded from each filter and from combined filter effluent where there are multiple filters. 5. For each filter, filter effluent turbidity is less than or equal to 0.3 nephelometric turbidity units (NTU) in at least 95% of the measurements either per filter cycle or per month. 6. For each filter, the maximum level of filter effluent turbidity is less than or equal to 1.0 NTU.
UV Disinfection	1. UV equipment is validated or certified based on a validation protocol or certification standard recognized by the Province of British Columbia. 2. UV equipment is operated within its validated or certified operating conditions. 3. UV equipment is operated such that a continuous UV dose is maintained throughout the lifetime of the UV lamp(s) that is at least the minimum continuous UV dose used in the validation protocol or certification standard for the targeted pathogen log reduction credit. 4. For UV equipment using the UV intensity set point control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours:

	– Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated or certified operating conditions) – Lamp status – UV intensity 5. For UV equipment using the calculated dose control strategy, the following parameters are tested at a minimum frequency of once every five minutes and are recorded at a minimum frequency of once every four hours: – Flow rate (not needed for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated operating conditions) – Lamp status – UV intensity – UV transmittance (UVT) 6. When UV equipment components are installed or replaced, they are the same as the components used for equipment validation and/or certification unless the UV equipment was revalidated or recertified. 7. Within 30 days following the end of a calendar month, a monthly summary report is prepared which sets out the time, date, and duration of each major or critical UV equipment alarm that occurred during the month, the reason for the alarm, the volume of water treated during each alarm period and the actions taken by the water supplier to correct the alarm situation.
Chlorination	1. Chemical disinfectant dosages are adjusted in response to variations in raw water quality. 2. At all times, $CT_{Calculated}$ is greater than or equal to the $CT_{Required}$ to achieve the pathogen log reduction credits assigned. 3. Sampling and testing for disinfectant residual are carried out by continuous monitoring equipment at or near a location where the intended contact time has been achieved.

11. Conclusion

This guideline document provides provincial guidance on the assignment of pathogen log reduction credits for the production of microbiologically safe drinking water based on the types of treatment processes used for disinfection and the applicable pathogen log reduction credit assignment criteria being met. Additional guidance is set out in the Design Guidelines for Drinking Water Systems in British Columbia. In all cases, a Drinking Water Officer should be consulted when planning or considering upgrades to a drinking water supply system.

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13. Glossary

Cartridge Filtration – a pressure driven physical separation process that removes particles greater than 1 μm using an engineered porous filtration media.

Challenge Test – a study conducted to determine the removal efficiency or log removal value for the challenge test of a membrane module, or cartridge filter for a particular organism, particulate, or surrogate.

Direct Integrity Test – physical test applied to a membrane unit in order to identify and/or isolate integrity breaches.

Groundwater at Low Risk of Containing Pathogens – groundwater that is considered to be at low risk of containing pathogens as a result of a GARP assessment (i.e. no hazards were identified following a GARP Stage 1: Hazard Screening and Assessment, or the groundwater source was determined to be at low risk following a Stage 2: GARP Determination). Refer to the Guidance Document for Determining Groundwater At Risk of Containing Pathogens (GARP) when assessing the risk that groundwater may become contaminated with pathogens.

Groundwater at Risk of Containing Pathogens (GARP) – any groundwater supply likely to be contaminated from any source of pathogens, continuously or intermittently. Potential sources of pathogens include sewage discharge to land, leaking municipal sewage pipes (especially force mains), agricultural waste stockpiles, runoff intrusion into poorly constructed wells, and surface water.

GARP-Virus Only – any groundwater supply determined to be 'at risk' of containing viruses (i.e. if the DWO has reason to believe that the source is only at risk of containing viruses, and not other pathogens). This would include water supply system wells located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport or other conditions indicating possible viral contamination, therefore requiring treatment of viruses.

Membrane Filtration – a pressure- or vacuum-driven separation process in which particulate matter larger than 1 μm is rejected by an engineered barrier, primarily through a size-exclusion mechanism and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test; includes common membrane classifications microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), as well as any "membrane cartridge filtration" (MCF) device that satisfies this definition.

Microfiltration (MF) – a pressure-driven membrane filtration process that typically employs hollow-fiber membranes with a pore size range of approximately 0.1 – 0.2 μm (nominally 0.1 μm).

Nanofiltration (NF) – a pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water; typically applied for membrane softening or the removal of dissolved organic contaminants.

Rainwater – water collected from natural precipitation from a roof or similar structure.

Reverse Osmosis (RO) – 1) the reverse of the natural osmosis process – i.e., the passage of a solvent (e.g., water) through a semi-permeable membrane from a solution of higher concentration to a solution of lower concentration against the concentration gradient, achieved by applying pressure greater than the osmotic pressure to the more concentrated solution; also, 2) the pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water.

Surface Water – water from a source which is open to the atmosphere and includes steams, lakes, rivers, creeks, and springs.

Ultrafiltration (UF) – a pressure-driven membrane filtration process that typically employs hollow-fiber membranes with a pore size range of approximately 0.01 – 0.05 μm (nominally 0.01 μm).

Appendices

Table A1: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 0.5 °C or Lower

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
≤ 0.4	23	46	69	91	114	137	27	54	82	109	136	163	33	65	98	130	163	195	40	79	119	158	198	237
0.6	24	47	71	94	118	141	28	56	84	112	140	168	33	67	100	133	167	200	40	80	120	159	199	239
0.8	24	48	73	97	121	145	29	57	86	115	143	172	34	68	103	137	171	205	41	82	123	164	205	246
1	25	49	74	99	123	148	29	59	88	117	147	176	35	70	105	140	175	210	42	84	127	169	211	253
1.2	25	51	76	101	127	152	30	60	90	120	150	180	36	72	108	143	179	215	43	86	130	173	216	259
1.4	26	52	78	103	129	155	31	61	92	123	153	184	37	74	111	147	184	221	44	89	133	177	222	266
1.6	26	52	79	105	131	157	32	63	95	126	158	189	38	75	113	151	188	226	46	91	137	182	228	273
1.8	27	54	81	108	135	162	32	64	97	129	161	193	39	77	116	154	193	231	47	93	140	186	233	279
2	28	55	83	110	138	165	33	66	99	131	164	197	39	79	118	157	197	236	48	95	143	191	238	286
2.2	28	56	85	113	141	169	34	67	101	134	168	201	40	81	121	161	202	242	50	99	149	198	248	297
2.4	29	57	86	115	143	172	34	68	103	137	171	205	41	82	124	165	206	247	50	99	149	199	248	298
2.6	29	58	88	117	146	175	35	70	105	139	174	209	42	84	126	168	210	252	51	101	152	203	253	304
2.8	30	59	89	119	148	178	36	71	107	142	178	213	43	86	129	171	214	257	52	103	155	207	258	310
3	30	60	91	121	151	181	36	72	109	145	181	217	44	87	131	174	218	261	53	105	158	211	263	316

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
≤ 0.4	46	92	139	185	231	277	55	110	165	219	274	329	65	130	195	260	325	390
0.6	48	95	143	191	238	286	57	114	171	228	285	342	68	136	204	271	339	407
0.8	49	98	148	197	246	295	59	118	177	236	295	354	70	141	211	281	352	422
1	51	101	152	203	253	304	61	122	183	243	304	365	73	146	219	291	364	437
1.2	52	104	157	209	261	313	63	125	188	251	313	376	75	150	226	301	376	451
1.4	54	107	161	214	268	321	65	129	194	258	323	387	77	155	232	309	387	464
1.6	55	110	165	219	274	329	66	132	199	265	331	397	80	159	239	318	398	477
1.8	56	113	169	225	282	338	68	136	204	271	339	407	82	163	245	326	408	489
2	58	115	173	231	288	346	70	139	209	278	348	417	83	167	250	333	417	500
2.2	59	118	177	235	294	353	71	142	213	284	355	426	85	170	256	341	426	511
2.4	60	120	181	241	301	361	73	145	218	290	363	435	87	174	261	348	435	522
2.6	61	123	184	245	307	368	74	148	222	296	370	444	89	178	267	355	444	533
2.8	63	125	188	250	313	375	75	151	226	301	377	452	91	181	272	362	453	543
3	64	127	191	255	318	382	77	153	230	307	383	460	92	184	276	368	460	552

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A2: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 5 °C

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	16	32	49	65	81	97	20	39	59	78	98	117	23	46	70	93	116	139	28	55	83	111	138	166
0.6	17	33	50	67	83	100	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	114	143	171
0.8	17	34	52	69	86	103	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175
1	18	35	53	70	88	105	21	42	63	83	104	125	25	50	75	99	124	149	30	60	90	119	149	179
1.2	18	36	54	71	89	107	21	42	64	85	106	127	25	51	76	101	127	152	31	61	92	122	153	183
1.4	18	36	55	73	91	109	22	43	65	87	108	130	26	52	78	103	129	155	31	62	94	125	156	187
1.6	19	37	56	74	93	111	22	44	66	88	110	132	26	53	79	105	132	158	32	64	96	128	160	192
1.8	19	38	57	76	95	114	23	45	68	90	113	135	27	54	81	108	135	162	33	65	98	131	163	196
2	19	39	58	77	97	116	23	46	69	92	115	138	28	55	83	110	138	165	33	67	100	133	167	200
2.2	20	39	59	79	98	118	23	47	70	93	117	140	28	56	85	113	141	169	34	68	102	136	170	204
2.4	20	40	60	80	100	120	24	48	72	95	119	143	29	57	86	115	143	172	35	70	105	139	174	209
2.6	20	41	61	81	102	122	24	49	73	97	122	146	29	58	88	117	146	175	36	71	107	142	178	213
2.8	21	41	62	83	103	124	25	49	74	99	123	148	30	59	89	119	148	178	36	72	109	145	181	217
3	21	42	63	84	105	126	25	50	76	101	126	151	30	61	91	121	152	182	37	74	111	147	184	221

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤ 9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	33	66	99	132	165	198	39	79	118	157	197	236	47	93	140	186	233	279
0.6	34	68	102	136	170	204	41	81	122	163	203	244	49	97	146	194	243	291
0.8	35	70	105	140	175	210	42	84	126	168	210	252	50	100	151	201	251	301
1	36	72	108	144	180	216	43	87	130	173	217	260	52	104	156	208	260	312
1.2	37	74	111	147	184	221	45	89	134	178	223	267	53	107	160	213	267	320
1.4	38	76	114	151	189	227	46	91	137	183	228	274	55	110	165	219	274	329
1.6	39	77	116	155	193	232	47	94	141	187	234	281	56	112	169	225	281	337
1.8	40	79	119	159	198	238	48	96	144	191	239	287	58	115	173	230	288	345
2	41	81	122	162	203	243	49	98	147	196	245	294	59	118	177	235	294	353
2.2	41	83	124	165	207	248	50	100	150	200	250	300	60	120	181	241	301	361
2.4	42	84	127	169	211	253	51	102	153	204	255	306	61	123	184	245	307	368
2.6	43	86	129	172	215	258	52	104	156	208	260	312	63	125	188	250	313	375
2.8	44	88	132	175	219	263	53	106	159	212	265	318	64	127	191	255	318	382
3	45	89	134	179	223	268	54	108	162	216	270	324	65	130	195	259	324	389

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A3: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 10 °C

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	12	24	37	49	61	73	15	29	44	59	73	88	17	35	52	69	87	104	21	42	63	83	104	125
0.6	13	25	38	50	63	75	15	30	45	60	75	90	18	36	54	71	89	107	21	43	64	85	107	128
0.8	13	26	39	52	65	78	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131
1	13	26	40	53	66	79	16	31	47	63	78	94	19	37	56	75	93	112	22	45	67	89	112	134
1.2	13	27	40	53	67	80	16	32	48	63	79	95	19	38	57	76	95	114	23	46	69	91	114	137
1.4	14	27	41	55	68	82	16	33	49	65	82	98	19	39	58	77	97	116	23	47	70	93	117	140
1.6	14	28	42	55	69	83	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	96	120	144
1.8	14	29	43	57	72	86	17	34	51	67	84	101	20	41	61	81	102	122	25	49	74	98	123	147
2	15	29	44	58	73	87	17	35	52	69	87	104	21	41	62	83	103	124	25	50	75	100	125	150
2.2	15	30	45	59	74	89	18	35	53	70	88	105	21	42	64	85	106	127	26	51	77	102	128	153
2.4	15	30	45	60	75	90	18	36	54	71	89	107	22	43	65	86	108	129	26	52	79	105	131	157
2.6	15	31	46	61	77	92	18	37	55	73	92	110	22	44	66	87	109	131	27	53	80	107	133	160
2.8	16	31	47	62	78	93	19	37	56	74	93	111	22	45	67	89	112	134	27	54	82	109	136	163
3	16	32	48	63	79	95	19	38	57	75	94	113	23	46	69	91	114	137	28	55	83	111	138	166

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤ 9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	25	50	75	99	124	149	30	59	89	118	148	177	35	70	105	139	174	209
0.6	26	51	77	102	128	153	31	61	92	122	153	183	36	73	109	145	182	218
0.8	26	53	79	105	132	158	32	63	95	126	158	189	38	75	113	151	188	226
1	27	54	81	108	135	162	33	65	98	130	163	195	39	78	117	156	195	234
1.2	28	55	83	111	138	166	33	67	100	133	167	200	40	80	120	160	200	240
1.4	28	57	85	113	142	170	34	69	103	137	172	206	41	82	124	165	206	247
1.6	29	58	87	116	145	174	35	70	106	141	176	211	42	84	127	169	211	253
1.8	30	60	90	119	149	179	36	72	108	143	179	215	43	86	130	173	216	259
2	30	61	91	121	152	182	37	74	111	147	184	221	44	88	133	177	221	265
2.2	31	62	93	124	155	186	38	75	113	150	188	225	45	90	136	181	226	271
2.4	32	63	95	127	158	190	38	77	115	153	192	230	46	92	138	184	230	276
2.6	32	65	97	129	162	194	39	78	117	156	195	234	47	94	141	187	234	281
2.8	33	66	99	131	164	197	40	80	120	159	199	239	48	96	144	191	239	287
3	34	67	101	134	168	201	41	81	122	162	203	243	49	97	146	195	243	292

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A4: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 15 °C

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	8	16	25	33	41	49	10	20	30	39	49	59	12	23	35	47	58	70	14	28	42	55	69	83
0.6	8	17	25	33	42	50	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
0.8	9	17	26	35	43	52	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88
1	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75	15	30	45	60	75	90
1.2	9	18	27	36	45	54	11	21	32	43	53	64	13	25	38	51	63	76	15	31	46	61	77	92
1.4	9	18	28	37	46	55	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
1.6	10	19	28	37	47	56	11	22	33	44	55	66	13	26	40	53	66	79	16	32	48	64	80	96
1.8	10	19	29	38	48	57	11	23	34	45	57	68	14	27	41	54	68	81	16	33	49	65	82	98
2	10	19	29	39	48	58	12	23	35	46	58	69	14	28	42	55	69	83	17	33	50	67	83	100
2.2	10	20	30	39	49	59	12	23	35	47	58	70	14	28	43	57	71	85	17	34	51	68	85	102
2.4	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86	18	35	53	70	88	105
2.6	10	20	31	41	51	61	12	24	37	49	61	73	15	29	44	59	73	88	18	36	54	71	89	107
2.8	10	21	31	41	52	62	12	25	37	49	62	74	15	30	45	59	74	89	18	36	55	73	91	109
3	11	21	32	42	53	63	13	25	38	51	63	76	15	30	46	61	76	91	19	37	56	74	93	111

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤ 9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	17	33	50	66	83	99	20	39	59	79	98	118	23	47	70	93	117	140
0.6	17	34	51	68	85	102	20	41	61	81	102	122	24	49	73	97	122	146
0.8	18	35	53	70	88	105	21	42	63	84	105	126	25	50	76	101	126	151
1	18	36	54	72	90	108	22	43	65	87	108	130	26	52	78	104	130	156
1.2	19	37	56	74	93	111	22	45	67	89	112	134	27	53	80	107	133	160
1.4	19	38	57	76	95	114	23	46	69	91	114	137	28	55	83	110	138	165
1.6	19	39	58	77	97	116	24	47	71	94	118	141	28	56	85	113	141	169
1.8	20	40	60	79	99	119	24	48	72	96	120	144	29	58	87	115	144	173
2	20	41	61	81	102	122	25	49	74	98	123	147	30	59	89	118	148	177
2.2	21	41	62	83	103	124	25	50	75	100	125	150	30	60	91	121	151	181
2.4	21	42	64	85	106	127	26	51	77	102	128	153	31	61	92	123	153	184
2.6	22	43	65	86	108	129	26	52	78	104	130	156	31	63	94	125	157	188
2.8	22	44	66	88	110	132	27	53	80	106	133	159	32	64	96	127	159	191
3	22	45	67	89	112	134	27	54	81	108	135	162	33	65	98	130	163	195

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A5: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 20 °C

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	6	12	18	24	30	36	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62
0.6	6	13	19	25	32	38	8	15	23	30	38	45	9	18	27	36	45	54	11	21	32	43	53	64
0.8	7	13	20	26	33	39	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66
1	7	13	20	26	33	39	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67
1.2	7	13	20	27	33	40	8	16	24	32	40	48	10	19	29	38	48	57	12	23	35	46	58	69
1.4	7	14	21	27	34	41	8	16	25	33	41	49	10	19	29	39	48	58	12	23	35	47	58	70
1.6	7	14	21	28	35	42	8	17	25	33	42	50	10	20	30	39	49	59	12	24	36	48	60	72
1.8	7	14	22	29	36	43	9	17	26	34	43	51	10	20	31	41	51	61	12	25	37	49	62	74
2	7	15	22	29	37	44	9	17	26	35	43	52	10	21	31	41	52	62	13	25	38	50	63	75
2.2	7	15	22	29	37	44	9	18	27	35	44	53	11	21	32	42	53	63	13	26	39	51	64	77
2.4	8	15	23	30	38	45	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
2.6	8	15	23	31	38	46	9	18	28	37	46	55	11	22	33	44	55	66	13	27	40	53	67	80
2.8	8	16	24	31	39	47	9	19	28	37	47	56	11	22	34	45	56	67	14	27	41	54	68	81
3	8	16	24	31	39	47	10	19	29	38	48	57	11	23	34	45	57	68	14	28	42	55	69	83

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤ 9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**	**0.5**	**1**	**1.5**	**2**	**2.5**	**3**
≤ 0.4	12	25	37	49	62	74	15	30	45	59	74	89	18	35	53	70	88	105
0.6	13	26	39	51	64	77	15	31	46	61	77	92	18	36	55	73	91	109
0.8	13	26	40	53	66	79	16	32	48	63	79	95	19	38	57	75	94	113
1	14	27	41	54	68	81	16	33	49	65	82	98	20	39	59	78	98	117
1.2	14	28	42	55	69	83	17	33	50	67	83	100	20	40	60	80	100	120
1.4	14	28	43	57	71	85	17	34	52	69	86	103	21	41	62	82	103	123
1.6	15	29	44	58	73	87	18	35	53	70	88	105	21	42	63	84	105	126
1.8	15	30	45	59	74	89	18	36	54	72	90	108	22	43	65	86	108	129
2	15	30	46	61	76	91	18	37	55	73	92	110	22	44	66	88	110	132
2.2	16	31	47	62	78	93	19	38	57	75	94	113	23	45	68	90	113	135
2.4	16	32	48	63	79	95	19	38	58	77	96	115	23	46	69	92	115	138
2.6	16	32	49	65	81	97	20	39	59	78	98	117	24	47	71	94	118	141
2.8	17	33	50	66	83	99	20	40	60	79	99	119	24	48	72	95	119	143
3	17	34	51	67	84	101	20	41	61	81	102	122	24	49	73	97	122	146

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A6: CT Values for Inactivation of *Giardia* Cysts by Free Chlorine at 25 °C

Free Chlorine Concentration mg/L	pH ≤ 6						pH = 6.5						pH = 7.0						pH = 7.5					
	Log Inactivation						Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
≤ 0.4	4	8	12	16	20	24	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	28	35	42
0.6	4	8	13	17	21	25	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43
0.8	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44
1	4	9	13	17	22	26	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45
1.2	5	9	14	18	23	27	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46
1.4	5	9	14	18	23	27	6	11	17	22	28	33	7	13	20	26	33	39	8	16	24	31	39	47
1.6	5	9	14	19	23	28	6	11	17	22	28	33	7	13	20	27	33	40	8	16	24	32	40	48
1.8	5	10	15	19	24	29	6	11	17	23	28	34	7	14	21	27	34	41	8	16	25	33	41	49
2	5	10	15	19	24	29	6	12	18	23	29	35	7	14	21	27	34	41	8	17	25	33	42	50
2.2	5	10	15	20	25	30	6	12	18	23	29	35	7	14	21	28	35	42	9	17	26	34	43	51
2.4	5	10	15	20	25	30	6	12	18	24	30	36	7	14	22	29	36	43	9	17	26	35	43	52
2.6	5	10	16	21	26	31	6	12	19	25	31	37	7	15	22	29	37	44	9	18	27	35	44	53
2.8	5	10	16	21	26	31	6	12	19	25	31	37	8	15	23	30	38	45	9	18	27	36	45	54
3	5	11	16	21	27	32	6	13	19	25	32	38	8	15	23	31	38	46	9	18	28	37	46	55

Free Chlorine Concentration mg/L	pH = 8.0						pH = 8.5						pH ≤ 9.0					
	Log Inactivation						Log Inactivation						Log Inactivation					
	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3	0.5	1	1.5	2	2.5	3
≤ 0.4	8	17	25	33	42	50	10	20	30	39	49	59	12	23	35	47	58	70
0.6	9	17	26	34	43	51	10	20	31	41	51	61	12	24	37	49	61	73
0.8	9	18	27	35	44	53	11	21	32	42	53	63	13	25	38	50	63	75
1	9	18	27	36	45	54	11	22	33	43	54	65	13	26	39	52	65	78
1.2	9	18	28	37	46	55	11	22	34	45	56	67	13	27	40	53	67	80
1.4	10	19	29	38	48	57	12	23	35	46	58	69	14	27	41	55	68	82
1.6	10	19	29	39	48	58	12	23	35	47	58	70	14	28	42	56	70	84
1.8	10	20	30	40	50	60	12	24	36	48	60	72	14	29	43	57	72	86
2	10	20	31	41	51	61	12	25	37	49	62	74	15	29	44	59	73	88
2.2	10	21	31	41	52	62	13	25	38	50	63	75	15	30	45	60	75	90
2.4	11	21	32	42	53	63	13	26	39	51	64	77	15	31	46	61	77	92
2.6	11	22	33	43	54	65	13	26	39	52	65	78	16	31	47	63	78	94
2.8	11	22	33	44	55	66	13	27	40	53	67	80	16	32	48	64	80	96
3	11	22	34	45	56	67	14	27	41	54	68	81	16	32	49	65	81	97

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A7: CT Values for Inactivation of Viruses by Free Chlorine

Temperature (°C)	Log Inactivation					
	2		3		4	
	pH		pH		pH	
	6 to 9	10	6 to 9	10	6 to 9	10
0.5	6	45	9	66	12	90
5	4	30	6	44	8	60
10	3	22	4	33	6	45
15	2	15	3	22	4	30
20	1	11	2	16	3	22
25	1	7	1	11	2	15

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A8: CT Values for Inactivation of *Giardia* Cysts by Chlorine Dioxide

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
0.5	10	4.3	4	3.2	2.5	2
1.0	21	8.7	7.7	6.3	5	3.7
1.5	32	13	12	10	7.5	5.5
2.0	42	17	15	13	10	7.3
2.5	52	22	19	16	13	9
3.0	63	26	23	19	15	11

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A9: CT Values for Inactivation of Viruses by Chlorine Dioxide

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
2	8.4	5.6	4.2	2.8	2.1	1.4
3	25.6	17.1	12.8	8.6	6.4	4.3
4	50.1	33.4	25.1	16.7	12.5	8.4

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A10: CT Values for Inactivation of *Cryptosporidium* Oocysts by Ozone

Log Inactivation	Temperature (°C)									
	≤0.5	1	2	3	5	7	10	15	20	25
0.5	12	12	10	9.5	7.9	6.5	4.9	3.1	2.0	1.2
1.0	24	23	21	19	16	13	9.9	6.2	3.9	2.5
1.5	36	35	31	29	24	20	15	9.3	5.9	3.7
2.0	48	46	42	38	32	26	20	12	7.8	4.9
2.5	60	58	52	48	40	33	25	16	9.8	6.2
3.0	72	69	63	57	47	39	30	19	12	7.4

CT units = min·mg/L
Source: (2006) Code of Federal Regulations, 40 CFR 141.720.

Table A11: CT Values for Inactivation of *Giardia* Cysts by Ozone

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
0.5	0.48	0.32	0.23	0.16	0.12	0.08
1.0	0.97	0.63	0.48	0.32	0.24	0.16
1.5	1.5	0.95	0.72	0.48	0.36	0.24
2.0	1.9	1.3	0.95	0.63	0.48	0.32
2.5	2.4	1.6	1.2	0.79	0.6	0.4
3.0	2.9	1.9	1.43	0.95	0.72	0.48

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A12: CT Values for Inactivation of Viruses by Ozone

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
2	0.9	0.6	0.5	0.3	0.25	0.15
3	1.4	0.9	0.8	0.5	0.4	0.25
4	1.8	1.2	1	0.6	0.5	0.3

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A13: CT Values for Inactivation of *Giardia* Cysts by Chloramine at pH 6-9

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
0.5	635	365	310	250	185	125
1.0	1270	735	615	500	370	250
1.5	1900	1100	930	750	550	375
2.0	2535	1470	1230	1000	735	500
2.5	3170	1830	1540	1250	915	625
3.0	3800	2200	1850	1500	1100	750

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Table A14: CT Values for Inactivation of Viruses by Chloramine at pH 6-9

Log Inactivation	Temperature (°C)					
	≤1	5	10	15	20	25
2	1243	857	643	428	321	214
3	2063	1423	1067	712	534	356
4	2883	1988	1491	994	746	497

CT units = min·mg/L
Source: USEPA (1991) Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems Using Surface Water Sources.

Guidelines for Ultraviolet Disinfection of Drinking Water

Version 1.0 / First Published January 2022

Ministry of Health

Table of Contents

1. Objective

To provide guidance on the reduction of pathogenic microorganisms[1] in drinking water using ultraviolet (UV) disinfection and the design, operation, and maintenance of UV equipment for drinking water applications.

2. Background and Regulatory Framework

The *Drinking Water Protection Act* (DWPA) (2001) and Drinking Water Protection Regulation (DWPR) (2003) specify water quality standards[2], monitoring schedules and recommended treatment aimed at reducing the risks from pathogens in drinking water. There are three main types of pathogens in drinking water that pose risks to human health: viruses, protozoa, and bacteria. The ingestion of these pathogens can result in short term illness and in some instances, serious long-lasting illnesses or even death.

To ensure the provision of clean, safe, and reliable drinking water in British Columbia, the multi-barrier approach is used. The multi-barrier approach is a system of procedures, processes and tools that collectively prevents or reduces the risk of contamination of drinking water from source-to-tap to reduce risks to human health[3]. Drinking water treatment is one component of the multi-barrier approach. Other components include source protection, operator training, water system maintenance, water quality monitoring and emergency response planning.

Section 5 of the DWPR requires that drinking water from a water supply system must be disinfected if the water originates from surface water, or groundwater that in the opinion of a Drinking Water Officer is at risk of containing pathogens. As "disinfection" is not defined in the DWPA or DWPR, technical guidance on disinfection is provided in this document for UV disinfection, the Design Guidelines for Drinking Water Systems in British Columbia (anticipated release date in 2022), the Guidelines for Pathogen Log Reduction Credit Assignment (2021) and in provincial drinking water treatment objectives.

Provincial drinking water treatment objectives are set out in the following guidance documents which are included in Part B to the Drinking Water Officers' Guide:

- Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia which provides a general overview of microbiological drinking water treatment objectives for surface water supplies; and

[1] Health risks posed from chemical, physical, or radiological parameters are beyond the scope of this document.

[2] Schedule A of the Drinking Water Protection Regulation specifies bacteriological water quality standards for *Escherichia coli* (*E. coli*) and total and fecal coliform bacteria as no detectable bacteria per 100 mL of drinking water. Where more than 1 sample is collected in a 30 day period, the standard for total coliform is at least 90% of samples have no detectable total coliform bacteria per 100 mL and no sample has more than 10 total coliform bacteria per 100 mL.

[3] B.C. Office of the Provincial Health Officer (2019). Clean, Safe, and Reliable Drinking Water.

- Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia which specifies guidance on the treatment necessary to address microbiological contamination of groundwater sources and the assignment of subsurface filtration treatment credits.

Provincial drinking water treatment objectives for harvested rainwater are set out in the following guidance document which supplements the existing provincial treatment objectives for surface water supplies:

- Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia which provides a general overview of assessing the risks and treatment of rainwater for potable use.

All surface water supplies require disinfection; however, the requirement to disinfect groundwater supplies only applies to groundwater sources at risk of microbiological contamination. The Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP) was developed to assist Health Authorities and water suppliers determine if a particular groundwater source requires disinfection. Risk factors that are discussed in the guideline include well construction, well location, aquifer characteristics and water quality results.

3. Purpose and Scope

This guideline provides provincial guidance[4] on the reduction of pathogenic microorganisms in drinking water using UV disinfection. The information in this document should be used by issuing officials during the approvals process, particularly with respect to the issuance of construction permits and operating permits under the *Drinking Water Protection Act* and the Drinking Water Protection Regulation. The information in this document can also be used by water suppliers, designers, and any other person or persons responsible for the planning and design of new water supply systems and when considering changes to existing systems.

This guideline is intended to supplement and not replace industry standards, guidelines, and best practices for UV disinfection of drinking water. More detailed information on the design and operation of drinking water systems can be found in the Design Guidelines for Drinking Water Systems in British Columbia.

4. Drinking Water Pathogens

The primary goal of drinking water disinfection is to reduce the presence of pathogens (disease-causing organisms) and associated health risks to an acceptable or tolerable level. The three main types of pathogens in drinking water that pose risks to human health are discussed below.

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[4] The guidance in this document is not legally binding. In the event of an inconsistency between the guidance in this document and the DWPA, DWPR, a drinking water operating permit or construction permit, or any direction of a Drinking Water Officer, the guidance in this document gives way to legally binding requirements.

4.1 Viruses

Viruses are submicroscopic infectious agents that replicate only inside the living cells of host organisms. UV disinfection can be used to reduce viruses in water, but the effectiveness of UV disinfection varies significantly depending upon the type of virus. For example, double-stranded DNA viruses, such as adenoviruses, are more resistant to UV than single-stranded RNA viruses, such as hepatitis A (Meng and Gerba, 1996; cited in Health Canada, 2011). Adenoviruses are excreted in large numbers by humans and are commonly found in untreated sewage and many surface water sources. Because some adenoviruses can cause illness, particularly in children and immunocompromised adults, adenovirus is sometimes used to establish UV disinfection requirements for viruses.

Other pathogenic viruses which pose risks to drinking water sources have also been studied for their UV disinfection requirements. Studies show that hepatitis A, poliovirus type 1, and various strains of coxsackievirus and rotavirus require a UV dose[5] ranging from 16 – 61 mJ/cm^2 from low pressure UV lamps for 4-log virus inactivation (see the Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses); of the viruses studied, rotavirus was the most resistant to UV disinfection after adenovirus.

Due to the high UV dosages required to reduce the concentration of enteric viruses in water, chemical disinfection (e.g. chlorination) is often the most appropriate treatment process for virus reduction.

4.2 Protozoa

Protozoa such as *Cryptosporidium* and *Giardia* are relatively large pathogenic single-celled microorganisms that, like enteric viruses, multiply only in the gastrointestinal tract of humans and other animals. *Cryptosporidium* oocysts and *Giardia* cysts[6] cannot multiply in the environment but can survive in water longer than intestinal bacteria. UV disinfection is the most effective means of oocyst and cyst inactivation.

4.3 Bacteria

Bacteria are single-celled microorganisms that can exist either as independent (free-living) organisms or as parasites (dependent on another organism for survival). Bacteria exhibit a range of UV sensitivity: many types are inactivated at low UV doses, while others (especially spore-forming bacteria) are considerably more resistant to UV disinfection than *Cryptosporidium* oocysts and *Giardia* cysts[7]. Bacterial reduction is normally sufficient if disinfection systems are designed to target virus reduction and as such, bacteria are not typically treated separately.

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[5] See Section 5 – UV Disinfection for more information on UV dose.

[6] Oocysts and cysts are the infective spore-like life stages of protozoa which are environmentally hardy and are shed by infected individuals in feces (CDC, 2020).

[7] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule. Also refer to Masjoudi *et al.* (2021), Sensitivity of Bacteria, Protozoa, Viruses, and Other Microorganisms to Ultraviolet Radiation.

5. UV Disinfection

UV light inactivates pathogens by damaging their nucleic acids (DNA and RNA) so that they cannot replicate and infect humans. The degree of pathogen inactivation depends upon the UV dose that is applied. For practical purposes, UV dose is expressed as the product of UV intensity, expressed in milliwatts per square centimeter of exposed area (mW/cm^2) and the amount of time that a microorganism is exposed to UV light in a reactor vessel (measured in seconds). The units of UV dose are expressed as millijoules per square centimeter (mJ/cm^2) which is equivalent to milliwatt seconds per square centimeter ($mW{\cdot}s/cm^2$).

UV dose delivery is influenced by the:

a) UV reactor design;
b) flow rate and fluid dynamics of water passing through the UV reactor;
c) UV transmittance (UVT) of the water being treated; and
d) UV intensity field within the reactor, which can be impacted by lamp sleeve transmittance and sleeve fouling, as well as lamp output, position, and aging.

Low pressure (LP) UV lamps (including low-pressure high-output lamps, LPHO) produce UV light at a single wavelength of 254 nm, which is an effective wavelength for the germicidal inactivation of pathogens. Medium pressure (MP) UV lamps produce polychromatic UV light which spans many wavelengths over the germicidal range (200 nm to 300 nm). Selection of lamp technology requires consideration of the reactor size, power demand and cost. Lamp and reactor selection (including dose monitoring strategy) should also consider monitoring and O&M requirements with respect to the water supplier's operational capacity. Refer to Section 11 – Monitoring Parameters and Section 12 – Equipment Verification and Calibration for more details.

The high efficacy and reliability of UV disinfection technology is well established within the drinking water sector. One of the advantages of using UV light for drinking water disinfection is that the disinfection by-products typically associated with the use of chemical disinfectants are not formed. However, unlike chlorine which can be used for both primary and residual disinfection, UV disinfection can only be used for primary disinfection because it does not have any residual disinfection capability.

UV dose requirements for the inactivation of *Cryptosporidium*, *Giardia,* and viruses, as developed by the U.S. EPA, are set out in Table 1. Note that due to the potential for particulate matter to interfere with UV disinfection, these dose requirements apply to post-filter applications of UV disinfection in filtered systems and to unfiltered systems that meet U.S. EPA filter avoidance criteria[8]. Particles in unfiltered water can interfere with UV disinfection in two ways: by decreasing the UVT, and by associating with microorganisms (including pathogens) and shielding them from UV light[9]. While the first effect can generally be captured by UVT monitoring, particle association with microorganisms can

[8] 40 CFR 141.71.

[9] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

affect UV dose-response and cannot be predicted through monitoring. Particles larger than approximately 7–10 µm are able to enmesh and protect coliform bacteria from UV light, and smaller particles can shield viruses from UV exposure, reducing disinfection efficiency[10].

Due to this potential for interference by particles, pathogen log reduction credit assignment for drinking water systems in British Columbia should be based on:

- post-filter applications of UV equipment, or
- application of UV equipment to drinking water systems that use
  - a groundwater source at low risk of containing pathogens,
  - a 'GARP-viruses only' water source, or
  - a water source that has been granted a filtration exemption by a Drinking Water Officer.

For unfiltered systems that meet filtration exemption criteria, special consideration should be given to UVT and particle data when UV disinfection is being considered as part of the treatment process. Particle count analysis can be used to determine the level and type of pre- and post-treatment that should be provided; for example, if a source water experiences turbidity excursions with high counts of particles larger than 7 µm, at a minimum, cartridge filtration pre-treatment should be considered (i.e. cartridge filters with adequate pore size for particle removal).

The UV dose requirements in Table 1 account for the UV dose-response relationships of the target pathogens but do not address other significant sources of uncertainty in full-scale UV reactor applications due to the hydraulic effects of the UV installation, the UV equipment, and the monitoring approach. Due to these factors, UV reactors undergo validation testing to determine the operating conditions under which the reactors deliver the required UV dose for pathogen log reduction credit[11]. Reactor validation is discussed in Section 6.

[10] Templeton et al. (2008). Particle-associated viruses in water: Impacts on disinfection processes. Critical Reviews in Environmental Science and Technology, 38:3, 137-164.

[11] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

Table 1: UV Dose Requirements (mJ/cm^2) for the Inactivation of *Cryptosporidium*, *Giardia* and Viruses[12]

Target Pathogen	Log Inactivation [a]							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Viruses (based on adenovirus) [b]	39	58	79	100	121	143	163	186

[a] In the U.S., the UV dose values in Table 1 are applicable to post-filter applications of UV in filtered systems and to unfiltered systems that meet filter avoidance criteria under Title 40 of the U.S. Code of Federal Regulations (40 CFR 141.71). In B.C., the UV dose values in Table 1 are recommended for post-filter application of UV, or application of UV equipment to drinking water systems that use a groundwater source at low risk of containing pathogens, a 'GARP-viruses only' water source, or a water source that has been granted a filtration exemption by a Drinking Water Officer.

[b] Typically, chemical disinfection is used for virus inactivation due to the high UV dosages required.

Adenovirus and Rotavirus

The UV dose requirements for virus inactivation in Table 1 are based on the log inactivation of adenovirus, which is used by some jurisdictions as a target pathogen for establishing UV virus inactivation requirements. In British Columbia, depending upon the results of a source water assessment from the water supplier or other studies conducted by the water supplier, a Drinking Water Officer has the discretion to base virus log inactivation requirements on either adenovirus or rotavirus.

For drinking water sources that are considered to be vulnerable to human fecal contamination[13] and based on the UV dose requirements set out in Table 1, a 40 mJ/cm^2 UV dose would provide 0.5-log inactivation of viruses based on adenovirus. Under such circumstances, two or more forms of treatment (e.g. chemical disinfection and UV disinfection), would be necessary to provide additional virus inactivation.

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[12] 40 CFR 141.720(d)(1) and USEPA (2006), Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

[13] The DWO may use their discretion to determine whether a drinking water source is at risk of fecal contamination. Key considerations could include hydraulic connection to a known human wastewater source (including onsite sewage) and elevated presence of fecal indicators (e.g. *E. coli* > 20 colony forming units/100 mL).

For drinking water sources that are considered to be at low risk from human fecal contamination, a Drinking Water Officer may decide that rotavirus is a more appropriate pathogen upon which to base virus inactivation requirements.

Unlike for adenovirus, standardized UV dose requirements have not been established for different levels of rotavirus inactivation. Some studies[14] have reported that 3 and 4-log rotavirus inactivation require UV doses greater than 40 mJ/cm^2. Until the UV dose response requirements for rotavirus are formally developed using modern testing protocols (Bolton *et al.*, 2015), a 40 mJ/cm^2 UV dose has been conservatively assigned a 2-log virus inactivation credit in British Columbia based on rotavirus inactivation.

6. Reactor Validation

UV reactors for medium and large water systems undergo validation testing to determine the operating conditions required to deliver a validated UV dose. Validation testing is based on reactor type/model and is typically conducted by a recognized third party at a facility specifically designed for reactor validation. There are no requirements for the periodic revalidation of a reactor once it has been validated.

Note: UV reactors for small water systems are typically certified based on a recognized certification standard. Reactor certification is not the same as reactor validation as the certification and validation processes are not equal (e.g. the factors associated with experimental uncertainty – including UV lamp fouling/aging and the differences in UV sensitivity between challenge organisms and target pathogens – are not accounted for in reactor certification). Reactor certification is discussed in Section 7.

There are several different protocols that are used to validate UV reactors. The following validation protocols are recognized by the Province of British Columbia:

- The German guideline DVGW W294;
- The Austrian standard ÖNORM M 5873; and
- The U.S. EPA UVDGM.

These protocols validate a UV reactor for a reduction equivalent dose (RED; also called the reduction equivalent fluence or REF) based on biodosimetry testing under variable flowrate, UVT and UV intensity settings. Biodosimetry testing is described in Section 6.1.

Validation testing should account for:

a) UVT or absorbance of the water;

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[14] Health Canada (2019). Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Enteric Viruses.

b) Lamp fouling and aging factors[15];
c) Measurement uncertainty of online sensors;
d) UV dose distributions arising from the velocity profiles through the reactor;
e) Failure of UV lamps or other critical components;
f) Inlet and outlet piping or channel configurations of the UV reactor;
g) RED bias (applicable to UVDGM-validated reactors); and
h) Action spectra bias (applicable to UVDGM-validated reactors).

6.1 Biodosimetry Testing

Biodosimetry testing is used to determine the reduction equivalent dose (RED) of a UV reactor by measuring the inactivation of a challenge microorganism after exposure to UV light in the reactor and comparing the results to the dose-response curve of the challenge microorganism determined by bench-scale collimated beam testing. Challenge microorganisms are described in more detail in Section 6.2.

Biodosimetry testing is necessary because it is difficult to predict full-scale reactor disinfection performance based on modeling or bench-scale testing. Biodosimetry testing includes the following steps:

1. **Collimated Beam Testing** – A collimated beam apparatus which produces a precise, uniform UV light output at a wavelength of 254 nm is used to determine the UV dose-response curve of a challenge microorganism. Water samples containing the challenge microorganism are irradiated in a bench-scale laboratory test and the concentrations of viable microorganisms are measured before and after exposure to various doses of UV light. A dose-response curve is graphed by plotting the log inactivation of the challenge microorganism versus the applied dose. The applied dose is calculated based on measured UV intensity, the UV absorbance of water, the depth of the water and the exposure time of the challenge microorganism to the collimated beam. The UV dose-response curve is a measurement of the sensitivity of the challenge microorganism to UV light and is unique to the microorganism. Note that the collimated beam apparatus uses a low-pressure (LP) lamp, and correction factors must be used to adapt the dose-response curves for use with medium pressure (MP) lamps (see Section 6.3)

2. **Full-Scale Reactor Testing** – Log inactivation data are collected from full-scale reactor testing for specific operating conditions (i.e. flow rate, UVT and UV intensity) using the same challenge microorganism as in the collimated beam tests.

3. **Reduction Equivalent Dose** – A reduction equivalent dose (RED) is estimated by interpolating the log inactivation results from full-scale reactor testing onto the UV dose-response curve

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[15] Note: If the source water at the proposed installation site has elevated inorganic constituents (iron, manganese, hardness) and pH, lamp fouling and aging factors may need to be determined during on-site commissioning. This may impact cleaning frequencies and overall project cost. Refer to Sections 9.2 and 9.23.

from collimated beam testing. RED values are specific to the challenge microorganism used for collimated beam testing and the validation test conditions for full-scale reactor testing.

4. **Pathogen Specific Validated Dose** (applicable to UVDGM only) – The RED value is adjusted for experimental uncertainties and biases using a pathogen-specific validation factor (VF) to produce a pathogen-specific validated dose:

Validated Dose = Reduction Equivalent Dose (RED) / Validation Factor (VF)

Further information on biodosimetry testing can be found in the Section 5.2 of the U.S. EPA UVDGM.

6.2 Challenge Microorganisms

Depending upon the validation protocol chosen and the target pathogen (*Cryptosporidium*, *Giardia*, adenovirus, or rotavirus), different challenge microorganisms may be used. Challenge microorganisms are non-pathogenic surrogates and include bacteria-specific viruses such as MS2 bacteriophage and bacterial spores such as *Bacillus subtilis*. Challenge microorganisms are set out in Table 2 for each of the validation protocols recognized by the Province of British Columbia. Section 5.3 of the UVDGM provides information on factors to consider during challenge microorganism selection.

Table 2: Challenge Microorganisms

Validation Protocol	Challenge Microorganisms
DVGW W294	Bacillus subtilis ATCC #6633
ÖNORM M 5873	Bacillus subtilis ATCC #6633
UVDGM	MS2 Bacteriophage ATCC #15597-B1 Bacillus subtilis ATCC #6633 Or other (see Table 5.2 in the U.S. EPA UVDGM)

ATCC – American Type Culture Collection

For the DVGW and ÖNORM validation protocols, the challenge microorganism *B. subtilis* is used to confirm that the minimum RED of 40 mJ/cm^2 is delivered by the reactor. The UVDGM validation protocol allows for different REDs to be targeted, which allows for more flexibility in terms of treatment objectives and operational needs (for example, the UV system may be designed for 1-log reduction of *Cryptosporidium* and *Giardia*, which will reduce power and operational costs compared to a DVGW-validated reactor). Furthermore, the 2020 U.S. EPA document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems" (discussed in Section 6.4) recommends using two or more challenge microorganisms with different UV dose-response, such as MS2 and T1UV phage.

6.3 Considerations for UVDGM-validated Reactors

For UVDGM-validated reactors, ideally the challenge microorganism should have the same UV dose-response (at 254 nm) and action spectra (dose-response over the germicidal range of UV wavelengths) as the target pathogen. In practice, both the UV dose-response and the action spectra of challenge microorganisms and target pathogens differ. Correction factors must be applied, otherwise the log reduction of the target pathogen may be overestimated.

The RED bias is defined as the ratio of the RED measured using the challenge microorganism used to validate the reactor and the RED that would have been delivered to the target pathogen. If the challenge microorganism has the same UV dose-response as the target pathogen, the RED bias is 1.0. If the challenge microorganism is more resistant to UV light than the target pathogen, the RED bias is greater than 1.0. Conversely, if the challenge microorganism is more sensitive to UV light than the target pathogen, the RED bias is less than 1.0.

Under the UVDGM validation protocol, the RED bias factor is a correction factor that accounts for the difference in the UV dose-response (at 254 nm) of the challenge microorganism and target pathogen. More information, including RED bias values based on UVT, log reduction targets, and challenge microorganism UV sensitivity, can be found in the U.S. EPA UVDGM.

The action spectra correction factor (ASCF) accounts for differences in spectral response. The ASCF is applicable to medium pressure UV reactors and other lamps which emit UV light at wavelengths other than 254 nm (for example, LEDs). Action spectra bias is particularly an issue as many challenge microorganisms are more susceptible to inactivation from low-wavelength UV light (<240 nm) than target pathogens, which leads to an overestimation of UV performance. Furthermore, most UV sensors cannot accurately measure intensity in the low-wavelength range, although low-wavelength sensors are now available[16]. Tabulated ASCFs for different challenge microorganisms and target pathogens can be found in the U.S. EPA UVDGM; however, these values do not account for factors which may lead to underestimation of the delivered UV dose (e.g. UV transmittance of the quartz sleeve, changes in water quality compared to the validation water, and lamp aging/fouling). The WRF Report #4376 "Guidance for Implementing Action Spectra Correction with Medium Pressure UV Disinfection" (2015)[17] provides details on different ASCF options, including:

- updated generic tabulated ASCFs;
- development of reactor-specific or site-specific ASCFs using computational fluid dynamics and UV intensity field models (CFD-I); and
- development of reactor-specific or site-specific ASCFs through validation tests.

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[16] USEPA (2020). Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

[17] Table ES.1.

Additional information about ASCF calculation using low-wavelength data is set out in the U.S. EPA 2020 document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems".

There are two other important considerations for UVDGM-validated reactors:

- because the action spectra of *Cryptosporidium* and *Giardia* are statistically similar, the ASCFs for *Cryptosporidium* can be directly used for *Giardia*[18]; and
- because adenovirus was used as the target pathogen for viruses, there are no tabulated RED bias or ASCF values for rotavirus. Appropriate correction factors should be discussed with an issuing official.

6.4 Innovative Approaches for Dose Monitoring and UVDGM Reactor Validation

New approaches and procedures for dose monitoring and UVDGM reactor validation are set out in the 2020 U.S. EPA document "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems" (also referred to as the "Innovative Approaches" document). These approaches and procedures include:

- Microbial methods and dose-response QA/QC bounds for commonly used microbial surrogates in UV reactor validation;
- Approaches for the development of calculated UV dose monitoring algorithms with improved accuracy that eliminate the need for RED bias factors;
- Approaches for the development of UV dose monitoring algorithms that do not require an online UV transmittance monitor for simplified UV system operations;
- For UV reactors equipped with medium pressure UV lamps, implementation of "low wavelength" UV sensors and approaches for the development of UV dose monitoring algorithms that account for the disinfection associated with wavelengths below 240 nm;
- Criteria for the development of a robust validation test matrix, monitoring algorithm goodness of fit and QA/QC requirements, and standardized approaches for defining the validated range of UV reactors;
- Target UV doses for 4.5, 5.0, 5.5 and 6.0 log inactivation of *Cryptosporidium*, *Giardia* and viruses for UV applications requiring higher levels of disinfection than the maximum 4.0 log provided by the UVDGM;
- General validation and data analysis procedures that are commonly implemented in UV reactor validation but are not explicitly documented in the UVDGM; and
- Modifications to the operating recommendations of the UVDGM to improve the accuracy of UV dose-monitoring with the water treatment application.

[18] WRF (2015) Report #4376 - Guidance for Implementing Action Spectra Correction with Medium Pressure UV Disinfection.

The approaches and procedures in the "Innovative Approaches" document are presented for consideration when applying UV disinfection for the inactivation of *Cryptosporidium*, *Giardia*, and viruses, and should not be construed as a replacement or revision to the UVDGM.

6.5 Validation Certificates and Validation Reports

Validation Certificates and Validation Reports document validated operating conditions for UV reactors. This documentation allows an issuing official to assess whether a UV reactor is appropriate for the specified application and it must be provided to the issuing official during the construction permit application review and approvals process.

Validation Certificates are used to document validated operating conditions for reactors that have been validated using the DVGW Guideline and the ÖNORM standard. Validation Certificates specify minimum UV intensity and the maximum flowrate through the reactor.

Validation Reports are used to document validated operating conditions for reactors that have been validated using the U.S. EPA UVDGM protocol. Validation Reports provide detailed documentation of all validation testing results and should include all elements of the validation test plan and a summary of the field-verified UV reactor properties. Validation Reports should also include the reactor's validated dose or range of validated doses, validation factors, log reduction credits for target pathogens, validated operating conditions, and the UV intensity set point(s) if the UV intensity set point monitoring/control strategy is used or the dose monitoring equation if the calculated dose monitoring/control strategy is used.

More information on validation reports including checklists for report content and review, can be found in Section 5.11.3 of the U.S. EPA UVDGM, as well as in Section 2.9 of the U.S. EPA 2020 "Innovative Approaches" document.

6.6 Validated Operating Conditions

To receive pathogen log reduction credits, UV reactors should operate within their validated operating conditions (also referred to as the "validation envelope"). These operating conditions should be considered during validation testing and should be explicitly tested or fall within the range of conditions tested.

Validated operating conditions should include flow rate, UV intensity as measured by a UV sensor, UV lamp status and UVT if a calculated dose control strategy is used (see Section 8.1). Alarms should activate when the measured UV intensity is below the validated UV intensity set point or when the calculated UV dose is below the dose required to meet the pathogen log reduction target. Refer to Section 13 for Alarm Conditions.

With the approval of the issuing official, UV reactors may be permitted to operate outside of their validated range where the UVT is above the validated range and/or the flow rate is less than the validated range, as long as the reactor can operate safely (i.e. without overheating).

6.7 On-site Validation

UV reactors are typically validated off-site at specialized third-party testing centres or at a UV manufacturer's facilities. On-site validation is used when:

- A UV reactor's validated operating conditions (previously obtained through validation testing) do not encompass the specified design criteria for the proposed installation (for example, an extended UVT, flow rate, or UV intensity/lamp output range);
- A design change deviating from previous validation is being sought for the reactor (e.g. new lamp or sleeve type); or
- Existing inlet/outlet piping configurations are constrained and cannot follow standard installation.

Before choosing on-site validation, the water supplier should contact the issuing official to discuss the development of a work program that is acceptable to the issuing official.

The work program for on-site validation should include the following tasks:

1) The collection of background information to support the validation of the reactor;
2) The development of a work plan including high-level schedule, subsequent tasks, and budget for presentation to and review by the issuing official;
3) Where applicable, an initial site visit to review reactor installation and operation, and to identify any issues that could potentially impact on-site validation;
4) The development of a test plan to establish validated operating conditions for the reactor. Multiple test conditions should be proposed which adequately cover the range of operating conditions to be validated in terms of:
    - Flow rates;
    - UVT values; and
    - Lamp power and configuration.

   The test plan should also include consideration of:
    - The challenge microorganism selected;
    - The target pathogen (e.g. *Cryptosporidium, Giardia*, rotavirus, or adenovirus);
    - The preparation of water to be used in the validation test (including assessing the need for chlorine quenching, methods to adjust UVT for the testing range, and mixing requirements for the challenge microorganism and/or chemical addition);
    - A plan for the safe discharge of the validation test water (may require permits);
    - The inclusion of appropriate QA/QC samples; and
    - Whether sensor linearity needs to be established or extended (i.e. if UVT targets extend beyond the normal validated range).
5) On-site validation testing using the test plan including:
    - Equipment set-up and functional testing to verify the operation of the test systems (including power consumption);
    - UV sensor testing (including reference sensor tests and duty UV sensor functional testing to characterize duty UV sensor readings);
    - Biodosimetry testing; and

   - Assessment of the site-specific aging/fouling factor.

6) A review meeting to discuss the on-site validation work with the water supplier and the issuing official and to present the draft report; and
7) The production of a final report that documents the work that was completed under the work program. The final report should be submitted to the issuing official.

On-site validation should be conducted by an independent third party that has the necessary competencies (knowledge, skills, and experience) to do the work. Individuals qualified for such oversight include professional engineers experienced in testing and evaluating UV reactors and scientists experienced in the microbial aspects of biodosimetry. The independent third party should provide oversight to ensure that validation testing and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV reactor manufacturer should oversee the validation testing.

7. Reactor Certification

Some UV reactors are certified using NSF/ANSI Standard 55 which establishes minimum requirements for the reduction of microorganisms using ultraviolet microbiological water treatment systems. NSF Standard 55 also specifies the minimum product literature and labeling information that a manufacturer must supply to authorized representatives and system owners, as well as the minimum service-related obligations that the manufacturer must extend to system owners.

NSF-certified equipment complies with the standards and procedures imposed by NSF including extensive product testing and material analyses. Equipment manufacturers are subjected to unannounced plant inspections and regular product retesting.

Small drinking water systems typically use UV disinfection systems that are certified to NSF Standard 55. There are two types of systems certified under the Standard: Class A systems and Class B systems.

Class A systems are designed to inactivate and/or remove microorganisms, including bacteria, viruses, *Cryptosporidium*, and *Giardia* from contaminated water. Class A systems are intended for visually clear water and are not intended for the treatment of water that has obvious contamination, such as raw sewage, or for the conversion of wastewater to drinking water[19]. Class B systems are designed for supplemental bacterial treatment of disinfected public water or other drinking water that has been tested and deemed acceptable for human consumption.

> It is recommended that NSF Standard 55 Class A certified systems should only be used for small water systems. Water systems that serve more than 500 people in any 24-hour period should use UV disinfection systems that have been validated using one of the validation protocols listed in Section 6. NSF Standard 55 Class B certified systems should not be used for the production of potable water.

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[19] NSF/ANSI 55 - 2019 Ultraviolet Microbiological Water Treatment Systems.

Class A systems are certified to deliver a UV dose that is at least equivalent to 40 mJ/cm^2 at the alarm set point when the system is tested in accordance with the Standard. Recommended maximum pathogen log reduction credits for NSF Standard 55 Class A devices are listed in Table 4. An issuing official has discretion in assigning pathogen log reduction credits based on an assessment of risk for any specific application.

NSF Standard 55 Class A certified systems should have the following:

a) a dedicated power line;
b) a built-in flow restrictor or automatic fixed flow rate control;
c) a UV intensity sensor to detect when the UV intensity at the sensor is below the required minimum;
d) a visual alarm, audible alarm or a system that terminates the discharge of water when the UV system is not operating effectively;
e) an emergency shut-off valve; and
f) a performance data sheet that includes the rated service flow of the reactor in litres/minute or litres/day. Class A systems are typically available for flow rates ranging from 37.9 to 114 litres/minute.

The NSF Standard 55 does not require Class A certified systems to have a UV monitor, which provides an online readout of UV intensity and/or dose delivered. However, provision of a UV monitor and a reference UV sensor may be requested by the issuing official to allow for monthly calibration verification checks of the duty UV sensor (refer to Section 12 – Equipment Verification and Calibration for more information).

Certification information for NSF/ANSI 55 Ultraviolet Microbiological Water Treatment Systems is available online via NSF's website. The information identifies manufacturer name, brand name/trade name/model, flowrate, and disinfection performance claim for Class A and Class B systems. The following organizations have also been accredited in Canada to certify UV reactors as meeting NSF/ANSI Standard 55:

- Water Quality Association (WQA);
- International Association of Plumbing & Mechanical Officials (IAPMO); and
- CSA Group.

8. Dose Monitoring/Control Strategies

There are two main dose monitoring/control strategies that are commonly used by UV equipment manufacturers: calculated dose and UV intensity set point.

8.1 Calculated Dose

The calculated dose control strategy uses a dose monitoring equation to estimate UV dose based on the operating conditions of the UV reactor (e.g. measured flow rate, UV intensity and UVT[20]). The calculated dose is divided by the reactor's Validation Factor and the resulting validated dose is compared to the required dose for the target pathogen and the targeted pathogen log inactivation level. When the validated dose is less than the required dose for the targeted pathogen log inactivation level, the produced water would be considered off-specification and an alarm condition should be activated.

This control strategy is only available for reactors validated using the U.S. EPA UVDGM protocol. Development of the dose monitoring equation is described in the UVDGM (Chapter 5) as well as in the EPA 2020 "Innovative Approaches" document.

8.2 UV Intensity Set Point

The UV intensity set point strategy is available under all validation protocols listed in Section 6. This strategy relies on one or more set points for UV intensity that are established during validation testing. These set points achieve a specific UV dose based on a maximum flowrate and either one or multiple minimum UV intensity values.

The simplest approach is "single set point" operation, which uses one UV intensity set point which achieves the targeted UV dose at a maximum flowrate. NSF 55 Class A certified systems operate with a "single set point" strategy. A "variable set point" approach validates multiple set point pairs of minimum UV intensity which are associated with different flow rates. During UV reactor operation, the measured UV intensity must meet or exceed the set point(s) to ensure the delivery of the required dose. UV reactors must also be operated within validated operating conditions for flow rate and lamp status.

UVT does not need to be monitored separately to confirm the UV dose delivered since the UV intensity readings account for changes in UVT. However, UVT should be monitored on a periodic basis (e.g. with grab samples) to confirm that it is within the range of validated operating conditions.

[20] UVT may not be required for some calculated dose monitoring approaches. See USEPA (2020), Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

9. Design and Installation Considerations

UV equipment design and installation should consider:

1. **Source Water Characterization Data** – For surface water and GARP water supplies, filtration should be installed upstream of UV disinfection to ensure that UV reactor performance is not compromised due to poor or changing water quality and UV reactors continuously operate within their validation envelope or range of certified operating conditions. If filtration is not installed upstream of UV disinfection, a water supply system must be approved for filtration exemption and meet the conditions for exemption set out in the 'Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia'.

   For a water supply system that meets the conditions for filtration exemption, source water characterization data should identify seasonal changes and annual trends in drinking water quality that may affect UV reactor performance (particularly for UVT). Ideally, at least two years of data should be used to inform reactor design decisions.

   If a MP reactor using a calculated dose control strategy is proposed which uses wavelengths shorter than 240 nm in the dose monitoring equation, low wavelength UVT (at ~220 nm) should also be characterized in the source water[21]. UVT data below 240 nm is not required for MP systems if ASCFs are applied per WRF Project 4376, because the ASCF values assume no dose delivery below 240 nm.

2. **Water Quality Requirements for Water Entering a UV Reactor** – UV reactor performance is affected by UVT, particle content, algae, upstream water treatment processes, and constituents in the water that foul reactor components. Water entering a UV reactor should meet water quality requirements specified by the UV equipment manufacturer and should ideally be of sufficient quality to minimize cleaning requirements.

   If the UV equipment manufacturer has not specified water quality requirements for water entering the reactor, the values in Table 3 are recommended. Different values for these parameters may be acceptable to an issuing official if:
   - The reactor was validated for different values (e.g. for an extended UVT range);
   - Experience with similar water quality and reactors demonstrates that adequate treatment is provided; or
   - For elevated inorganic constituents (iron, manganese, hardness) or pH, the combined aging and fouling factor (CAF) is determined during on-site commissioning. Refer to point 23 – Fouling/Aging Factors.

[21] USEPA (2020). Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

Table 3: Recommended Water Quality for Water Entering a UV Reactor

Parameter [a]	Value
Turbidity	< 1.0 NTU
Hardness	< 120 mg/L
Iron	< 0.3 mg/L
Manganese	< 0.05 mg/L
Hydrogen sulphide (if odour present)	Non-detectable
Total suspended solids (TSS)	< 10 mg/L
pH	6.5 to 9.5
Total coliform	< 1000/100 mL
UVT [b]	> 75 %

[a] Parameters from 10 State Standards (2018), except [b].
[b] UVT for fair water quality, U.S. EPA Guidance Manual on Alternative Disinfectants and Oxidants (1999).

3. **Design Flow Rate** – UV facility design should consider the average, maximum and minimum flow rates that the UV equipment will experience. Long-term population projections should be considered as well as current and long-term maximum day demand.

4. **Maximum Flow Rate and Pressure** – Design and installation should ensure that the maximum rated flow rate and pressure cannot be exceeded for the UV equipment.

5. **Inlet and Outlet Piping Configuration** – Inlet and outlet piping to a UV reactor should result in UV dose delivery that is equal to or greater than the UV dose delivered when the UV reactor was validated for the targeted pathogen log inactivation level. The piping configuration used for validation is usually included in the Validation Report. The issuing official may request a preferred piping configuration as recommended in sections 3.6.2 and 4.1.1 of the U.S. EPA UVDGM.

6. **UV Intensity Sensor** – UV reactors should have a UV intensity sensor to verify that sufficient UV light is being delivered to the reactor. Water should not be able to flow through the reactor when the reactor lamps are off or not fully energized unless the reactor was validated with some of the lamps off and the reactor is operating within its validation envelope.

7. **Temperature Sensor and Control** – UV reactors should have a temperature sensor to monitor water temperature within the reactor. If water temperature exceeds the recommended operating range for the reactor, the reactor should shut off to minimize the potential for reactor lamps to overheat. Some reactors may require provisions for cooling water which should be considered during design.

8. **Lamp Status** – UV equipment should have a lamp status indicator that indicates whether a UV lamp is on or off.

9. **Lamp Sleeve** – UV assemblies should be insulated from direct contact with influent water by a natural or synthetic quartz lamp sleeve. The quartz lamp sleeve type used in day-to-day equipment operation should be the same type as was used for equipment validation.

10. **UV Assembly Inspection and Cleaning** – UV assemblies should be accessible for visual observation, cleaning and replacement of the UV lamps, lamp sleeves and sensor window/lens. Lamp sleeves may be cleaned via online mechanical cleaning (with an automated wiper), online mechanical-chemical cleaning (automated wipers with a cleaning solution), or offline chemical cleaning at prescribed frequencies. If online cleaning mechanisms are included, components (wipers, motors/drives, cleaning solution reservoirs, etc.) should also be accessible for observation and maintenance.

11. **Power Quality** – UV equipment installation must consider local power quality. A power quality assessment should be conducted for areas where there are known power quality problems or for remote areas where power quality is unknown. Where power quality is identified as a concern, provisions should be made for power quality monitoring and/or power conditioning, as well as sufficient emergency power supply and/or uninterruptible power supply (UPS) to fully operate the UV equipment.

12. **Lamp Power** – Under normal operating conditions, UV lamps should not run at or near 100% power. UV reactors should be sized appropriately, such that lamp power is efficient under normal operating conditions, and that normal water quality fluctuations do not trigger operation of standby reactors.

13. **Reactor Bypasses** – UV reactor bypasses should not be installed unless specifically authorized by a Drinking Water Officer for the provision of emergency water supply. Adequate safeguards should be put in place to protect public health.

14. **Off-Specification Events** – In the event that a UV reactor malfunctions, loses power, or ceases to provide the required level of disinfection, there should be a feature that causes an alarm to sound or ensures that water from the affected reactor is prevented from entering the distribution system. Refer to Section 14 – Off-Specification Water for more details.

15. **Audible Alarm** – For UV equipment with an audible alarm, the alarm should sound in the building or structure where the UV equipment is installed or at a location where an operator is normally present.

16. **Critical Alarm Conditions** – For UV equipment with an automatic shut-off, UV reactors should automatically shut down under critical alarm conditions (e.g. multiple lamp/ballast failures, low liquid level, or high temperature) to prevent damage to the UV equipment. These alarm conditions should be considered during design to reduce the potential for downstream

pressure transients in the distribution system during sudden shut-offs. For treatment facilities with duty and standby reactors, duty reactors should automatically switch to standby reactors during critical alarm shutdown to minimize disruption to the drinking water supply.

17. **On-line Lamp Breaks** – On-line lamp breaks occur when a lamp and lamp sleeve break while water is flowing through a UV reactor. On-line lamp breaks may be caused by debris, improper lamp orientation, loss of water flow and temperature increases, pressure related events, lamp handling and maintenance errors, and UV reactor manufacturing problems. Preventative measures should be considered, and emergency response procedures to protect customers from mercury and broken glass should be documented in the Emergency Response and Contingency Plan for the drinking water system. More information on UV lamp breaks including preventative measures for on-line lamp breaks can be found in Appendix E to the U.S. EPA UVDGM.

18. **Equipment Component Installation and Replacement** – When UV equipment components are installed or replaced, they should be the same as the components used for equipment validation and/or certification unless the UV equipment was revalidated or recertified. When lamps are replaced from a lamp row or group, the lamp with the longest run time should be moved closest to the UV sensor, and the new lamp installed in the remaining space.

19. **Automated/Unattended Operation** – For UV equipment with automated/unattended operation:

    a. **Real-Time Monitoring** – Real-time monitoring should be used to continuously monitor equipment operation at the remote location. UV dose, alarm history, lamp hours and any other parameters necessary for the proper operation of the equipment should be recorded. A historian function should be included which retains instrumentation and control data for unattended periods (i.e. overnight) for operator review;

    b. **Self-Diagnostic Testing** – UV equipment should have a self-diagnostic test feature that will not disengage the auto shut-off valve until proper disinfection is occurring; and

    c. **Automatic Shut-off Valves** – Automatic shut-off valves should be maintained and checked at the frequency recommended by the equipment manufacturer to ensure reliable operation. Maintenance records should be available for inspection by a Drinking Water Officer when requested.

20. **Equipment Redundancy** – To avoid interruption of flow and where physically possible, a minimum of two UV reactor trains should be installed at treatment facilities that have continuous flow requirements. Full redundancy should consider the effect of shutting down the largest UV reactor for routine maintenance and for changing UV lamps. Redundancy should also consider the effects of equipment failure and the time required for equipment repair. Additional replacement components for the reactor and monitoring systems should be stored onsite; refer to Section 6.3.3 of the UVDGM for a recommended spare parts inventory.

21. **UV Equipment Software** – UV equipment software should be compatible with the SCADA[22] software used for the drinking water system.

22. **Real-time UVT Monitoring** – Real-time UVT monitoring should be used for UV disinfection systems that use the calculated dose control strategy. The provision of multiple UV analyzers should be considered for redundancy, and to allow for one analyzer to be taken out of service for calibration and maintenance.

23. **Fouling/Aging Factors** – Sleeve fouling, sleeve aging, lamp aging, and UV sensor window fouling (if applicable) affect long-term UV reactor performance. Combined aging and fouling factors (CAF) are often used to size a UV reactor for a particular application (i.e. to make sure that the lamp output can still meet the targeted log inactivation, even with an estimated amount of fouling and aging on sleeves and sensors).

    If a higher (less conservative) CAF is used and the water being treated causes heavy fouling, the reactor will produce off-spec water unless the cleaning frequency is increased (i.e. more wiper cycles or offline chemical cleans). In this case, an on-site fouling study should be conducted to inform the cleaning schedule; refer to Section 3.4.5 of the U.S. EPA UVDGM for details on fouling study considerations. Alternatively, a lower (more conservative) CAF could be used during UV equipment design.

    Warranties from UV vendors should be based on the CAF measured in the field by UV sensors.

24. **UV-LED Equipment** – Ultraviolet light-emitting diodes (UV-LEDs) are emerging as a viable technology for drinking water disinfection. Compared to conventional mercury UV lamps, UV-LED lamps are mercury-free, compact, robust, suffer minimal damage from repeated cycling, have longer life and reach full power faster. These advantages, along with virtually instantaneous start-ups and tunable wavelengths, offer great flexibility in UV-LED reactor design. Many applications of UV-LED reactors have focused on small-scale, point-of-use systems due to cost and power considerations (Jarvis *et al.* 2019); however, some larger-scale applications have been developed and approved for installation under the U.S. EPA UVDGM validation protocol.

    To be considered for pathogen log reduction credit assignment, UV-LED equipment for drinking water disinfection should be validated under an approved validation protocol or have NSF Standard 55 Class A certification (see Section 7 – Reactor Certification).

[22] SCADA (Supervisory Control and Data Acquisition) is a process control system that enables drinking water treatment operators to collect data from process sensors and/or to control equipment manually or automatically. The SCADA system may be accessible in the treatment facility and/or from a remote location.

10. Pathogen Log Reduction Credit Assignment

In order for a UV disinfection system to receive pathogen log reduction credits, it should be validated or certified by an accredited or independent third party based on a validation protocol or certification standard recognized by the Province of British Columbia. Independent third-party oversight ensures that validation and/or certification testing, and data analyses are conducted in a technically sound manner and without bias. A person independent of the UV equipment manufacturer should oversee the validation and/or certification testing.

Full-scale UV reactor validation and/or certification testing should document the operating conditions (maximum flow rate, UV intensity, UV lamp status (on/off) and minimum UVT) under which the reactor can deliver the required UV dose to achieve the required pathogen log reduction.

Pathogen log reduction credit assignment is based on:

1. Post-filter applications of UV equipment, or application of UV equipment to drinking water systems that use:
    a. A groundwater source at low risk of containing pathogens;
    b. A 'GARP-viruses only' water source; or,
    c. A water source that has been granted a filtration exemption by a Drinking Water Officer.
2. The UV equipment being fully operational; and
3. The recommended pathogen log reduction credit assignment criteria being met (see Section 7 of the 'Guidelines for Pathogen Log Reduction Credit Assignment').

Pathogen log reduction credit assignment is set out in Table 4 for the validation protocols and certification standards that are recognized by the Province of British Columbia.

Table 4: Pathogen Log Reduction Credit Assignment

Validation Protocol or Certification Standard	Minimum UV Dosage [a]	Maximum Pathogen Log Reduction Credits Assigned [b, c]		
		Cryptosporidium Oocysts	*Giardia* Cysts	Viruses [d]
DVGW W294	RED = 40 mJ/cm^2	3	3	0.5 or 2
NSF Standard 55 (Class A Systems only)	40 mJ/cm^2	3	3	0.5 or 2
ÖNORM M 5873	RED = 40 mJ/cm^2	3	3	0.5 or 2
UVDGM	Validated dose ≥ required dose for target pathogen log inactivation [e]	Determined on a case by case basis	Determined on a case by case basis	Determined on a case by case basis

RED = Reduction Equivalent Dose. May also be called the REF (Reduction Equivalent Fluence).

[a] Validated reactors establish a RED for a specific organism (e.g. an MS2 RED or a *B. subtilis* RED). Similarly, NSF Standard 55 Class A certified systems are designed to deliver a UV dose that is at least equivalent to the MS2 bacteriophage dose-response at 40 mJ/cm^2 when the systems are tested in accordance with the Standard.

[b] Pathogen log reduction credit assignment is based on post-filter applications of UV equipment, or application of UV equipment to drinking water systems that use a groundwater source at low risk of containing pathogens; a 'GARP-viruses only' water source; or a water source that has been granted a filtration exemption by a Drinking Water Officer.

[c] Pathogen log reduction credit assignment is based on UV equipment being fully operational and the applicable pathogen log reduction credit assignment criteria being met (see Section 7 of the Guidelines for Pathogen Log Reduction Credit Assignment).

[d] For drinking water sources that a Drinking Water Officer considers to be at risk from human fecal contamination, a 0.5-log reduction credit should be assigned because of the high level of resistance of adenovirus to UV treatment. For drinking water sources that a Drinking Water Officer does not consider to be at risk from human fecal contamination[23], a 2-log reduction credit should be assigned based on rotavirus inactivation.

[e] Refer to Table 1 for the required dose for target pathogen log inactivation.

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[23] The DWO may use their discretion to determine whether a drinking water source is at risk of fecal contamination, based on a source water assessment from the water supplier, or other studies conducted by the water supplier and provided to the DWO. Key considerations could include hydraulic connection to a known human sewage source and elevated presence of fecal indicators (i.e. *E. coli* > 20 colony forming units/100 mL).

11. Monitoring Parameters

Depending upon the UV control strategy used and in addition to any other sampling, analysis and recording that may be required by a Drinking Water Officer, the monitoring parameters set out in Table 5 should be tested at a minimum frequency of once every five minutes and should be recorded at a minimum frequency of once every four hours. If there is an alarm condition, the test parameters should be recorded at a minimum frequency of once every five minutes until the alarm condition has been corrected.

Table 5: UV Equipment Monitoring Parameters

UV Control Strategy	Parameter Used as the Operational Set Point	Monitoring Parameters
UV Intensity Set Point	UV Intensity	Lamp Status UV Intensity Flow Rate [a]
Calculated Dose	Calculated or Validated Dose [b]	Lamp Status UV Intensity Flow Rate UVT [c]

[a] Not required for UV reactors that have a device that limits the maximum flow rate through the reactor based on the reactor's validated or certified operating conditions.

[b] The calculated dose is estimated using a dose-monitoring equation. For the calculated dose control strategy, the validated dose is equal to the calculated dose divided by the validation factor for the target pathogen to account for biases and experimental uncertainty. Refer to the U.S. EPA UVDGM for more information.

[c] UVT may not be required for some calculated dose monitoring approaches. See USEPA (2020), Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems.

11.1 Lamp Status

UV lamp status indicates whether a particular UV lamp in a reactor is on or off. Lamp status is sometimes used in the dose monitoring equation and is considered to be a validated operating condition.

11.2 UV Intensity

UV intensity measured as milliwatts per square centimeter of exposed area (mW/cm^2) describes the magnitude of UV light measured with a radiometer in bench-scale UV experiments and by a UV sensor in a reactor[24] (USEPA, 2006). Depending on the reactor design there may be multiple sensors at different points in the reactor.

UV intensity measurements are influenced by changes in lamp output due to lamp power settings, lamp aging, lamp sleeve aging, and lamp sleeve fouling. UV intensity measurements may also be influenced by the UVT of the water being treated and substances in the water which absorb or block UV transmission, such as inorganic compounds (especially iron and manganese) and natural organic matter.

11.3 Flow Rate

Water flow rate through a UV reactor should be monitored using a flow meter (either installed separately upstream or as part of the reactor); otherwise a device that limits the maximum flow rate into the reactor should be installed. A UV reactor should operate only at flow rates that are within its validation envelope or certified operating conditions.

For UV reactors that require flow rate monitoring, the method of flow measurement should be selected based on the flow rate variability of the treatment facility. Each UV reactor should have a dedicated flow measuring device to confirm that the reactor is operating within its specified operating range. The flow rate should be displayed locally and where required, be input directly into a control loop for the UV reactor and/or SCADA system. Minimum, maximum, and average daily flow rates should be clearly identified and recorded.

11.4 UV Transmittance

UV transmittance (UVT) is a measure of the percentage of incident light at a specified wavelength transmitted through a material (e.g. water) over a specified distance (pathlength normally 1 cm). UVT is typically measured at 254 nm.

12. Equipment Verification and Calibration

Equipment verification and calibration tests should be conducted on a regular basis to ensure that UV equipment is operating within validated or certified operating conditions and is delivering the correct UV dose for the required pathogen log inactivation.

Procedures for equipment verification and calibration tests are set out in the U.S. EPA UVDGM, DVGW W294 and ÖNORM M 5873.

12.1 Duty and Reference UV Sensors

Duty UV sensors are online sensors that are installed in a UV reactor to continuously measure UV intensity during reactor operation. Reference UV sensors are offline sensors that are used to evaluate

[24] One watt = 1000 mJ/s.

and confirm duty UV sensor performance. Both types of sensors should be checked and calibrated on a regular basis to ensure that accuracy does not drift over time.

Duty UV sensors should be checked against a reference UV sensor at a minimum frequency of once every month or on a more frequent basis depending upon the recommendations of the equipment manufacturer. The calibration ratio (intensity measured with the duty UV sensor/intensity measured with the reference UV sensor) should be less than or equal to 1.2. If the calibration ratio is greater than 1.2, the duty UV sensor should be replaced with a calibrated UV sensor or a UV sensor correction factor should be applied while the problem with the duty UV sensor is being resolved.

Reference UV sensors should be factory calibrated by the sensor manufacturer at a minimum frequency of once every three years or on a more frequent basis depending upon the recommendations of the manufacturer. Reference UV sensors should be calibrated against a traceable standard such as the NIST, NPL, ÖNORM, or DVGW standards. A factory calibrated sensor should have a valid calibration certificate.

12.2 Flow Meters

Flow meters should be calibrated based on the frequency recommended by the flow meter equipment manufacturer or on a more frequent basis at the discretion of a Drinking Water Officer. Flow meter measurements should be within +/- 5% accuracy.

12.3 UVT Analyzers

UVT can be measured with a benchtop spectrophotometer or can be continuously measured by an online UVT analyzer. If the calculated dose monitoring/control strategy is used to estimate UV dose, online UVT analyzer measurements should be evaluated on at least a weekly basis by comparing online UVT measurements to UVT measurements using a calibrated benchtop spectrophotometer. The benchtop spectrophotometer should be maintained and calibrated at the frequency required by the equipment manufacturer. Calibration of UVT analyzers is necessary to determine whether a reactor is operating within its validated operating conditions. The calibration monitoring frequency can be decreased or increased based on the performance demonstrated over a one-year period. For example, the frequency could be reduced to once per month if the UVT analyzer is consistently within the allowable calibration error for more than a month during the first year of monitoring[25].

During UV reactor operation, the difference between the online UVT analyzer measurement and the UVT measured by the benchtop spectrophotometer should be less than or equal to 2%.

[25] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule.

13. Alarm Conditions

Alarm conditions may be designated as minor, major, or critical depending upon the severity of the condition being indicated[26]:

- Minor alarms generally indicate that a UV reactor requires maintenance but that the reactor is still operating within its validated or certified operating conditions.
- Major alarms indicate that the UV reactor requires immediate attention, and that the reactor may be operating outside of its validated or certified operating conditions.
- Critical alarms typically shut down the reactor until the cause of the alarm condition can be fixed to prevent damage to the UV equipment.

Table 6: Typical Alarm Conditions

Minor Alarms	Major Alarms	Critical Alarms
• Lamp Age • UV Sensor Calibration Check [a]	• Low UV Validated Dose [b] • Low UV Intensity • Low UVT [c] • High Flow Rate (if flow restrictor not used) • Mechanical Wiper Function Failure (if applicable) • Single Lamp/Ballast Failure	• Multiple Lamp/Ballast Failures • Low Liquid Level and/or High Temperature [b]

[a] May not be applicable to NSF 55 Class A certified devices, although UV sensors can be calibrated with the provision of a UV monitor (see Section 7. Reactor Certification).

[b] May not be applicable to NSF 55 Class A certified devices.

[c] Only applicable to UV reactors with online UVT monitoring (e.g. using UV intensity set point dosing strategy).

If a UV reactor malfunctions, loses power, or ceases to provide the appropriate level of disinfection, an operator should take the appropriate action at the location where the equipment is installed before water is again directed to users of the drinking water system (for systems with automatic shut-off) or before the alarm is deactivated.

For power quality alarms, if within two minutes of the alarm a further test indicates that power quality is no longer a concern, an operator need not be present at the location where the equipment is installed before water can be again directed to users of the drinking water system. The two-minute window allows a UV reactor to undergo a self-diagnostic test and to automatically reset itself.

Within 30 days following the end of a calendar month, a monthly summary report should be prepared which sets out the time, date, and duration of each major or critical UV equipment alarm that occurred

[26] USEPA (2006). Ultraviolet Disinfection Guidance Manual for The Final Long Term 2 Enhanced Surface Water Treatment Rule. Refer to Tables 4.2, 6.7 and 6.8 for alarm and monitoring schedules.

during the month, the reason for the alarm, the volume of water treated during each alarm period and the actions taken by the water supplier to correct the alarm situation. Unless otherwise notified, these summary reports should be stored onsite by the water supplier for inspection at the discretion of the DWO.

14. Off-Specification Water

Off-specification water[27] is produced when UV equipment is not achieving the required UV dose or log inactivation, as determined by at least one of the following criteria:

- The flowrate through the equipment is higher than the validated range;
- UVT is lower than the validated range[28];
- UV sensors are not properly calibrated; or
- UV equipment does not conform uniformly to the validated unit (i.e. the equipment does not have the same specifications as the equipment that was used for full-scale reactor validation).

Some regulatory bodies/agencies specify that in order to receive pathogen log reduction credits, at least 95% of the water delivered to the public each month should be treated by UV equipment that is operating within its validation envelope. This means that up to 5% of the water provided to drinking water users each month could be off-specification and in the absence of any other form of treatment, could potentially pose a risk to human health. This rule is intended to accommodate operational anomalies or unexpected issues, such as power outages or surges.

Production and management of off-specification water is typically addressed in terms and conditions to a water supply system's operating permit. UV equipment should be designed and selected to prevent off-specification water from entering the distribution system.

15. Training

Training should be provided to all personnel who are associated with UV disinfection equipment.

The training should include classroom and hands-on sessions, and should cover at least the following topics:

- An overview of how the UV equipment (as part of the water treatment facility) meets the provincial drinking water treatment objectives, including guidelines and standards that pertain to UV disinfection;
- An overview of UV disinfection principles;
- Water quality and performance monitoring;

[27] Definition adapted from AWWA Standard F110 Ultraviolet Disinfection Systems for Drinking Water (2016).

[28] Note that flowrate through the equipment and UVT will be linked for reactors using calculated dose strategies or UV intensity variable set point strategies (i.e. units can deliver target UV dose at low UVT and low flow rates but can also deliver target UV dose at higher flow rates when UVT is higher). This validation envelope is specified in the Validation Report or Validation Certificate.

- Normal and emergency operating procedures;
- UV equipment operation and maintenance;
- UV equipment alarms and reporting requirements;
- UV equipment verification and calibration; and
- Safety requirements for operating and maintaining UV equipment, including exposure to UV light, and responding to lamp/sleeve breaks.

16. Equipment Start-Up and Commissioning

Before the start-up and commissioning of new UV equipment, the following documents should be submitted to the issuing official for review:

1. A commissioning plan for the new equipment including equipment calibration, functional testing, and performance testing per Section 6.1 of the U.S. EPA UVDGM;
2. A draft Operation and Maintenance Manual (O&M Manual); and
3. A training plan for all personnel who are associated with the UV disinfection facility, including operators, maintenance workers, instrumentation technicians, electricians, laboratory staff, custodial staff, engineers, and administrators (refer to Section 15 – Training).

After UV equipment installation, the following steps should be included in the reactor start-up and commissioning stages[29]:

- Prior to reactor start-up, a written certification should be obtained from the UV equipment manufacturer confirming that the UV equipment has been installed correctly.
- Upstream piping should be verified as free of sediment or debris that could damage sleeves and lamps.
- A lamp-break response procedure should be prepared, including mercury release response and cleanup procedure.
- The UV system O&M Manual standard operating protocol should be reviewed.
- Calibration checks should be performed on the instruments, sensors, and meters that will be used during equipment testing, including UVT analyzers, UV intensity sensors, and power consumption meters.
- Dry testing should be conducted with a follow-up period of wet testing. The UV equipment supplier should identify the tests that require testing with a dry reactor and those that require wet testing. Ancillary equipment should be included, such as flow meters and modulating valves.
- The UV system should be tested under all design conditions to verify that:
  - The UV dose programmed into the UV system controller matches validation with proper response to the validated range ("verification testing").
  - The UV reactor is adjusting power to maintain the target UV dose at varying flows and UVTs.

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[29] Washington State Department of Health (2019). Water System Design Manual.

  - The UV system records and displays correct information for continuous monitoring and monthly reporting.
  - All alarm set points are working correctly.
  - The values reported on the UV control panel(s) match the values displayed and recorded in the SCADA system.
  - Automatic shut-off valves are working correctly (e.g. under a power failure scenario).
  - Alarms and/or automatic shut-off valves operate correctly under major and critical alarm scenarios.
  - The sleeve cleaning system is operating correctly, if included.
- The UV system should be tested for several days to verify proper performance under normal operation.

In addition to the above:

- Where required, an on-site fouling study should be conducted to inform the reactor cleaning, maintenance, and parts replacement schedule. Refer to Section 3.4.5 of the U.S. EPA UVDGM for details.

17. Conclusion

The information in this guideline provides provincial guidance on the reduction of pathogenic microorganisms in drinking water using UV disinfection and the design, operation, and maintenance of UV equipment for drinking water applications. Additional guidance is set out in the Design Guidelines for Drinking Water Systems in British Columbia, the Guidelines for Pathogen Log Reduction Credit Assignment and in the validation protocols and certification standard referenced in this document. In all cases, a Drinking Water Officer should be consulted when planning or considering upgrades to a drinking water supply system.

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19. Glossary

Action Spectra Correction Factor (ASCF) – a correction factor that is used to account for the greater proportional inactivation of a challenge microorganism compared to the target pathogen that results from differences in action spectra.

Action Spectrum – the relative efficiency of UV over a range of wavelengths at inactivating microorganisms. Each microorganism has a unique action spectrum.

Ballast – an electrical device that provides the proper voltage and current required to initiate and maintain the operation of a UV lamp.

Biodosimetry – a test procedure used to determine the reduction equivalent dose (RED) of a UV reactor by measuring the inactivation of a challenge microorganism after exposure to UV light in the reactor and comparing the results to the dose-response curve of the challenge microorganism determined by bench-scale collimated beam testing.

Calculated Dose Approach – a method that uses a dose-monitoring equation to determine a calculated UV dose based on the reactor's current operating conditions (flowrate, UV intensity and UVT where applicable). The calculated UV dose is divided by the reactor's Validation Factor to determine the validated UV dose. The dose-monitoring equation is normally developed during validation testing.

Challenge Microorganism – a non-pathogenic surrogate microorganism used in UV reactor validation testing with similar UV sensitivity and characteristics as the target pathogen.

Collimated Beam Test – a controlled laboratory bench-scale test that is used to determine the dose-response of a challenge microorganism. The collimated beam test apparatus uses a low-pressure UV lamp to produce collimated UV light (i.e. a beam with parallel rays and minimal dispersion) at 254 nm.

Dose-Response – the level of inactivation of a microorganism as a function of dose.

EPA – the United States Environmental Protection Agency.

Groundwater at Low Risk of Containing Pathogens – groundwater that is considered to be at low risk of containing pathogens as a result of a GARP assessment (i.e. no hazards were identified following a GARP Stage 1: Hazard Screening and Assessment, or the groundwater source was determined to be at low risk following a Stage 2: GARP Determination). Refer to the Guidance Document for Determining Groundwater At Risk of Containing Pathogens (GARP) when assessing the risk that groundwater may become contaminated with pathogens.

Groundwater at Risk of Containing Pathogens (GARP) – any groundwater supply likely to be contaminated from any source of pathogens, continuously or intermittently. Potential sources of pathogens include sewage discharge to land, leaking municipal sewage pipes (especially force mains), agricultural waste stockpiles, runoff intrusion into poorly constructed wells, and surface water.

GARP-Virus Only – any groundwater supply determined to be 'at risk' of containing viruses (i.e. if the DWO has reason to believe that the source is only at risk of containing viruses, and not other pathogens). This would include water supply system wells located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport or other conditions indicating possible viral contamination, therefore requiring treatment of viruses;

Rainwater – water collected from natural precipitation from a roof or similar structure.

Reduction Equivalent Dose (RED) – the UV dose derived by interpolating the log inactivation measured during full-scale reactor testing on the UV dose-response curve that was derived through collimated beam testing. May also be called the reduction equivalent fluence (REF).

Required Dose – the UV dose in units of mJ/cm^2 needed to achieve the target log inactivation for the target pathogen.

Supervisory Control and Data Acquisition (SCADA) – a process control system that enables drinking water treatment operators to collect data from process sensors and/or to control equipment manually or automatically. The SCADA system may be accessible in the treatment facility and/or from a remote location.

Surface Water – water from a source which is open to the atmosphere and includes steams, lakes, rivers, creeks, and springs.

Target Log Inactivation – the log inactivation that the water supplier wants to achieve using UV disinfection for the target pathogen.

Target Pathogen – the microorganism targeted for inactivation credit using UV disinfection.

UV Absorbance (A) – a measure of the amount of light that is absorbed as it passes through a material (e.g. water) over a specified distance (pathlength, normally 1 cm). UV absorbance is normally measured at 254 nm, typically on a per centimeter (cm^{-1}) basis.

UV Dose – the UV energy per unit area incident on a surface, typically reported in units of mJ/cm^2. The UV dose received by a waterborne microorganism in a reactor vessel accounts for the effects on UV intensity of the absorbance of the water, absorbance of the quartz sleeves, reflection and refraction of light from the water surface and reactor walls, and the germicidal effectiveness of the UV wavelengths transmitted.

UV Equipment – the UV reactor and related components of the UV disinfection process, including (but not limited to) UV reactor appurtenances, ballasts, and control panels.

UV Intensity – the power passing through a unit area perpendicular to the direction of propagation. UV intensity is used in this guidance manual to describe the magnitude of UV light measured by UV sensors in a reactor and with a radiometer in bench-scale UV experiments.

UV Intensity Set Point Approach – a method that uses one or more UV intensity set points to determine UV dose. The set points are based on the validation testing for the UV reactor.

UV Light – light with wavelengths from 200 to 400 nm.

UV Reactor – the vessel or chamber where exposure to UV light takes place, consisting of UV lamps, quartz sleeves, UV sensors, quartz sleeve cleaning systems, and baffles or other hydraulic controls. The UV reactor also includes additional hardware for monitoring UV dose delivery; typically comprised of (but not limited to) UV sensors and UVT monitors.

UV Reactor Validation – experimental testing to determine the operating conditions under which a UV reactor delivers the dose required for inactivation credit of *Cryptosporidium*, *Giardia lamblia*, and viruses.

UV Transmittance (UVT) – a measure of the fraction of incident light at a specified wavelength transmitted through a material (e.g. water) over a specified distance (pathlength normally 1 cm). UVT is typically measured at 254 nm unless otherwise specified (i.e. as low wavelength UVT at ~220 nm).

Validation – the full-scale testing of a reactor to determine its disinfection performance under all operating conditions, including flow, UVT, and lamp power.

Validated Dose – the UV dose in units of mJ/cm^2 delivered by the UV reactor as determined through validation testing. The validated dose is compared to the required dose to determine log inactivation credit.

Validation Factor – an uncertainty term that accounts for the bias and uncertainty associated with validation testing under the U.S. EPA UVDGM protocol.

Validated Operating Conditions – the operating conditions under which a UV reactor is confirmed as delivering the dose required for pathogen log reduction credit. Operating conditions should include flowrate, UV intensity as measured by a UV sensor and UV lamp status.

Drinking Water Officers' Guide Part B: Section 17

Design Guidelines for Drinking Water Systems in British Columbia

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Preamble

These *Design Guidelines for Drinking Water Systems in British Columbia* (the *Design Guidelines*) provide guidance to Issuing Officials (i.e. Drinking Water Officers and Public Health Engineers) during the approvals process for changes in waterworks, particularly with respect to the issuance of Construction Permits under the *Drinking Water Protection Act* (DWPA) and Drinking Water Protection Regulation (DWPR). The *Design Guidelines* can also be used by Water Suppliers, Designers, and any other person or persons responsible for the planning and design of new water supply systems and when considering changes to existing systems.

The *Design Guidelines* have been incorporated into Part B of the *Drinking Water Officers' Guide* (DWOG) which is established as a guideline by the Minister of Health under section 4(1)(a) of the DWPA. According to section 4(1)(a) of the DWPA, as part of the DWOG the *Design Guidelines* must be considered by Drinking Water Officers and other officials in exercising powers and performing duties under the Act.

These *Design Guidelines* build on leading practices currently in place in British Columbia, incorporate applicable standards from other jurisdictions such as the Recommended Standards for Waterworks (also known as the "10 State Standards")[1], and reflect the diversity of water systems that serve communities across the province. The *Design Guidelines* emphasize the importance of well-integrated design, review, approval, and construction processes to protect public health and the environment. The approach is not to specify comprehensive design criteria and standards, but to focus on the factors in waterworks design that protect public health and the environment. Comprehensive design information is available from a number of sources, including those listed in Chapter 23 – References, and through various industry organizations.

Projects involving changes in waterworks should be based on a teamwork approach, involving drinking water system Owners, Designers, and Issuing Officials. Early communication and engagement with Issuing Officials is strongly recommended at the various stages of the planning, design, and construction phases to facilitate the approvals process.

These *Design Guidelines* are a living document and will be updated as required. Recommendations for additions and/or modifications can be forwarded to the Health Protection Branch of the Ministry of Health via email at HP-PHW@gov.bc.ca.

[1] Great Lakes – Upper Mississippi River Board of State and Provincial Public Health and Environmental Managers (2018). Recommended Standards for Water Works.

Contents

1 Introduction

1.1 Purpose

Well-designed drinking water systems are critical for the protection of public health. The purpose of these *Design Guidelines for Drinking Water Systems in British Columbia* (the *Design Guidelines*) is to support the implementation of British Columbia's *Drinking Water Protection Act* and Drinking Water Protection Regulation by establishing guidance that can be used to inform the planning, design, review, and approval processes for the construction of new drinking water systems, and when considering changes to existing drinking water systems.

The *Design Guidelines* are not intended to be a comprehensive resource for waterworks design; instead, the *Design Guidelines* build on existing industry best practices and standards while recognizing the diverse and unique considerations of drinking water systems in the Province. The *Design Guidelines* provide guidance and design options that can be adapted for different situations, allowing for flexibility and innovation in design while addressing site-specific risks and concerns. Users of the *Design Guidelines* are encouraged to rely on their best professional judgement where the *Design Guidelines* are silent or not relevant to the proposed changes in waterworks or their unique situation. The *Design Guidelines* do not diminish the responsibility of the Designer or 'Engineer-of-Record', nor do they diminish the independence or authority of the Issuing Official in project approvals.

1.2 Legislative Framework

In British Columbia, the *Drinking Water Protection Act* (DWPA) and Drinking Water Protection Regulation (DWPR) specify roles and responsibilities, water quality standards, monitoring schedules and treatment aimed at reducing the risks of pathogens in drinking water. Administration of the DWPA and DWPR is the responsibility of the Ministry of Health.

Section 4(1)(a) of the DWPA enables the Minister of Health to establish guidelines that must be considered by Drinking Water Officers and other officials in exercising powers and performing duties under the Act. The Drinking Water Officers' Guide (DWOG), established by the Minister of Health under Section 4(1)(a) of the DWPA, contains provincial health policy related to drinking water. The DWOG provides guidance to Issuing Officials (i.e. Drinking Water Officers and Public Health Engineers) in their day-to-day statutory decision-making.

Part B of the DWOG contains several technical documents and best practice documents that provide guidance on applying B.C.'s drinking water legislation including:

- Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia;
- Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia;
- Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia;
- British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems;
- Guidelines for Pathogen Log Reduction Credit Assignment; and
- Guidelines for Ultraviolet Disinfection of Drinking Water.

As the *Design Guidelines* have been incorporated into Part B of the DWOG, they must be considered by Drinking Water Officers and other officials in exercising powers and performing duties under the DWPA.

1.2.1 Water Supply System Definition

Section 6 of the DWPA states that subject to the regulations, a Water Supplier must provide, to the users served by its water supply system, drinking water from the water supply system that is potable and meets any additional requirements established by the regulations or its operating permit.

The DWPA defines a water supply system as a domestic water system other than:

(a) a domestic water system that serves only one single-family residence, and
(b) equipment, works or facilities prescribed by regulation as being excluded.

Section 3 of the DWPR excludes the following from the DWPA definition of domestic water system:

(a) equipment, works and facilities constructed, operated or maintained
  - (i) under a licence, as defined in the *Water Sustainability Act*, for conservation, power or storage purposes,
  - (ii) under a permit issued under the *Water Sustainability Act*,
  - (iii) for bottled water production or distribution, or
  - (iv) for drinking water dispensing machines;

(b) a reservoir relating to a licence or permit referred to in paragraph (a);
(c) a building system[2];
(d) a system within a system[3].

Furthermore, Section 3.1 of the DWPR states that the following are exempt from Section 6 of the DWPA:

(a) a small system, if
  - (i) each recipient of the water from the small system has a point of entry or point-of-use treatment system that makes the water potable, and
  - (ii) the Water Supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

(b) a water supply system, including a small system, if
  - (i) the system does not provide water for human consumption or food preparation purposes,
  - (ii) the system is not connected to a water supply system that provides water for human consumption or food preparation purposes, and
  - (iii) the Water Supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

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[2] *Building system* means a system, within a building, to which the British Columbia Plumbing Code applies, that receives water from a water supply system operating under a valid operating permit under the DWPA.
[3] *System within a system* means a water supply system that, in the opinion of a Drinking Water Officer or Issuing Official, (a) redistributes water from a water supply system operating under a valid operating permit under the DWPA, and (b) does not require further treatment processes, additional infrastructure or ongoing maintenance to prevent a drinking water health hazard.

In addition to the above exclusions and exemptions in the DWPR, the DWOG advises that regional Health Authorities should consult with their legal counsel in determining whether or to what extent the DWPA may apply to any particular case involving:

(a) Lands or facilities with federal oversight:
   (i) Canadian Forces Bases;
   (ii) Department of Fisheries' facilities; and
   (iii) Parks Canada.
(b) Drinking water systems managed by First Nations communities.

1.2.2 Issuing Officials

As defined in the DWPA, Issuing Official means a person authorized under the regulations (DWPR) to issue a Construction Permit, Operating Permit or other permit required under the Act. According to the Drinking Water Officers' Guide, a Construction Permit is generally issued by a Public Health Engineer (PHE) and an Operating Permit is issued by a Drinking Water Officer (DWO) or their delegates. These Issuing Officials work together to coordinate their respective functions.

1.3 Design Guidelines Audience

These *Design Guidelines* provide guidance to Issuing Officials at the regional Health Authorities during the approvals process, particularly with respect to the issuance of Construction Permits under the DWPA and the Drinking Water Protection Regulation (DWPR). The *Design Guidelines* can also be used by Water Suppliers, Designers, and any other person or persons responsible for the planning and design of new water supply systems and when considering changes to existing systems.

Table 1-1 below describes the *Design Guidelines* audience and the intended application of the guidelines.

Table 1-1 Design Guideline Audience

Design Guideline Audience	Intended Application of the Design Guidelines
Water Suppliers	Will use the *Design Guidelines* for planning changes in waterworks and to understand the expectations of the Issuing Official for water system design.
Designers	Will use the *Design Guidelines*, with their best professional judgement and experience, to inform the design of changes in waterworks. Where departure from the guidance in the *Design Guidelines* occurs, Designers should consult with the Issuing Official. Designers should document the technical rationale (e.g. supporting calculations, bench- or pilot-scale studies to support the design decision, demonstration of successful implementation in other jurisdictions) and justification for such departure to the satisfaction of the Issuing Official.
Issuing Officials	Will use the *Design Guidelines* in the exercise of their duties. Issuing Officials have the authority to depart from the guidance in the *Design Guidelines* in cases where, in their best professional judgement, the guidance is not suitable for the situation and alternative approaches are warranted or appropriate.

1.4 Consultation with Other Officials and Relevant Parties

In British Columbia, drinking water regulation and oversight intersect with many different agencies and parties in addition to the regional Health Authorities. Table 1-2 shows the officials and parties (outside of the regional Health Authorities) that might need to be consulted during proposed changes in waterworks based on the type of work being considered.

Table 1-2 Other Officials and Parties for Consultation

Officials/Parties	Watershed	Water Treatment	Water Distribution	Waste Residuals Management
ENV	✔			✔
First Nations	✔	✔	✔	✔
First Nations Health Authority	✔	✔	✔	✔
EOCP		✔	✔	
MOTI			✔	
Technical Safety BC		✔	✔	
WLRS	✔	✔		✔
WorkSafe BC	✔	✔	✔	✔

The following is a brief list of the other officials and their roles in relation to drinking water regulation and oversight.

Ministry of Environment and Climate Change Strategy (ENV) should be contacted about any questions related to discharges to the environment which require authorization under the *Environmental Management Act*.

ENV is also responsible for the following:

.1 Regulating pollutants that may contaminate water supplies (*Environmental Management Act*); and
.2 Ambient and targeted water quality monitoring.

First Nations: In BC, First Nations, Indigenous Services Canada (ISC) and the First Nations Health Authority (FNHA) work in partnership to support the provision of safe drinking water for First Nation communities. First Nations operate and maintain water supply systems on reserves, infrastructure funding is provided by ISC, and FNHA's Drinking Water Safety Program provides public health advice and guidance (see more details under "First Nations Health Authority" below).

When planning a new water system or making changes to a water system that may impact a First Nation, it is recommended that the First Nation is engaged early on in the planning stages.

First Nations Health Authority (FNHA): The FNHA provides community-based programs and services, largely focused on health promotion and disease prevention, to over 200 First Nations communities and citizens across BC. The FNHA collaborates, coordinates, and integrates health programs and services with the regional Health Authorities and the Ministry of Health to achieve better health outcomes for BC First Nations. The FNHA is a component of the British Columbia First Nations Health Governance

Structure, which was formed through and is supported by a series of plans and agreements between the Tripartite partners: B.C. First Nations, the Province of BC, and the Government of Canada.

The FNHA Drinking Water Safety Program (DWSP) works in partnership with First Nations communities to support access to safe and reliable drinking water from their community water systems. As part of the DWSP team, Environmental Health Officers (EHOs) provide support in a number of ways, including the review of plans for new or upgraded community water systems from a public health perspective. FNHA's DWSP team should be consulted when planning for the construction of new drinking water systems and when considering changes to existing systems in communities served by FNHA.

Environmental Operator's Certification Program (EOCP) is a society established under the Society Act. As per Section 12 of the DWPR, the Environmental Operators Certification Program (EOCP) classifies water supply systems and certifies water supply system operators. A person is qualified to operate, maintain, or repair a water supply system if the person is certified by the Environmental Operators Certification Program for that class of system. The classification of the system determines the certification level of the operator required to operate the system.

The EOCP's mission statement is to "protect human health, the environment, and the investment in facilities through increased knowledge, skill, and proficiency of the members of the Program in all matters relating to water treatment and distribution, and wastewater collection, treatment, reuse, and disposal"[4].

Ministry of Transportation and Infrastructure (MOTI) is responsible for issuing utilities permits for any utility construction within the provincial highway right-of-way. A utilities permit is required for work, including watermains, crossing provincial highways and any watermains within provincial highway rights-of-way. Refer to MOTI's Utility Policy Manual for further information. MOTI should be consulted when expanding a water system outside of incorporated areas.

MOTI also will need to review and approve drainage plans if discharging from municipal land to existing drainage courses within electoral areas.

Ministry of Water, Land and Resource Stewardship (WLRS) – in relation to water, WLRS is responsible for providing provincial leadership on water policy and strategies and the integration of science-based land, aquatic resource, and geographic data. Examples include:

- Leading provincial water related strategies, such as the Watershed Security Strategy and Fund;
- Coordinating government's source to tap strategy to protect drinking water;
- Developing ambient water quality objectives and source drinking water guidelines;
- Advancing policy regarding water related legislation such as the *Water Protection Act* and the *Water Sustainability Act*;
- Progressing surface, groundwater, and watershed science; and
- Collecting well and groundwater related information and data.

WLRS is responsible for water utilities that are regulated under the *Water Utility Act*, including any water utilities created for subdivision approval by developers as part of a rural land development. Prior

[4] EOCP Program Guide (2021)

to construction, private utilities must get approval from the Comptroller of Water Rights (the Comptroller) through a Certificate of Public Convenience and Necessity (CPCN). The CPCN authorizes a private water utility in B.C. to construct and operate a water system to serve customers within a defined area.

WLRS is also responsible for issuing water licenses, regulating provincial water resources, and administering the *Water Sustainability Act* (WSA). A water licence is required as per Section 6 of the WSA to divert water from a stream or aquifer. Additionally, under Section 11 of the WSA, a change approval is required for any complex changes in and about a stream. Similarly, under the Dam Safety Regulation, any alteration, improvement or replacement of all or part of a dam must be authorized under the WSA through a change approval, unless the work is for routine maintenance, addressing hazardous conditions or a condition investigation.

Additionally, WLRS is responsible for area-based planning to protect surface water and groundwater resources (under the *Environmental Management Act*, *Water Sustainability Act*, and Riparian Areas Protection Regulation).

More information on water in B.C. can be found at:
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water

Information for well drillers and pump installers is also available at:
https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/information-for-well-drillers-well-pump-installers

Technical Safety BC oversees the safe installation and operation of technical systems and equipment in B.C. Technical Safety BC administers the *Safety Standards Act* and *Railway Safety Act*. Refer to the Technical Safety BC website for either an installation permit or an operating permit.

Other officials and relevant parties may need to be consulted when planning the construction of new drinking water systems, and when considering changes to existing systems. It is up to the Designer to consult with the correct officials and parties. This may include federal, provincial, or local officials.

WorkSafeBC provides safe work practices that should be followed in the design and operation of water supply systems in B.C. WorkSafeBC should be consulted to ensure that the proposed design meets its requirements. Exposure limits should be reviewed when designing chemical treatment systems.

1.5 Materials Standards

When making changes in waterworks, in addition to these guidelines, the following standards should be considered during the design phase:

- .1 National Sanitation Foundation (NSF) International standards;
- .2 American Water Works Association (AWWA) standards; and
- .3 Canadian Standards Association (CSA) standards.

Generally, these standards ensure that materials in contact with potable water are acceptable in terms of public health. The Designer should ensure that materials in contact with potable water do not create a risk to public health.

1.6 Safety

Besides ensuring the provision of clean, safe and reliable drinking water, Designers must incorporate safety considerations into the design and operation of drinking water systems. Risks to operator and staff safety should be assessed and mitigated early in the design process, and should be revisited at different stages of design.

In addition to requirements and recommendations from WorkSafeBC and Technical Safety BC, practices and processes to identify risks and implement design changes or engineering controls should be incorporated into the design process. Examples of methodologies include:

.1 Process hazard analysis, including hazard and operability (HAZOP) studies; and
.2 Prevention through Design: industry-specific guidance can be found in the Water Research Foundation *Report #3104 – Water Utility Safety and Health: Review of Best Practices,* and *Report #4236 – Workforce Health and Safety: Prevention Through Design.* Similar approaches may be referred to as “safety in design” or “safety by design”.

2 Acronyms and Definitions

2.1 Acronyms

AA	Activated alumina
ACI	American Concrete Institute
ACWWA	Atlantic Canada Water & Wastewater Association
ADD	Average day demand
AFN	Assembly of First Nations
ALARA	As low as reasonably achievable
ANA	Anatoxin-a
ANSI	American National Standards Institute
AO	Aesthetic objective
AOP	Advanced oxidation process
APHA	American Public Health Association
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ASTTBC	Applied Science Technologists & Technicians of BC
ATP	Adenosine triphosphate
AWWA	American Water Works Association
BC	British Columbia
BCBC	BC Building Code
BCGWA	BC Ground Water Association
BCWWA	BC Water and Waste Association
BDOC	Biological dissolved organic carbon
BEP	Best efficiency point
CEC	Canadian Electric Code
CEFT	Critical environmental flow threshold
CFD	Computational fluid dynamics
CFR	Code of Federal Regulations
CFU	Colony forming unit
CGSB	Canadian General Standards Board
CIP	Clean-in-place
COD	Chemical oxygen demand
CPCN	Certificate of Public Convenience and Necessity
CS2TA	Comprehensive Source-to-Tap Assessment
CSA	Canadian Standards Association
CSMR	Chloride-to-sulphate mass ratio
CT	Contact time
CU	Colour unit

DAF	Dissolved air flotation
DBP	Disinfection by-product
DBP-FP	Disinfection by-product formation potential
DC	Direct current
DCS	Distributed control system
DDT	Dichlorodiphenyltrichloroethane
DE	Diatomaceous earth
DFO	Department of Fisheries and Oceans
DI	Ductile iron
DIC	Dissolved inorganic carbon
DO	Dissolved oxygen
DOC	Dissolved organic carbon
DP	Decentralized peripheral
DPD	N,N-diethyl-P-phenylenediamine
DWO	Drinking Water Officer
DWPA	Drinking Water Protection Act
DWPR	Drinking Water Protection Regulation
EBCT	Empty bed contact time
EC	Electrolysis cells
EDC	Endocrine disrupting chemicals
EDR	Electrodialysis reversal
EGBC	Engineers and Geoscientists BC
EHU	Essential household use
EOCP	Environmental Operators Certification Program
ENV	Ministry of Environment and Climate Change Strategy
EPDM	Ethylene propylene diene monomer
ERP	Emergency Response Plan
FAU	Formazin attenuation units
FBWW	Filter backwash water
FCM	Federation of Canadian Municipalities
FF	Fire flow
FITFIR	“First in time, first in right”
FOC	Fisheries and Oceans Canada
FNU	Formazin nephelometric unit
FUS	Fire Underwriters Survey
G	Velocity gradient
GAC	Granular activated carbon
GARP	Groundwater at risk of containing pathogens
GCDWQ	Guidelines for Canadian Drinking Water Quality
GFCI	Ground force circuit interrupter
GFI	Ground fault interrupter

GHG	Greenhouse gases
GIS	Geographic information system
GWPR	Groundwater Protection Regulation
HAAs	Haloacetic acids
HART	Highway Addressable Remote Transducer
HDPE	High density polyethylene (pipe)
HHR	Health Hazards Regulation
HGL	Hydraulic grade line
HMI	Human machine interface
HP	Horsepower
HPC	Heterotrophic plate count
HRT	Hydraulic retention time
HTH	High test hypochlorite
HVAC	Heating, Ventilation, and Air Conditioning
ICC	International Code Council
ID	Inside diameter
IEEE	Institute of Electrical and Electronic Engineers
IESNA	Illuminating Engineering Society of North America
IEX	Ion exchange
INAC	Indian and Northern Affairs Canada
IOC	Inorganic chemical
IP	Internet protocol
IPCC	Intergovernmental Panel on Climate Change
ISC	Indigenous Services Canada
ISO	International Organization for Standardization
km^2	Square kilometre
L	Litre
L/cap/day	Litres per capita per day
L/s	Litres per second
LAN	Local area network
LEL	Lower explosive limit
LP	Low pressure
LPHO	Low pressure-high output
LSI	Langelier saturation index
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
m	Metre
m^3/s	Cubic metres per second
MAC	Maximum acceptable concentration
MCC	Motor control center
MCL	Maximum contaminant level
MDD	Maximum day demand

MDF	Maximum day factor
MF	Microfiltration
mg/L	Milligrams/Litre (parts per million)
µg/L	Micrograms/Litre (parts per billion)
MHO	Medical Health Officer
MIB	2-Methylisoborneol
ML	Megalitre (one million litres)
ML/d	Megalitres per day
MLR	Microcystin-LR
MMCD	Master Municipal Contract Document
MOH	Ministry of Health
MOTI	Ministry of Transportation and Infrastructure
MP	Medium pressure
MWCO	Molecular weight cut-off
MWH	MWH Global Inc. (Stantec Inc.)
NA	Not applicable
NBC	National Building Code
NBR	Nitrile-butadiene rubber
NDMA	N-nitrosodimethylamine
NF	Nanofiltration
NFC	National Fire Code
NFPA	National Fire Protection Association
NH_3-N	Ammonia nitrogen
NIOSH	National Institute for Occupational Safety and Health
NOM	Natural organic matter
NORM	Naturally occurring radioactive materials
NPSH	Net positive suction head
NPV	Net present value
NSF	National Sanitation Foundation
NTU	Nephelometric turbidity unit
OCCT	Optimal Corrosion Control Treatment
OD	Outside diameter
OHS	Occupational Health and Safety
O & M	Operations and maintenance
ORP	Oxidation reduction potential
OSHG	On-site hypochlorite generation
PA	Process automation
PAC	Powder activated carbon
PBDE	Polybrominated diphenyl ethers
PCA	Portland Cement Association
PCB	Polychlorinated biphenyls

PCIC	Pacific Climate Impacts Consortium
PDC	Power distribution center
PE	Polyethylene
PET	Polyethylene terephthalate
PEX	Crosslinked polyethylene
PFAS	Perfluoroalkyl and polyfluoroalkyl substances
P&ID	Piping and Instrumentation Diagram
PIEVC	Public Infrastructure Engineering Vulnerability Committee
PHD	Peak hourly demand
PHE	Public Health Engineer
PHO	Provincial Health Officer
PHSA	Provincial Health Services Authority
PLC	Programmable logic controller
POE	Point-of-entry
POP	Persistent organic pollutant
POU	Point-of-use
PP	Polypropylene
PPCP	Pharmaceutical and personal care product
PPE	Personal protective equipment
PRV	Pressure reducing valve
psi	Pounds per square inch
PTA	Packed tower aeration
PVC	Polyvinyl chloride
PVDF	Polyvinylidene fluoride
QA/QC	Quality assurance/quality control
QMRA	Quantitative microbial risk assessment
QWD	Qualified Well Driller
RCP	Representative concentration pathways
RCRA	Resource Conservation and Recovery Act
RO	Reverse osmosis
SAC	Strong acid cationic
SBA	Strong base anionic
SCADA	Supervisory Control and Data Acquisition
SDS	Safety data sheet
SDWQGs	Source Drinking Water Quality Guidelines
SOC	Synthetic organic chemical
SSR	Sewerage System Regulation
SUVA	Specific UV absorbance
TCLP	Toxicity Characteristic Leaching Procedure
TCU	True colour units

TDH	Total dynamic head
TDS	Total dissolved solids
THM	Trihalomethanes
TMP	Transmembrane pressure
TOC	Total organic carbon
TSS	Total suspended solids
TWL	Top water level
UC	Uniformity coefficient
UF	Ultrafiltration
ULC	Underwriters Laboratories of Canada (UL Canada)
UPS	Uninterruptable power supply
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
UV254	Ultraviolet absorbance at 254 nm
UVT	Ultraviolet transmittance
VFD	Variable frequency drive
VOC	Volatile organic compound
WAC	Weak acid cationic
WBA	Weak base anionic
WCB	Workers Compensation Board
WEF	Water Environment Federation
WHMIS	Workplace Hazardous Materials Information System
WHO	World Health Organization
WLRS	Ministry of Water, Land and Resource Stewardship
WRF	Water Research Foundation
WSA	Water Sustainability Act
WTP	Water treatment plant

2.2 Definitions

Word	Definition
Adaptation	Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Also, actions/measures that reduce the negative impacts of climate change, while taking advantage of potential new opportunities.
Aeration	Aeration systems add air to water and can be used to oxidize specific contaminants.

Word	Definition
Air stripping	Air stripping systems remove gases from water and may be used to remove objectionable concentrations of dissolved gases (e.g. hydrogen sulphide, carbon dioxide), trihalomethanes or volatile organic compounds (VOCs).
Alkalinity	The capacity of water to neutralize acid. It is the sum of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), and hydroxide (OH^-) anions in the water.
Anion	A negatively charged ion (e.g. Cl^-, OH^-).
Aquifer	Defined in the *Water Sustainability Act* as: (a) a geological formation, (b) a group of geological formations, or (c) a part of one or more geological formations, that is groundwater bearing and capable of storing, transmitting and yielding groundwater.
Average day demand (ADD)	The average actual or estimated water consumption (as a flow rate) that is, or expected to be, used over a 24-hour period. When water use data is available, ADD can be determined as the product of the following: (a) design population of the facility (e.g. population during the design year); and (b) the average daily per capita flow (where several years of data is available, the greatest average value should be used) Refer to Section 21.4.1 – Domestic Water Demand for options if water use data is not available.
Backflow	A hydraulic condition, caused by a difference in pressures, which causes non-potable water or other fluid to flow into a potable water system.
Backpressure	A pressure that can cause water to backflow into a water supply system when a user’s water system is at a higher pressure than the water supply system.
Backsiphonage	A form of backflow caused by a negative or sub-atmospheric pressure within a water supply system.
Bacteria	Unicellular prokaryotic microorganisms, occurring in a wide variety of forms, existing either as free-living organisms or as parasites. Can be pathogenic or symbiotic.

Word	Definition
Blowdown	(a) the continuous or intermittent removal of a portion of any process flow to maintain the constituents of the flow within desired levels. (b) the water discharged from a boiler, cooling tower or membrane water treatment system to dispose accumulated dissolved solids.
Building system	Defined in the DWPR as a system, within a building, to which the British Columbia Plumbing Code applies, that receives water from a water supply system operating under a valid Operating Permit under the DWPA.
Capacity	The flow rate that a treatment process unit, process train or treatment plant is capable of producing. See also rated capacity.
Cation	A positively charged ion (e.g. Fe^{2+}).
Cavitation	The formation and sudden collapse of vapour bubbles in a liquid, usually resulting from local low pressures, as on the trailing edge of a propeller. This phenomenon develops a momentary high local pressure that can cause mechanical damage to the surface on which the bubbles collapse. Cavitation can occur in pumps when the suction side has insufficient head for the current.
Change approval	Written authorization to make complex changes in and about a stream, per the *Water Sustainability Act*.
Changes in waterworks	Improvements to a water supply system which includes, per Section 7(1) of the DWPA, the construction, installation, alteration, or extension of: (a) a water supply system, or (b) works, facilities or equipment that are intended to be a water supply system or part of a water supply system.
Chemically enhanced backwash	Backwashing of a membrane with the addition of chlorine or other chemicals. Also referred to as maintenance clean or wash, enhanced flux maintenance, or extended backpulse clean.
Clarification	All methods of removing solids from process water, not including filtration processes.
Clean-in-place (CIP)	A chemical cleaning process in which the membranes in a membrane water treatment system: (a) are not removed from their housings (pressure vessels) or the system, and (b) are cleaned by being exposed to cleaning solutions, which are commonly recirculated through the cleaning system and membranes. May also be referred to as a recovery clean.

Word	Definition
Clearwell	A tank or vessel used for storing treated water. Typical examples of storage needs include: (a) chemically-disinfected water storage to provide contact time to achieve CT for primary disinfection, (b) finished water storage to prevent the need to vary the rate of filtration with variations in distribution system demand, and (c) backwash water for filters. Clearwells are located on-site at a water treatment plant. A clearwell may also be called a filtered water reservoir.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods.
Coagulant aid	A chemical added during coagulation to improve the process by stimulating floc formation or by strengthening the floc so it holds together better. Such a chemical is also called a flocculant aid.
Coagulation	The process of consolidating colloidal particles by chemical neutralization of negatively charged dissolved and particulate matter, to facilitate removal from the treated water by clarification and/or filtration.
Coliform	A group of bacteria, defined by a set of biochemical characteristics, which are commonly used as indicators of fecal contamination.
Compound gauge	A compound gauge is used to measure atmospheric and vacuum pressure. Atmospheric pressure is measured in kilopascals (kPa) or pounds per square inch (psi). Vacuum pressure is generally measured in mm of Hg.
Concentrate	The concentrated solution containing constituents removed or separated from the feedwater by a membrane water treatment system. Concentrate is also called reject, brine, retentate or blowdown, depending on the specific membrane process.
Connection	Defined in the DWPR as the line from the watermain to a dwelling, campsite or premises.
Construction Permit	A permit required under Section 7 of the DWPA to make changes in waterworks.
Contact time	The period of time provided for disinfection in water treatment. Refer to T_{10} definition for more information.
Contaminant	Any undesirable physical, chemical, biological or radiological substance or matter in water.

Word	Definition
CT	A measure of efficacy for chemical disinfectants, which is the product of the residual concentration of the disinfectant (C, in units of mg/L) and the contact time (T, in units of minutes).
Design Guidelines	These *Design Guidelines for Drinking Water Systems in British Columbia* by the Ministry of Health.
Design year	The expected design period, which is used to forecast flowrates for equipment/infrastructure sizing (e.g. the 20-year MDD). Also called the planning period or design horizon.
Designer	The qualified professional responsible for the design of changes in waterworks.
Detention time	The theoretical time required for water to pass through a tank, pipe or process at a given flow rate. May be calculated (e.g. using T_{10}) or estimated empirically using tracer tests. Also referred to as retention time or residence time.
Dissolved inorganic carbon (DIC)	An estimate of the amount of total carbonates in the form of carbon dioxide gas (CO_2 or H_2CO_3), bicarbonate ion (HCO_3^-), and carbonate ion (CO_3^{2-}). Appendix B of the USEPA's *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems* (2016) provides a lookup table for systems to determine dissolved inorganic carbon (DIC) based on pH and alkalinity.
Distribution mains	Pipes that deliver water to individual customer service lines and provide water for fire protection through fire hydrants, if applicable.
Domestic purposes	Defined in the DWPA as the use of water for: (a) human consumption, food preparation or sanitation, (b) household purposes not covered by paragraph (a), or (c) other prescribed purposes.
Domestic water system	Defined in the DWPA as a system by which water is provided or offered for domestic purposes, including: (a) works used to obtain intake water, (b) equipment, works and facilities used for treatment, diversion, storage, pumping, transmission and distribution, (c) any other equipment, works or facilities prescribed by regulation as being included, (d) a tank truck, vehicle water tank or other prescribed means of transporting drinking water, whether or not there are any related works or facilities, and (e) the intake water and the water in the system,

Word	Definition
	but excluding equipment, works or facilities prescribed by regulation as being excluded.
Drinking water	Defined in the DWPA as water used or intended to be used for domestic purposes.
Drinking water health hazard	Defined in the DWPA as: (a) A condition or thing in relation to drinking water that does or is likely to: (i) endanger the public health, or (ii) prevent or hinder the prevention or suppression of disease. (b) a prescribed condition or thing, or (c) a prescribed condition or thing that fails to meet a prescribed standard.
Drinking Water Officer	As per Section 3 of the DWPA: (1) Unless another person is appointed under subsection (2), the Drinking Water Officer for an area is: (a) the person appointed by the Medical Health Officer as the Drinking Water Officer, or (b) if no appointment is made under paragraph (a), the Medical Health Officer. (2) The Minister may, by order, appoint persons, by name or by title, as Drinking Water Officers and establish the area of their jurisdiction. (3) In determining the qualifications for appointments under subsection (2), the Minister must consult with the Provincial Health Officer. (4) Subject to the regulations, a Drinking Water Officer may, in writing, delegate to any person a power or duty of the Drinking Water Officer under this or another enactment.
Drinking water source	Defined in the DWPA as a stream, reservoir, well or aquifer from which drinking water is taken. Rainwater may also be a drinking water source.
Effective size (D10)	The size of a sieve opening that will allow for no more than 10% of a representative sample of granular filter media to pass through.
Empty bed contact time (EBCT)	A standard convention or measure of the time during which water to be treated is in contact with the treatment medium (for example, sand in a filter column). The empty bed contact time is calculated as: $EBCT = V/Q$ Where (in any consistent set of units):

Word	Definition
	V = the empty volume of the vessel that will be occupied by the treatment medium and Q = the flow rate. Because the treatment medium, such as granular activated carbon, will occupy some volume, the EBCT overestimates the actual time that the flow resides in the vessel.
Engineer-of-Record	The Professional Engineer responsible for a specific portion of the project design.
Environmental flow needs	Defined in the WSA, and in relation to a steam, as the volume and timing of water flow required for the proper functioning of the aquatic ecosystem of the stream.
Environmental Health Officer	A person designated by a health authority as an Environmental Health Officer under Section 78 of the *Public Health Act*.
Filter-to-waste	Water used to condition filters after backwashing that has turbidity above regulatory action levels.
Filtration system	A treatment process which uses physical straining to remove particulate matter. Refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* for details on pathogen inactivation/removal credits.
Fire protection	The ability to provide water through a distribution system for fighting fires in addition to meeting the normal demands of water usage.
Floating storage (floating on the system)	A method of operating a water storage facility such that daily flow into the facility approximately equals the average day demand for water. When consumer demands for water are low, the storage facility will be filling. During periods of high demands, the facility will be emptying.
Flocculation	The process following coagulation which uses gentle mixing to bring suspended particles together so they will form larger, more settleable aggregate particles, called floc.
Flux	For a membrane separation process, the volume or mass of permeate passing through the membrane per unit area per unit time. Solvent (water) flux rate is commonly expressed in cubic metres per square metre per second, or metres per second.
Force main	A pipeline that conveys wastewater under pressure from the discharge side of a pump to a discharge point.

Word	Definition
Freeboard	The vertical distance from the maximum operating water surface elevation (including overflow condition) to ground surface, top of berm, underside of slab, or equivalent natural or built structure.
Groundwater	Defined in the *Water Sustainability Act* as water naturally occurring below the surface of the ground.
Gt	The product of the velocity gradient, G (expressed in units per second), and the flocculation or mixing time (in seconds).
Health Authority	Defined in the *Public Health Act* as a regional health board or a prescribed body. There are five regional health authorities in British Columbia: Fraser Health, Interior Health, Island Health, Northern Health, and Vancouver Coastal Health.
Hydrant	An upright pipe with a spout, or other outlet, to which a hose can be attached, and water can be drawn from a watermain. Typically, this would be a fire hydrant or standpipe.
Hydropneumatic tank (or pressure tank)	A tank that is used in connection with a water distribution system for a single household, for several houses, or for a portion of a larger water system, which is airtight and holds both air and water, and in which the air is compressed and the pressure is transmitted to the water.
Instantaneous demand	The maximum rate of flow that is drawn from a water system to meet customer consumption demands from the water storage and distribution system.
Instantaneous flow rate	A flow rate of water measured at any particular instant, such as by a metering device.
Intake water	Per the DWPA, in relation to a domestic water system, the water at or near the point of intake into the system.
Issuing Official	Defined in the DWPA as a person authorized under the regulations to issue a Construction Permit, Operating Permit or other permit required under the DWPA.
L10	The predicted service life, for a given population of identical bearings operating under controlled conditions, for which 90% will meet or exceed the predicted life, and 10% will fail before reaching that value.
Laboratory	A corporation, agency or other person engaged in conducting analyses for the purposes of these *Design Guidelines*. Section 8(4) of the DWPR requires that laboratories monitoring for *E. coli* and total coliform bacteria in water be approved in writing by the Provincial Health Officer. For the analysis of other parameters, the laboratory should be CALA accredited and/or a

Word	Definition
	qualified laboratory under the Environmental Data Quality Assurance Regulation.
Langelier saturation index	The most known of the calcium carbonate ($CaCO_3$) saturation indexes, the formula for the Langelier index is based on a comparison of the measured pH of a water (pHa) with the pH the water would have (pHs) if at saturation with $CaCO_3$ (calcite form) given the same calcium hardness and alkalinity for both pH cases. The basic formula is LSI = pHa – pHs.
Licence	A conditional licence or a final licence under the *Water Sustainability Act*.
Local Authority	Defined in the DWPA as: (a) a local government, (b) an improvement district, as defined in the *Local Government Act*, that is responsible for the provision of drinking water, (c) a greater board, as defined in the Community Charter, that is responsible for the provision of drinking water, and (d) a local body prescribed by regulation as a local authority for the purposes of the provision in which the term appears.
Local Government	Defined in the DWPA as: (a) the council of a municipality, (b) the board of a regional district, and (c) a local trust committee under the *Islands Trust Act*.
Major changes in waterworks	Major changes in waterworks include but are not limited to: (a) the creation of a new water supply system; (b) an existing unpermitted water supply system becoming a permitted water supply system; (c) modifications to or the addition of treatment infrastructure; and (d) modifications to or the development of a water source.
Maximum day demand (MDD)	The highest actual or estimated water consumption (as a flow rate) that is, or expected to be, used over a 24-hour period, excluding unusual events or emergencies. MDD is normally expressed as m^3/day or ML/day.
Medical Health Officer (MHO)	A physician appointed under the *Public Health Act* to advise and report on local public health issues within a Health Authority. The MHO is responsible for fulfilling the role of a DWO unless the MHO delegates the responsibility to another qualified individual.
Membrane backwash	A cleaning operation that typically involves periodic reverse flow to remove particulate accumulated on a membrane surface. Also referred to as backpulse, backpulse clean, or flux maintenance.

Word	Definition
Monitoring well	Defined in the WSA as a well that: (a) is used or intended to be used for the purpose of monitoring, observing, testing, measuring or assessing: (i) the level, quantity or quality of groundwater, or (ii) subsurface conditions, including geophysical conditions, and (b) is not used or intended to be used for the purpose of (i) exploring for or diverting groundwater for a water use purpose, or (ii) injecting water or any other substance into groundwater on an ongoing basis.
Nephelometric turbidity unit (NTU)	The unit of measurement that is used for evaluating the level of turbidity (suspended and colloidal particles and/or microscopic organisms) in water.
Operating Permit	A permit under Section 8 of the DWPA to operate a prescribed water supply system.
Owner	As defined by the DWPA, in relation to a water supply system includes: (a) a person who is (i) responsible for the ongoing operation of the water supply system, or (ii) in charge of managing that operation, and (b) if (i) parts of the water supply system are owned by different persons, or (ii) all or part of the system is jointly owned by different persons, all of those persons;
Pathogen	An organism (normally a microorganism) that causes disease.
Peak hourly demand (PHD)	The maximum hourly rate of flow supplied by a water system. Typically two to five times the maximum daily demand, depending on the population.
pH	A measure of water acidity which is related to the hydrogen ion concentration (H^+ or H_3O^+).
Potable water	As defined in the DWPA, water provided by a domestic water system that: (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment.

Word	Definition
Protozoa	Unicellular eukaryotic microorganisms, occurring in a wide variety of forms, existing either as free-living organisms or as parasites. Can be pathogenic (e.g. *Cryptosporidium* and *Giardia*) or symbiotic.
Public Health Engineer	Public Health Engineers review submitted proposals (i.e. Construction Permit applications) and provide an assessment of the potential health risks in the design and a public health assessment of whether the design will meet health protection objectives.
Qualified Professional	Includes professional engineers, geoscientists and architects and other professional entities as required by applicable laws or industry practice. The Qualified Professional should be qualified to practice in B.C. and be in good standing through the completion of the works.
Rainwater	Water collected from natural precipitation from a roof or similar structure.
Rainwater harvesting system	Any system used to collect, convey, store, treat and distribute rainwater for use.
Rated capacity	The maximum volume of treated water expressed in m^3/day, that a water treatment facility is capable of producing that: (a) meets the Water Quality Standards for Potable Water prescribed in Schedule A to the DWPR; and (b) can be supplied from the water treatment facility to the distribution system in any 24-hour period.
Raw water	Water from the supply source prior to treatment.
Readiness to connect	The state of the changes in waterworks in which all changes have been completed, satisfactorily tested to confirm hydraulic and electrical continuity, and the water demonstrated to be potable. This state can occur at the readiness to commission stage, when offline commissioning is not practical or feasible, or at the construction permit close-out where systems are commissioned offline.
Reclaimed Water	As defined in the Municipal Wastewater Regulation, municipal wastewater that is: (a) treated by a wastewater facility, and (b) suitable for reuse in accordance with the regulation.
Recovery clean	Recirculating a cleaning solution and/or soaking the membranes in a cleaning solution to restore the membrane transmembrane pressure. Also known as clean-in-place (CIP).

Word	Definition
Recovery rate	In a membrane water treatment system, the fraction of the feedwater that is converted to permeate, filtrate or product. Recovery is sometimes called permeate recovery, product water recovery, feedwater recovery, or conversion.
Regional Health Authority	One of B.C.'s five regional Health Authorities that deliver health services to meet the needs of the population within their respective geographic regions. Regulated under the *Health Authorities Act*.
Residual	(a) any gaseous, liquid, or solid by-product of a treatment process that ultimately will be disposed. For example, in a fixed-bed filter for removing particles from water, both the filter backwash water and the solids in the backwash water are residuals. (b) the concentration of free available chemical disinfectant remaining after a given contact time under specified conditions or treatment chemical after the final process (i.e. in the treated water).
Resilience	Resilience refers to the ability of a system, community or society exposed to hazards to resist, absorb, accommodate to, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management.
Reverse osmosis	A water filtration process using high pressure to force water through a membrane.
Risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.
Safety data sheet (SDS)	A summary document required under the Workplace Hazardous Materials Information System (WHMIS) which contains information on the use, handling and storage of specific chemicals or products. Safety data sheets contain mandated types of information concerning physical characteristics, reactivity, required personal protective equipment and other safeguards.
Sanitary sewer	A gravity pipe carrying untreated wastewater.
Secondary disinfection	The maintenance of a disinfectant residual in the distribution system to protect water from microbiological re-contamination, reduce bacterial re-growth, control biofilm formation, and serve as an indicator of distribution system integrity (loss of disinfectant residual indicating that the system integrity has been

Word	Definition
	compromised). Only chlorine and monochloramine provide a persistent disinfectant residual and can be used for the maintenance of a residual in a distribution system. Also called residual disinfection.
Sedimentation	The process by which flocculated particles are removed from suspension through settling.
Sludge	(a) the accumulated solids separated from a liquid, such as water, during processing, (b) organic deposits on the bottoms of streams or other bodies of water, (c) the removed material resulting from chemical treatment, coagulation, flocculation, sedimentation, or flotation (in which case the sludge is called float) of water, and (d) any solid material containing large amounts of entrained water and collected during water treatment.
Small system	Defined in the DWPR as a water supply system that serves up to 500 individuals during any 24-hour period.
Specific DBP yield	The mass of disinfection by-product (DBP) produced by disinfection, divided by the dissolved organic carbon (DOC) in the water prior to disinfection, in units of µg DBP/mg DOC.
Specific throughput	The volume of water passed through an ion exchange resin bed or water treatment system before the exchanger or system reaches exhaustion.
Stormwater management system	Management system for the capture, diversion and/or treatment of stormwater runoff. Can include basins, tanks, filters, infiltrators, storm drains, vortex separators, seepage manholes and swales, among other options.
Stormwater sewer	A gravity pipe, natural ditch or roadside ditch (including highway and driveway culverts if connected to ditch) carrying surface water runoff to a point of discharge.
Surface water	Water bodies (lakes, wetlands and ponds, including dug-outs), water courses (rivers, streams, drainage ditches), infiltration trenches and areas of temporary precipitation ponding. Defined in the DWPR as water from a source which is open to the atmosphere and includes streams, lakes, rivers, creeks and springs.
System within a System	Defined in the DWPR as a water supply system that, in the opinion of a Drinking Water Officer or Issuing Official, (a) redistributes water from a water supply system operating under a valid Operating Permit under the DWPA, and

Word	Definition
	(b) does not require further treatment processes, additional infrastructure, or ongoing maintenance to prevent a drinking water health hazard.
T_{10}	The length of time during which not more than 10% of the influent water passes through a process. The use of T_{10} ensures that 90% of the water will therefore have a longer contact time.
Tank	A structure or container used to hold solids or liquids for such purposes as aeration, disinfection, equalization, holding, sedimentation, treatment, mixing, dilution, feeding, or other handling of chemical additives.
Threat	In relation to drinking water, a condition or thing, or circumstance that may lead to a condition or thing, that may result in drinking water provided by a domestic water system not being potable.
Total dynamic head (TDH)	The difference in height between the hydraulic grade line on the discharge side of the pump and the hydraulic grade line on the suction side of the pump. This head is a measure of the total energy that a pump must impart to the water to move it from one point to another.
Transmission mains	Pipes that convey water from the source, treatment, or storage facilities to the distribution system.
Treated water	Water that has been subjected to treatment processes.
Turndown ratio	The ratio of the design range of an instrument to the range of acceptable accuracy or precision.
Uniformity coefficient	A ratio of the sieve size opening that will pass 60% of the media sample divided by the sieve size opening that will just pass 10% of the media sample.
Velocity gradient (g)	A measure of the mixing intensity in a water process. The velocity gradient, which is expressed in units per second, is dependent on the power input, the viscosity and the reactor volume. Very high velocity gradients (greater than 300 per second) are used for complete mixing and dissolution of chemicals in a coagulation process, whereas lower values (less than 75 per second) are used in flocculation to bring particles together and promote agglomeration.
Vulnerability	A condition or set of conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an asset or a community to the impact of hazards.
Water Supplier	As defined in the DWPA, a person who is the owner of a water supply system.

Word	Definition
Water supply system	Defined in the DWPA as a domestic water system, other than (a) a domestic water system that serves only one single-family residence, and (b) equipment, works or facilities prescribed by regulation as being excluded.
Watershed	An area of land that drains runoff to a common point, such as a surface water or an aquifer. A watershed is also called a catchment area, drainage area or drainage basin.
Waterworks	Any part of a drinking water system including collection, production, treatment, storage, supply and distribution of water, or any part of such works.
Well	Defined in the WSA as an artificial opening in the ground made for the purpose of: (a) exploring for or diverting groundwater, (b) testing or measuring groundwater, (c) recharging or dewatering an aquifer, (d) groundwater remediation, (e) use as a monitoring well, (f) use as a closed-loop geoexchange well, or (g) use as a geotechnical well, but does not include: (h) an artificial opening, other than a water source well, to which the *Geothermal Resources Act* or the *Oil and Gas Activities Act* applies, or (i) an artificial opening of a prescribed class, made for a prescribed purpose or in prescribed circumstances.
Well cap	Defined in the WSA as a secure cap or lid that prevents vermin, contaminants, debris or other foreign objects or substances from entering the interior of the production casing, and includes a sanitary well seal.
Well cover	Defined in the WSA as a secure cover, lid or structure that prevents vermin, contaminants, debris or other foreign objects or substances from entering the well.
Well pump	Defined in the WSA as a pump that: (a) is at or in a well, and (b) is used or intended to be used for the purposes of (i) diverting groundwater from a well, (ii) adding water to a well to recharge the well or an aquifer, or (iii) dewatering an aquifer.

Word	Definition
Well recharge zone	Defined in the DWPA as the area of land from which water percolates into an aquifer and is transmitted from there into one or more wells that are used, or are intended to be used, to provide drinking water.
Wellhead	Defined in the WSA as: (a) the physical structure, facility, well cover, adapter or device (i) that is at the top of, or at the side and near the top of, a well, and (ii) from or through which groundwater flows or is pumped from the well, and (b) any casing, well cap, valve, grout, liner, seal, vent or drain relating to the well, but does not include a well pump or a pump house.
Wet well	A wet well is a below-grade structure often located within the treatment building that provides storage for finished, potable water. A wet well is used to ensure that a minimum volume is available to be pumped to subsequent unit processes or the distribution system. The level in the wet well may vary, and the pumping rate may be changed, to respond to needed changes in the flow rate and to permit continuous plant operation. The wet well should be watertight.
Wetland	Defined in the WSA as a swamp, marsh, fen or prescribed feature.
Yield test	A pumping test that provides an approximate estimate of the capacity of the well. It should be completed after construction and prior to installing the permanent pump to provide an approximate estimate of the capacity of the well.

3 General Design Guidance

3.1 General

This chapter provides general recommendations for planning, designing, and commissioning a water supply system. This includes design considerations which affect various aspects and phases of design: water quantity/demand calculations, water quality objectives, preliminary testing to demonstrate treatment (bench- and pilot-scale testing), and start-up/commissioning processes.

For design guidance for specific treatment processes, refer to Chapters 7 through 15.

3.2 Water Quantity

When designing water system infrastructure, Designers should determine the quantity of water that will be needed under current and future projected demand scenarios. Designers should size infrastructure to meet the minimum, average and maximum anticipated water demands for the selected design year with consideration to:

a) efficient allocation of financial resources,
b) the likelihood of anticipated changes in water demand,
c) the effects of demand management,
d) the quality of water under current and future demand conditions,
e) the potential impacts of climate change,
f) the design life expectancy of the infrastructure,
g) the ease of staging and expansion,
h) the relative importance or criticality of the infrastructure,
i) negative impacts to the natural environment, and
j) any other factors that may be relevant to the safe and reliable supply of drinking water under current and future conditions.

During times of scarcity or drought, water use restrictions may be applied under rules of the WSA to manage critical ecological and domestic demands on streams and aquifers.

Design year is a key consideration for infrastructure sizing. Water system infrastructure planning should generally include the development of the current, 10-year, 20-year and 50-year or build-out projected demand conditions early in the design process in order to understand the financial, operational, and environmental impacts on the water system under each scenario. Furthermore, specific components equipment are often sized to different design years depending on cost, feasibility, and operational considerations. Additional discussion of design year selection and general guidance for water system infrastructure sizing is provided in Section 3.2.1 – Source Development and Raw Water Supply Infrastructure and Section 3.2.2 – Treatment Facilities and Treatment Infrastructure.

Refer to Chapter 4 – Climate Change Risk Assessment and Adaptation for specific considerations related to climate change and water system infrastructure sizing.

3.2.1 Source Development and Raw Water Supply Infrastructure

Source development and raw water supply infrastructure should generally be sized to meet the water system maximum day demand (MDD) of the selected design year. Where treated water storage is not provided, the source and raw water supply infrastructure should be sized to meet the peak hourly demand (PHD) of the selected design year.

Due to the level of difficulty, high costs of construction, and potential impacts on the environment, the sizing of source diversion facilities or infrastructure that is constructed in or near waterbodies[5] should be based on a minimum 50-year projected demand (e.g. MDD for 50-year design) or build-out condition of the water system. Source water conveyance and mechanical systems should be based on a minimum 20-year projected demand. Where cost is an overriding driver, source infrastructure sizing may be based on a minimum 10-year projected demand, with provision to expand to meet the 20-year projected design flow. The design year should be selected in consultation with the water supply system Owner and should consider public health protection, and financial and environmental impacts.

3.2.2 Treatment Facilities and Treatment Infrastructure

Treatment facilities and treatment infrastructure should be sized to meet the water system maximum day demand of the design year. Where treated water storage is not provided, the treatment infrastructure should be sized to meet the peak hourly demand of the selected design year and coordinated with the source water supply infrastructure sizing.

Sizing of treatment facilities should be based on a minimum 20-year projected demand condition of the water system, with provision to expand to meet the 50-year or build-out projected demand. Conveyance and mechanical systems should be based on a minimum 20-year projected demand. Where cost is an overriding driver, conveyance and mechanical sizing may be based on a minimum 10-year projected demand, with provision to expand to meet the 20-year and 50-year projected design flows.

Treatment infrastructure sizing should include consideration to seasonal fluctuations in water demands (i.e. due to transient populations or increased water use due to higher temperatures/low rainfall) such that the infrastructure is properly configured and designed to reliably meet the minimum and maximum projected demand conditions. This may include a separate dosing system for low flow conditions or a side streamflow meter if the piping does not remain full during low flow. Designers should consider whether batch versus continuous operation would be most suitable for the infrastructure operation to reliably meet the anticipated variation in system water demand.

3.2.3 Distribution Water Storage Facilities, Transmission Mains and Distribution Mains

Distribution water storage facilities should be designed to meet the greater of the peak hourly demand (PHD) or the maximum day demand plus fire flow demand condition of the design year. Fire flow requirements should be determined in accordance with the latest version of the Fire Underwriters Survey™, or other industry standards where more appropriate for the specific situation. Reference should be made to Chapter 16 – Transmission and Distribution.

[5] Reference *Standards and Best Management Practices for Instream Works in British Columbia* and *Change Approval for Work In and About a Stream.*

3.2.4 Calculating Demand

To calculate demand (including maximum day demand and peak hourly demand for the design year), the Designer should consider the following:

a) Future demands (e.g. water conservation, population growth, and climate change);
b) Local government by-laws and design guidelines, where applicable;
c) Historic demand;
d) The *Design Guidelines for Rural Residential Community Water Systems*, 2012 (prepared by the former Ministry of Forests, Lands, Natural Resource Operations & Rural Development); and
e) The *Master Municipal Contract Documents (MMCD) Design Guidelines*, 2014.

Additional guidance for demand calculations is provided for small systems in Section 21.4 – Water Demand.

3.3 Water Quality

The Water Supplier is responsible for demonstrating compliance with the DWPA and DWPR through ongoing monitoring and reporting, as directed by the DWO. Potable water is defined under the DWPA as water provided by a domestic water system that (a) meets the standards prescribed by regulation, and (b) is safe to drink and fit for domestic purposes without further treatment. Refer to Chapter 22 – Water Quality Monitoring for specific recommendations to demonstrate treatment effectiveness.

At a minimum, drinking water needs to be treated to meet Schedule A of the DWPR which specifies bacteriological water quality standards for potable water.

In addition, the following should be considered based on potential risks to the drinking water system:

.1 Provincial drinking water policy as outlined in the *Drinking Water Officers' Guide*, including the provincial drinking water treatment objectives (refer to Section 3.3.1 – Treatment Objectives);
.2 Finished water quality parameters listed in the *Guidelines for Canadian Drinking Water Quality*, including the Guideline Technical Documents. Note: The Ministry of Health has departed from the *Guidelines for Canadian Drinking Water Quality* for selenium. The maximum acceptable concentration (MAC) for selenium in drinking water in B.C. is 10 µg/L;
.3 Stable and non-corrosive water; reference should be made to the *Guidelines on Evaluating and Mitigating Lead in Drinking Water Supplies, Schools, Daycares and Other Buildings,* and Chapter 12 – Internal Corrosion Control;
.4 Operational water quality parameters for the proper performance and operation of water treatment equipment (e.g. turbidity for filtration); and
.5 Any additional requirements specified by a DWO in terms and conditions to the water supply system's Operating Permit.

3.3.1 Treatment Objectives

Minimum performance targets for surface water and groundwater at risk of containing pathogens are set out in provincial drinking water treatment objectives.

Surface Water

The *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia* establish a minimum performance target for water suppliers to treat surface water to produce microbiologically safe drinking water. These objectives are often referred to as the "4-3-2-1-0 objectives" and are as follows:

- 4-log (99.99 percent) reduction of enteric viruses
- 3-log (99.9 percent) reduction of *Giardia* and *Cryptosporidium* (both protozoa)
- 2 forms of treatment for pathogen log reduction
- 1-Less than or equal to 1 nephelometric turbidity unit (NTU) of turbidity
- 0 detectable *E. coli,* total coliform, and fecal coliform

The *Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia* recommends that rainwater treatment should achieve 4-log reduction of both protozoa and viruses.

Groundwater

The *Drinking Water Treatment Objectives (Microbiological) for Groundwater Supplies in British Columbia* specify treatment objectives for groundwater at risk of containing pathogens (GARP), groundwater at risk of containing viruses only ('GARP-viruses only') and groundwater at low risk of containing pathogens.

Drinking water systems that draw water from sources determined to be GARP or 'GARP-viruses only' must employ disinfection. As a minimum, GARP water sources require disinfection by treatment methods that are equivalent to surface water supplies (i.e. 4-log reduction of enteric viruses, 3-log reduction of *Giardia* and *Cryptosporidium*, 2 forms of treatment for pathogen log reduction, less than 1 NTU turbidity, and 0 detectable *E. coli*, total coliform, and fecal coliform in delivered water). Water sources that are determined to be 'GARP-viruses only', require treatment for 4-log virus reduction only. Two forms of treatment are not required for 'GARP-viruses only' raw water sources.

Groundwater sources determined to be at low risk of containing pathogens do not require disinfection unless specified by a Drinking Water Officer per the DWPA.

Table 3-1 below sets out the provincial drinking water treatment objectives for the different types of raw water supply.

Table 3-1 Provincial Drinking Water Treatment Objectives for Various Source Waters

Provincial Drinking Water Treatment Objectives	Source Water			
	Rainwater	Surface Water and GARP	GARP – Viruses Only	Groundwater at low risk of containing pathogens
4-log virus inactivation	✓	✓	✓	
4-log protozoa inactivation	✓			
3-log protozoa inactivation		✓		
2 Forms of treatment	✓	✓		
1 Less than or equal to 1 NTU [2]	✓	✓	1	
0 *E. coli*, Fecal Coliforms and Total Coliforms	✓	✓	✓	✓

1. GARP-viruses only wells should be designated on the basis that risk of enteric viral contamination is the only GARP-associated hazard identified during well assessment, and that turbidity is consistent and stable. Accordingly, raw water turbidity in the groundwater should not pose a hazard and therefore should not require treatment. Refer to the ***Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP)*** for more details.
2. ***Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Turbidity*** by Health Canada states that it is best practice to keep turbidity levels below 1.0 NTU to minimize the potential for interference with disinfection. In addition, to minimize particulate loading and effectively operate the distribution system, it is also good practice to ensure that water entering the distribution system has turbidity levels below 1.0 NTU.

The provincial drinking water treatment objectives in Table 3-1 provide minimum performance targets for water suppliers to produce microbiologically safe drinking water. The assessment of source water quality could identify other parameters of concern that could require treatment or management in addition to the microbiological parameters identified in the table. Depending on source water quality and the risks identified during a source-to-tap assessment, the actual level of treatment required to produce microbiologically safe drinking water might be higher.

To define when greater levels of treatment may be warranted, quantitative microbial risk assessment (QMRA) may be conducted - refer to the *Health Canada Guidance on the Use of QMRA in Drinking Water (2019)* for more information. Alternatively, source water can be monitored for *Cryptosporidium* concentration, assigned to risk-related "bins", and treatment requirements determined per the US EPA LT2ESWTR approach.

The *Guidelines for Pathogen Log Reduction Credit Assignment* by the Ministry of Health provide guidance on pathogen log reduction credit assignment for the production of microbiologically safe drinking water and should be reviewed when designing a new water supply system or when considering changes to an existing system.

3.4 Bench- and Pilot-Scale Testing Recommendations

Bench- and pilot-scale testing are key tools to inform treatment process selection for a specific water source. Bench- and pilot-scale testing allows Designers to assess the reliability and efficiency of water treatment, determine final design and operational parameters, and estimate construction and operational costs. Bench- and/or pilot-scale testing may not be necessary for all designs, but even simple treatment designs may benefit from preliminary testing (e.g. to determine disinfectant dose and potential DBP production in bench-scale tests).

The scope of bench- and pilot-scale testing should balance practical, cost and design limitations. Where possible, bench- and/or pilot-scale testing should be long or extensive enough to demonstrate the effectiveness, stability, and reliability of the proposed treatment system. The tests should include the period of most challenging water quality. If the bench- or pilot-scale study is too short or misses important seasonal changes in source water quality, the process may not work as designed or incur higher than expected operational costs. The challenges and costs of water collection, laboratory analysis, and conducting the tests can limit the feasibility of extensive bench- and/or pilot-scale testing so flexibility may be warranted.

3.4.1 Bench-Scale Testing Recommendations

Bench-scale testing can be used for initial testing of the effectiveness of various treatment processes and chemicals without an extensive amount of equipment. Bench-scale testing allows the Designer to:

a) Shortlist the most effective chemicals and/or processes for pilot testing;
b) Optimize chemical coagulants;
c) Determine chemical application sequence(s);
d) Confirm proper mixing conditions for flocculation;
e) Estimate the hydraulic surface loading for the sedimentation process through the measurement of floc settling velocities;
f) Determine disinfectant demand and doses;
g) Assess the total levels of disinfection by-products (DBPs) potentially produced by the water; and
h) Test methods for control of taste- and odour-producing compounds through the use of oxidants or activated carbon.

Some common bench-scale methods include:

.1 Disinfectant demand and DBP formation potential tests;
.2 Jar-testing to optimize the coagulation, flocculation and settling processes by experimenting with mixing speeds, chemical dosing and settling velocities. Reference should be made to the ASTM D2035 *Standard Practice for Coagulation-Flocculation Jar Test of Water*;
.3 Lab-scale filtration tests, including reduced-size media filters and rapid small-scale column tests (RSSCTs). These can be used for regular filtration media and for adsorptive media including GAC, ion exchange and activated alumina.

Less commonly employed bench-scale methods which require more specialized equipment include:

.4 Flat-sheet membranes to test membrane filtration at a bench-scale;
.5 Collimated beam experiments to test UV disinfection at a bench-scale; and
.6 A continuous-flow bench-scale ozone system to test ozone at a bench-scale.

It should be noted that the treatment processes assessed through methods .3 to .6 are normally completed at pilot-scale instead of bench-scale.

Designers should understand the limitations of bench-scale testing and use caution when extrapolating results from bench- to full-scale. Chemical balance calculations (manually or through modelling software) can be helpful to assess and/or validate bench scale results, especially if the testing period may not capture challenging water quality conditions.

3.4.2 Pilot Test Recommendations

Pilot plants are scaled-down versions of a proposed treatment process; as opposed to bench-scale tests (which are normally batch tests), pilot testing is commonly run continuously for a predetermined duration. Pilot tests are often used to assess the viability of the chosen treatment approach or to confirm and/or optimize operational parameters.

Pilot studies should attempt to replicate the anticipated operating conditions and treatment results expected at full-scale as closely as possible. Where practical, pilot studies should be conducted to confirm the treatment process suitability, anticipated treatment parameters (see Table 3-2) and treatment operating conditions.

Pilot testing typically provides more accurate and reliable information than bench-scale testing; however, it also adds considerable costs. Depending on the treatment processes being considered, bench-scale testing combined with desktop or modelling calculations may provide sufficient information for design.

Pilot testing is recommended for the following situations:

a) Development of a new water source;
b) Assessment of treatment for challenging raw water quality, for example: high levels of contamination (i.e. chemical parameters drastically exceeding GCDWQ MACs) or conditions which may interfere with treatment (i.e. high hardness or low alkalinity);
c) Assessment and improvement of existing treatment processes, especially for large WTPs seeking cost optimization;
d) Selection of novel or non-conventional treatment processes;
e) Deviation from the design criteria set out in the *Design Guidelines*; and
f) Operation under non-conventional operating conditions.

The following should be considered to determine the scope of a pilot study:

.1 Selection of an appropriate treatment technology;
.2 The operational feasibility of the selected technology;
.3 Full-scale water treatment design criteria;
.4 The development of more refined cost estimates;
.5 Requirements for hands-on training for operators and other water system personnel;
.6 Projected hydraulic impacts on the water system; and
.7 Waste disposal requirements and constraints.

Pilot studies should ideally be carried out for at least one year; however, as with bench-scale testing, the scope and duration of pilot studies should balance practical, cost and design limitations. Recommended pilot study durations for different treatment processes are listed in Table 3-2, but flexibility is warranted for pilot duration.

If there are plans to include a recycled water stream (i.e. recycled backwash) at the full-scale WTP, this should be considered in the pilot study design as well. Filtration pilots should be preceded by flocculation/clarification pilot units as appropriate.

Table 3-2 outlines the duration and objectives of piloting for various technologies. For all pilot studies, finished water quality should be included as a parameter to optimize.

Table 3-2 Pilot Studies Duration and Objectives

Treatment	Contaminants Targeted/ Purpose	Minimum Recommended Duration	Parameters to Monitor and/or Optimize
Adsorption	DBP precursors, inorganic chemicals (IOCs), volatile organic compounds (VOCs), synthetic organic chemicals (SOCs)	6-12 months; this can be reduced if rapid small-scale column tests are used	• Run length • Hydraulic loading rate • Empty bed contact time
Ion exchange	IOCs	2-12 months	• Regeneration frequency • Leakage • Resin stability • Potential for chromatographic peaking • pH/corrosion control
Oxidation/ filtration	IOCs	1-6 weeks	• Oxidant type, demand and dose • Coagulant dose (if required) • Media type • Hydraulic loading rate • Filter run length
Reverse osmosis	Desalination, softening, dissolved solids	2-7 months	• Pretreatment required • Flux rate and stability • Back flush parameters
Coagulation, flocculation, and clarification	Organics and turbidity	6-12 months	• Mixing intensity • Chemical feed rate • Various coagulants and coagulant aids • Flocculation time • Retention times • Surface overflow rate/Loading rates • Plate/tube design criteria • Weir loading rates, recycle rates • Air concentration and bubble diameters • Sludge flows and concentration • Coagulant dose(s) • Polymer dose(s)

Treatment	Contaminants Targeted/ Purpose	Minimum Recommended Duration	Parameters to Monitor and/or Optimize
			• Types of coagulants and coagulant aid • Sufficient alkalinity • pH adjustment • Sedimentation rate
Rapid rate filtration	Organics, turbidity	6–12 months	• Filtration rates • Types of media • Depths of media • Length of filter run • Head loss • Filter breakthrough conditions • Backwash parameters • Length of backwash cycles • Disinfection by-product (DBP) precursor removal • Finished water quality • Quantities and make-up of the backwash • Impacts of recycling backwash
Slow sand filtration	Organics, turbidity	12 months	• Pretreatment requirements • Ripening period • Run length • Filter loading rate • Sand type
Biological filtration	IOCs, organics and turbidity	12 months or sufficient to ensure establishment of steady-state biological activity and to encompass all anticipated operational conditions.	• All parameters listed in “Rapid rate filtration” • Continuous vs. cyclical operation • EBCT • Enzyme activity and/or ATP analysis • Additional chemical addition (peroxide, nutrients) • Prior to the initiation of design plans and specifications, a pilot study report should be prepared including the engineer’s design recommendations.
Diatomaceous earth (DE) filtration	Organics	1–4 months	• Pretreatment requirements • Precoat rate • Filter media grade • Screen size • Body feed rate • Run length

Treatment	Contaminants Targeted/ Purpose	Minimum Recommended Duration	Parameters to Monitor and/or Optimize
Cartridge filtration	Turbidity	2–6 weeks	• Pretreatment requirements • Replacement frequency to estimate operational costs • Viability of treatment method
Membrane filtration	Organics	4–7 months	• Pretreatment requirements • Flux rate and stability • Back flush parameters • Chemical dose(s) • Cleaning frequency and chemical types required • Fibre breakage • DBP precursor removal • Finished water quality • To determine membrane types, materials, and manufacturers best suited for source water
Pressure filtration	Specific contaminant removal (i.e. Fe, Mn)	Sufficient to encompass all anticipated operational conditions.	• All parameters listed in “Rapid rate filtration”
Chemical disinfection	Pathogens	Sufficient to encompass all anticipated operational conditions.	• Disinfectant demand • Contact time • Residual concentrations • Disinfectant decay • DBP production
Thickening / Dewatering processes	Liquid waste residual treatment prior to disposal	6-12 months	• Flows • Solids content as well as chemical, physical and microbiological quality • Treatment requirements including equalization • Chemical addition • Effluent quality and clarification requirements • Recycling feasibility

Pilot study monitoring programs should be developed to collect representative data to demonstrate the operating conditions and treatment process performance under normal and worst-case operating conditions and include:

.1 Complete raw water characterization;
.2 Climatic conditions during the piloting;
.3 Water quality parameters and the associated sampling location(s) for each unit process being tested;
.4 Monitoring frequency for each parameter and sampling locations; and
.5 Monitoring equipment and calibration standards.

The final piloting report should contain the following:

a) Description of the piloting process;
b) Schematic of pilot facility design, including unit processes, pipe sizes, pipe connections, flow direction, chemicals and application points, monitoring points, flow control devices, monitoring equipment or gauges, and various process elements (such as intakes, pumps and blowers);
c) Summary of raw water quality and climatic conditions during the pilot testing period;
d) Summary of sampling results demonstrating treatment process performance;
e) Sufficient detail to prove that the proposed treatment can sufficiently treat the water;
f) Quality assurance procedures followed;
g) Capital cost estimates as well as cost projections for full-scale operation (yearly, monthly, and per customer);
h) Comparison of recommended design and operational parameters to design goals, water quality goals, and other performance benchmarks;
i) Final design and operational parameters; and
j) Recommendations for full-scale implementation.

3.5 Testing and Commissioning

3.5.1 Performance and Operational Testing

A testing period should be conducted for all new or upgraded drinking water treatment infrastructure to calibrate all new instruments, pressure test, leak test, and prove the equipment’s functionality. The testing period can be divided into performance testing and operational testing, as described in the following sections. These tests may require temporary pumps and piping; additionally, test water will need to be disposed of correctly through an approved method.

A Testing Plan should be developed, which details all of the procedures proposed for performance testing and operational testing. The Testing Plan should be organized by unit process or major equipment for ease of planning and scheduling. The Testing Plan should contain a schedule of the planned activities with the anticipated dates of each test. The Testing Plan should include forms that can be completed during the performance and operational testing periods to document the testing results.

3.5.1.1 Performance Testing

Performance testing is used to test each item installed to demonstrate compliance with the specified performance requirements. Performance testing should be incorporated into contract documents for equipment supply and installation contracts or similar agreements.

Prior to beginning the performance testing the following should be completed:

.1 Installation inspection (including piping alignment, adjustment and placement of pipe hangers, anchors, thrust restraints and expansion joints);

.2 Cleaning (construction debris, dust, etc.);
.3 Pressure and/or leakage tests of piping and tanks;
.4 Functional checkout of all electrical systems;
.5 Resistance tests for all electrical equipment and electrical systems;
.6 Simulated controls testing to verify programming logic;
.7 Component calibration, loop test, loop commissioning and tuning;
.8 Pre-operational checkout for all mechanical equipment including lubrication, rotation/torque tests/cold alignment, setting pressure regulating/release valves, installation of seals or packing; and
.9 Disinfection of process piping, tanks, and other equipment (per *AWWA C651, C652 and C653*).

The performance testing period should include the following tests:

.1 Test all electrical equipment, instrumentation, mechanical, and piping system;
.2 Functional tests of all mechanical, electrical, and instrumentation equipment and systems, which should include the following:
    a. Manufacturer or equipment representatives should conduct field installation inspections and site acceptance tests as required to confirm performance of specific equipment and/or systems; and
    b. Functional testing may include pump tests (confirming pump curve), chemical dosing calibration, noise/vibration checks, gate/valve testing, testing water level calibration and control, etc.

3.5.1.2 Operational Testing

Operational testing is initiated upon successful completion of the performance testing. The purpose of operational testing is to prove the operation and coordination of all aspects of the system including mechanical, electrical and instrumentation. As with performance testing, operational testing should be incorporated into contract documents for equipment supply and installation contracts or similar agreements.

During operational testing, the systems are filled with their respective liquid, and liquids are circulated and continuously operated for an agreed upon period of time. If the testing is halted for any reason the operational test period should be restarted. The operational testing may include pressure/leak testing, disinfection certification, alignment data, calibration forms, and check-out tags with sign-off for the equipment supplier, if required.

3.5.2 Commissioning

Once the testing period has successfully been completed, the commissioning period will verify the proper performance of the modified or new system. Any temporary installations that were used for the testing period should be removed prior to commissioning. It is recommended that operations staff are on-site during the commissioning to observe the operation of the new equipment.

Prior to beginning commissioning, a Commissioning Plan should be developed, setting forth a step-by-step description of the procedures for commissioning all equipment and systems. The document will serve as the guidance manual for the commissioning process. The Commissioning Plan should include a schedule establishing the dates of the planned work. The Commissioning Plan should also contain a P&ID with the sample taps labelled with the parameters of concern that the WTP is designed to remove and the treated water quality objectives for the plant.

The Designer should make provision for testing the control system during a period of operation or an appropriate period that reflects the range of operating conditions anticipated, which includes periods of seasonal changes or the extremes of the treatment conditions, to compare the actual control sequences with those described in the control narratives. Control narratives should be updated after the testing and as needed to reflect the "as is" status.

In advance of commissioning the following should be verified for completion:

- .1 Confirmation that process piping and/or storage reservoirs have been properly disinfected following appropriate *American Water Works Association (AWWA) Standards* or an equivalent;
- .2 Confirmation that all components of the primary disinfection system are working in accordance with the Designer's design or manufacturer's specification, where applicable;
- .3 If secondary disinfection is required, confirmation that the system has adequate secondary disinfection residual levels (i.e. either free chlorine or combined chlorine dependent on the system and how it is designed);
- .4 Confirmation by the Water Supplier that the Emergency Response and Contingency Plan, and the Operating and Maintenance Manual have been updated to reflect the changes that have been made;
- .5 Confirmation on system start up, that all analyzers have been calibrated (and confirmed), and that all alarms have been tested and are functioning properly. Sampling points should be installed/located throughout the treatment system to facilitate effective treatment process performance monitoring;
- .6 Confirmation that any new watermain connecting the new WTP to the existing distribution system has been pressure tested, swabbed, super chlorinated, flushed and that there are two subsequent satisfactory microbiological tests results;
- .7 Confirmation that a suitably trained and certified operator will be taking over control and operation of the facility;
- .8 Where applicable, confirmation that the water treatment facility is capable of achieving adequate contact time under worst case operating conditions. Provide calculations to verify this is being achieved. Refer to the *Guidelines for the Pathogen Log Reduction Credit Assignment;*
- .9 Confirmation that all components and chemicals in contact with water meet NSF standards or the equivalent; and
- .10 Confirmation that post-treatment drinking water quality meets the requirements in the *Guidelines for Canadian Drinking Water Quality (GCDWQ)* and in provincial standards and guidelines. Parameters subject to seasonal variations should remain within their limits for a period of 12 months following commissioning.

A Post Commissioning Report following the commissioning period should document and address any problems and alarms that occurred during the demonstration period as well as a description of the tests that were performed and their evaluation.

Table 3-3 recommends the length of time for commissioning various treatment processes and the key tasks that should be completed. During commissioning the processes should be stress tested to confirm performance under worst case operating scenarios including peak demand and poor water quality.

Before the system can be put into operation, all tanks, pipes and equipment which convey or store potable water should be disinfected in accordance with AWWA procedures as well as the Designer's plans and specifications.

Table 3-3 Treatment Process Commissioning Recommendations (sourced from Washington State Guidelines)

Treatment	Minimum Recommended Duration	Final Commissioning Tasks
All types of treatment	N/A	Confirm instrumentation and process control work correctly; test alarms. Compare instrumentation output with readings in SCADA. Complete applicable portions of operational reports. Check finished water quality.
Coagulation/ flocculation/clarification	7 days	Confirm set points for mixing speeds, pH and chemical dosing with jar testing results. These will need to be monitored as water quality changes with the seasons.
Rapid rate filtration	30 days	Assess backwash process, settings, and filter-to-waste. Complete at least two filter runs, including backwash and filter-to-waste cycles.
Slow sand filtration	3 months	Allow filters to fully ripen. Complete coliform or other biological testing.
Diatomaceous earth (DE) filtration	7 days	Complete at least two filter cycles (precoat, body feed, DE removal) to ensure all systems work.
Bag and cartridge filtration	8 hours	Confirm that instrumentation works correctly, test alarms (if applicable).
Membrane filtration	30 days	Complete at least 16 hours of operational multiple filtration cycles, test maintenance cleaning process.
UV disinfection	7 days	Refer to the Ministry of Health *Guidelines for Ultraviolet Disinfection of Drinking Water*. Additional time may be required to determine combined aging and fouling factor.

4 Climate Change Risk Assessment and Adaptation

4.1 Introduction

Water resources are under increasing pressure in British Columbia due to a changing climate and increasing demand from population growth *(BC Ministry of Environment, 2008).* Climate change will impact drinking water systems in several ways. Changes in precipitation and temperature will impact source water quality and quantity. Hazards such as wildfire and flood pose significant risks to drinking water infrastructure and operations. In this context, anticipating and understanding the potential impacts of climate change is an important consideration in the planning, design, operation, and maintenance of drinking water systems. Resilient system design is crucial for ensuring public health and long-term access to safe drinking water in communities. When investing in new drinking water systems, or upgrading existing infrastructure, understanding the risk of a changing climate will lead to robust decision-making and guide the development of adaptation measures and strategies.

It is important for Designers to recognize that climate adaptation strategies will differ between each drinking water system, as each strategy should be uniquely suited to the needs, resources, and environment in which the drinking water system operates. The climate hazards facing each drinking water system are location-specific as climate varies spatially (across regions) and temporally (from one season and/or year to another) throughout British Columbia. The risks associated with climate hazards depend on several factors including type of infrastructure, infrastructure condition, environmental conditions, and socioeconomic considerations. Therefore, it is prudent for Designers to take a risk management-based approach to design and assess climate risks unique to the system and location. This chapter provides Designers with a framework for identifying and assessing climate risks and developing climate adaptation plans. Some examples of climate impacts to drinking water systems are provided to help Designers understand the types of climate related hazards to consider.

Although there is uncertainty related to future climate change scenarios, the impacts of climate change on drinking water system infrastructure are already being experienced. Where water systems have typically been designed using climate norms incorporating historic variability, future climate is projected to deviate significantly from these norms. The cost of relying on historic norms may be greatly underestimated and can be offset by taking preventative action today and planning for an anticipated future state. Studies have shown that for every dollar invested in climate adaptation, six dollars is saved in future damages *(Insurance Bureau of Canada & Federation of Canadian Municipalities, 2020).*

By incorporating climate change into a risk management-based approach to system planning, design, and operations, new infrastructure investments can significantly improve the reliability of water resources and drinking water systems throughout their life cycle. Taking a holistic, interdisciplinary, and collaborative approach to climate adaptation planning can ensure that actions will address a broad range of challenges while remaining flexible enough to adapt to changing conditions and new information. Figure 4-1 illustrates the relationship between climate change effects on water resources and management responses. When identifying climate adaptation responses, there may be opportunities to provide co-benefits, such as more sustainable and efficient operations which contribute to a reduction of greenhouse gas emissions.

Note: As defined by the Intergovernmental Panel on Climate Change (IPCC) (2014), climate change mitigation is a human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs). Although climate mitigation will be discussed briefly in Section 4.10 – Climate Change Mitigation, the focus in the *Design Guidelines* is on climate change adaptation.

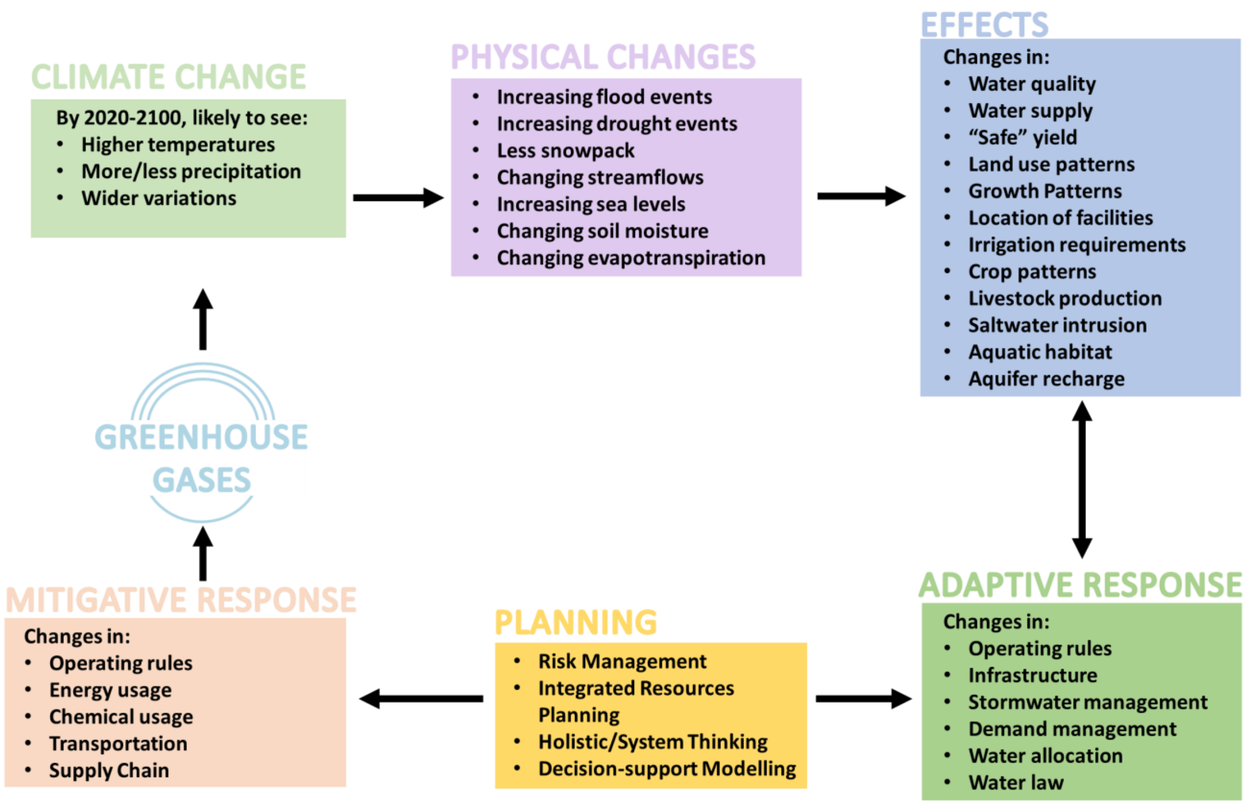


Figure 4-1 Relationship between Climate Change Effects, Effects on Water Resources, and Management Responses. Figure was produced by the American Water Works Association (AWWA). From: AWWA M71 Manual: Climate Action Plans – Adaptive Management Strategies for Utilities, 2021. p. 9. Copyright 2021 by the American Water Works Association.

4.1.1 Climate Change Terms and Definitions

The following terms will be used throughout this document. Definitions included below are from *Infrastructure Canada's Climate Lens – General Guidance (2019).*

Table 4-1 Climate Change Terms and Definitions (from Infrastructure Canada (2019) Climate Lens – General Guidance)

Term	Definition
Adaptation	Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change. Actions/measures that reduce the negative impacts of climate change, while taking advantage of potential new opportunities.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is, in addition to natural climate variability, observed over comparable time periods.
Climate hazard	The potential occurrence of a natural or human-induced physical event or trend, or physical impact, that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, and environmental resources.
Climate impacts	The effects on lives, livelihoods, health status, ecosystems, economic, social, and cultural assets, services (including environmental), and infrastructure due to the interaction of climate changes or hazardous climate events occurring within a specific time period and the vulnerability of an exposed society or system. Impacts are also referred to as consequences and outcomes.
Climate resilience	The capacity of a community, business, or natural environment to anticipate, prevent, withstand, respond to, and recover from a climate change related disruption or impact.
Risk	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically (quantitatively or qualitatively).
Vulnerability	A condition or set of conditions determined by physical, social, economic and environmental factors or processes that increase the susceptibility of an asset or a community to the impact of hazards.

4.1.2 Guidelines for Professional Practice

Engineering professionals are bound by their code of ethics to “hold paramount the safety, health and welfare of the public, protection of the environment and promote health and safety in the workplace.” *(Engineers Canada, 2018)*. These *Design Guidelines* seek to assist Designers in understanding their professional obligations in relation to climate change resilience for drinking water systems.

In response to climate change in British Columbia, Engineers and Geoscientists British Columbia (EGBC), released a Climate Change Position Paper on evolving responsibilities for engineers and geoscientists *(Engineers and Geoscientists BC, 2014)* which states the following:

.1 EGBC recognizes that the climate is changing and commits to raising awareness about the potential impacts of the changing climate as they relate to professional engineering and geoscience practice, and to provide information and assistance to EGBC registrants in managing implications for their own professional practice; and

.2 EGBC registrants (professional engineers, professional geoscientists, provisional members, licensees, limited licensees, engineers-in-training and geoscientists-in-training) are expected to keep themselves informed about the changing climate and consider potential impacts on their professional activities.

EGBC also presents a definition for a Qualified Professional as a part of the Professional Practice Guideline for *Developing Climate Change-Resilient Designs for Highway Infrastructure in British Columbia*. The definition of a Qualified Professional (within the context of climate change) is presented here, along with the associated definition of a Climate Specialist, to help Designers understand the qualifications required to complete a Climate Change Risk Assessment. If Designers do not have the relevant knowledge to complete a Climate Change Risk Assessment as outlined below, they should engage with the appropriate Qualified Professionals.

> **Qualified Professional:** An Engineering/Geoscience Professional with the appropriate knowledge and experience to carry out a Climate Change Risk Assessment. The Qualified Professional should have knowledge of climate science as it relates to the practice of professional engineering and geoscience, in order to be able to carry out appropriately comprehensive Climate Change Risk Assessments. This knowledge should include familiarity with the climate models, tools, and resources appropriate for the project, and the ability to implement design changes in consideration of the Climate Change Risk Assessment. The Qualified Professional is not expected to have competencies like those of a Climate Specialist but should understand what information must be obtained from a Climate Specialist, in order to carry out a Climate Change Risk Assessment when required. *(EGBC, 2020)*

> **Climate Specialist:** A specialist who studies long-term weather patterns and the processes that cause them. Climate Specialists use long-term meteorological data to study trends in weather patterns, understand their causes, and make predictions. *(EGBC, 2020)*

Not all professional regulatory bodies have guidelines directly related to climate change. Other regulated professions should consult with their respective regulatory bodies for guidance where it may exist with regards to climate change adaptability in design or design support practice.

4.2 Climate Impacts on Drinking Water Systems – Source to Tap

The following sections identify climate change phenomena which may affect the supply, treatment, storage, distribution and operation of drinking water supply systems. The information in this section is meant to serve as an illustration of the variety of climate change parameters, indices and processes which can influence safe and reliable access to drinking water and is not wholly encompassing. The information provided in this chapter is intended to prompt Designers to identify potential impacts which may impact the system.

4.2.1 Source Water Impacts

In British Columbia, climate change scenarios indicate that average annual temperatures and precipitation amounts are projected to increase, with greater regional and seasonal variability. For example, although precipitation is projected to increase annually, summer precipitation may decrease.

Some areas will receive significantly more precipitation and others will experience reduced recharge and longer/more severe droughts.

For communities considering major upgrades to drinking water treatment facilities, specific assessments of long-term source water reliability should be conducted. Considerations should include potential changes to aquifer recharge, climate impacts to the quality of groundwater versus surface water and balancing increased water demand associated with higher temperatures with reductions in source availability. Communities should also focus on protecting and enhancing the health of surface water and groundwater through watershed and groundwater protection. *(AFN, 2008)*

Water Suppliers are encourage to monitor source water quantity and quality parameters in order to establish baseline source characterization and assess climate effects over time. Planning for anticipated changes in water availability and quality degradation is critical to ensure continued supply of clean, safe, and reliable drinking water.

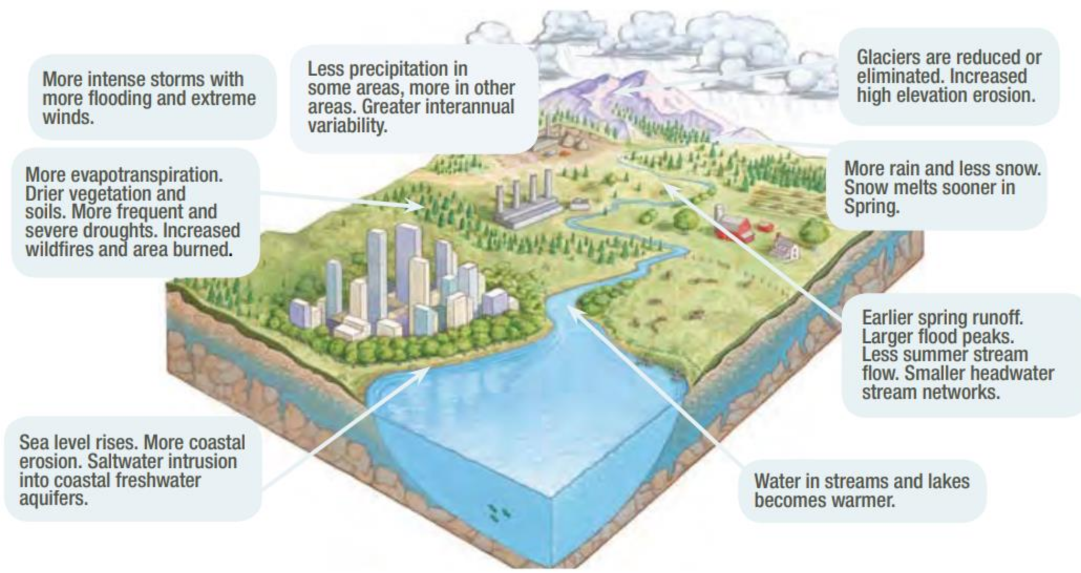


Figure 4-2 Projected Climate Changes to the Hydrologic Cycle, Note: this figure was produced by the US Department of Agriculture from "Climate Change and Water Perspectives from the Forest Service", by U.S. Department of Agriculture, 2008, Sustaining Healthy Watershed, FS 908

4.2.1.1 Surface Water Quantity

Although numerous surface water sources in British Columbia have historically provided sustainable yields as sources for drinking water systems, future streamflow will be impacted by variability in annual and seasonal precipitation and temperature. While annual variability in streamflow is a component of water supply planning, these historical norms can no longer be relied upon for future system planning. As environmental flow needs for a stream must be considered under the *Water Sustainability Act*, there may be increasing pressure on streams to meet both ecological and community water needs.

The following table provides examples of how source water availability may be affected for surface water sources. These impacts should also be considered in determining the viability of a rainwater harvesting system as a main source of potable water. *(BC Ministry of Environment, 2016; Bush & Lemmen, 2019; Compendium of Forest Hydrology in British Columbia, 2016).*

Table 4-2 Observed and Possible Impacts to Surface Water Quantity

Climate Impact	Design Considerations
Changes in snowpack	Changes to water availability in snow dominated watersheds, seasonal streamflow.
Shifts in rainfall patterns	Changing streamflow patterns, including magnitude and timing of peak flows.
	Increased probability and duration of drought.
Increasing atmospheric temperature	Reduction in water availability in watersheds fed by glaciers, impacting streamflow, timing of freshet, and temperature of glacial fed water systems.
	Contributes to increased evaporative losses from water bodies, vegetation, and soils.
Drought	Reduced water availability in summer months.

4.2.1.2 Surface Water Quality

The following table highlights potential impacts for Designers to consider related to surface water quality. Changing surface water quality may impact treatment requirements to meet drinking water quality guidelines.

Table 4-3 Observed and Possible Impacts to Surface Water Quality

Climate Impact	Design Considerations
Increasing temperature	Warmer water temperatures will support algae growth, which can deplete dissolved oxygen levels. Harmful algae (i.e. blue-green algae) usually bloom when water temperatures are warmer than usual. Harmful algal blooms may release cyanotoxins into source water. *(EPA, 2019; AWWA, 2016)*
	Waterborne pathogens may thrive more readily as a result of warmer temperatures.
	Changing water temperatures may change thermal structure, stratification, and mixing of lakes which could impact water quality.
	Warmer water holds less dissolved oxygen, making instances of low oxygen levels ("hypoxia") more likely and altering the toxicity of some pollutants. *(EPA, 2014)*
Extreme precipitation events	Increased runoff, which could impact water quality by increasing nutrient levels, waterborne pathogen concentrations, organic matter, turbidity, metals, major ions, or sedimentation. *(EPA, 2014)*
Flooding	Flooding of sewage infrastructure (lagoons and lift stations), sewage backflows, or direct overflows associated with sanitary and storm water infrastructure could add significantly to the waterborne pathogen load of the floodwater. Inundation of fuel tanks and chemical storage areas could likewise release petroleum hydrocarbons and other pollutants.

Sea level rise	For rivers discharging into the ocean, sea level rise may lead to saltwater intrusion and increased salinity further upstream. Reduced river flows are likely to exacerbate this issue. *(EPA, 2016)*
Wildfire	May change watershed characteristics, impacting both source water quantity and quality. May increase soil erosion and sedimentation, increase water pollution, increase risk of flooding, and pose a threat to aquatic habitats and water infrastructure. Wildfire can affect drinking water quality due to build-up of ash, soil erosion, and fire debris. This may impact taste, colour, smell, and treatability of drinking water. In the event that fire retardant is used and enters the water supply, it may cause an increase in levels of phosphate, nitrate, and nitrite. *(HealthLinkBC, 2018)*

4.2.1.3 Groundwater Quantity

As an integral part of the hydrologic cycle, the availability of groundwater resources providing critical freshwater supply are likely to be affected by climate change. However, the direct impacts of changes to temperature, precipitation and evapotranspiration on the aquifer recharge are complex to predict. Regional or site-specific aquifer characterization and groundwater monitoring is required to determine how climate change could impact the recharge rates of a particular aquifer.

4.2.1.4 Groundwater Quality

Climate change may impact groundwater quality, Table 4-4 describes some impacts of climate change on groundwater.

Table 4-4 Observed and Possible Impacts to Groundwater Quality

Climate Impact	Design Considerations
Sea level rise	Saltwater intrusion may be exacerbated if there is increased demand and increased groundwater pumping. *(EPA, 2016)*
Flooding	May mobilize pathogens and could lead to the release of chemical contaminants.
Drought	Aquifer depletion may require deeper wells with poorer water quality *(Famiglietti, 2014)*. May have other site-specific, complex impacts on quality.

4.2.2 Water Demand Impacts

Climate change will cause increased demand on water systems, especially in summer months, due to:

.1 Increased irrigation demand due to higher temperatures, reduced summer precipitation and/or summer drought; and
.2 A lengthened growing season which could lead to increased annual agricultural demand for water.

Designers should consider that peak demand will likely coincide with periods of lowest supply. Strategies incorporating increased monitoring, response planning, and community water conservation programs should be implemented to manage water demand.

4.2.3 Site and Facility Impacts

When selecting a site for new drinking water treatment infrastructure or upgrading existing systems, Designers should be aware of climate change impacts that could affect the facility and future levels of service. Table 4-5 provides some examples of climate change impacts on sites and facilities.

Table 4-5 Observed and Possible Site and Facility Impacts

Climate Impact	Design Considerations
Increased flood risk (due to changing precipitation patterns and/or extreme storm events) and fluvial flooding	Site flood risk may increase as flood risk areas expand in the future. Flood elevations should be considered for assets, especially critical infrastructure and/or assets with a long design life.
Increased wildfire risk (increased summer temperatures and drought)	Site wildfire risk may increase requiring design modification to improve resilience and/or support emergency response (for example, alternative and/or remote site access).
Changes in snowfall	Changes to winter precipitation, including the possibility of heavier, wetter, snow, could impact the structural design of above ground facilities.
Changing wind patterns	Extreme wind events could impact the structural design of above ground facilities.
Increased precipitation – extreme storm events	Changes in precipitation may impact stormwater management practices and building envelope design.

An additional consideration for Designers is related to indirect climate change impacts which could impact facility operations. For example, extreme weather events could disrupt utility service from third party utility providers or damage roads, limiting site access. There could also be supply chain impacts which could impact operations.

4.2.3.1 Considerations for Coastal Sites

Coastal areas of British Columbia may face additional challenges *(EPA, 2014 and AFN, 2008 and Lemmen and Warren, 2004),* including:

.1 Rising sea levels which may shift ocean and estuarine shorelines by inundating lowlands, displacing wetlands, and altering the tidal range in rivers and bays; and
.2 Storm surges resulting from more extreme weather events which will increase areas subject to periodic inundation.

These overlapping impacts make protecting water resources and infrastructure in coastal areas especially challenging. Impacts could vary from increased distribution system maintenance due to saltwater intrusion, to overall site inundation. As noted by the EPA (2014) “watershed-level planning will need to incorporate an integrated approach to coastal management in light of sea level rise including land use planning, building codes, land acquisition and easements, shoreline protection structures (e.g. seawalls and channels), beach nourishment, wetlands management, and underground injection to control salt water intrusion to fresh water supplies”. Ongoing monitoring of coastal impacts will be an important component of adaptation planning for coastal facilities.

4.2.4 Impacts to Treatment Process

As outlined in the previous section, climate change may result in impacts to raw water quality. Designers should consider these potential impacts and determine how the treatment process may need to be altered to accommodate projected changes to water quality. Designers may also consider taking a flexible approach to their design to allow for future modifications to the treatment process if water quality changes.

For example, higher concentrations of organic matter due to higher temperatures and increased turbidity due to precipitation events in surface water are projected impacts of climate change. Greater extremes and variations in raw water quality will require planning for adaptable treatment processes, and considerations for more intensive operations, maintenance and management of waste residuals. Some examples of planning for adaptability in treatment may include the ability to add or modify chemical dosing in pre- or post-treatment processes; selecting treatment options which are less sensitive to changing water quality; or including space provisions for additional treatment process installation or expansion if needed. Another consideration for treatment is that while increased organic loading may increase the types and concentrations of chemicals used and decrease filtration rates, increased water temperatures may also benefit chemical reaction and filtration rates.

4.2.5 Storage System Impacts

Climate change is altering snow deposition and snow melt patterns. This is important because snow acts as a massive slow-release water reservoir. Changes to the timing and rate of snow melt and seasonal precipitation can have significant implications for long term storage in community water systems, especially in mid-to-late summer and early fall when peak summer demand coincides with seasonal lows in water levels. Designing sufficient storage for projected demands should consider these changes in seasonal variability. In addition, as peak demand increases during summer months, peak hourly demand calculations for treated water storage may be insufficient without the implementation of strategic demand management practices. Ensuring water quality in storage systems may also become increasingly challenging in a changing climate. For example, designs for water storage infrastructure should account for water quality and rising temperatures that will promote algal and bacterial growth in standing water.

4.2.6 Building - Electrical and Mechanical System Impacts

Electrical systems can be vulnerable to projected changes in climate. For example, the risk of extreme storm events may result in a higher incidence of power outages, resulting in increased requirements for back-up generators. Designing electrical and mechanical systems for flood risk is another important consideration to ensure that critical equipment is located above flood levels. Ensuring access to critical equipment in the event of a flood or other natural disasters is another important design consideration, and may include considerations of alternative site access methods or remote SCADA control.

HVAC design will need to consider future temperatures to ensure that heating and cooling will be sufficient in a changing climate. This will be of particular importance for cooling capacity since temperatures are generally projected to rise. Ensuring adequate cooling capacity is important both from a health and safety perspective for operations and maintenance staff, as well as to ensure spaces that house electrical and heat generating mechanical equipment are kept cool. Consideration should be given to increased condensation on pipes and floors as a result of air conditioning. Additionally, changing air quality due to increased wildfire events may impact operations and maintenance of HVAC systems (i.e. filter requirements and replacements).

4.2.7 Conveyance System Impacts

Transmission and distribution system infrastructure may be impacted by extreme precipitation events leading to flooding or soil failures. Sea level rise or storm surge impacts could vary from increased underground infrastructure system maintenance due to saltwater intrusion, to overall site inundation *(EPA, 2015)*. Increases to winter seasonal freeze-thaw cycles could lead to greater incidences of fractures, cracking and deterioration of underground infrastructure, leading to increased operations and maintenance.

4.3 Climate Change Risk Assessment

Determining the regional and local effects of climate change is critical to assessing vulnerability and risk, which is necessary information to create implementable adaptation strategies. The following sections include key concepts and a risk assessment framework for Designers.

4.3.1 Methodologies for Climate Change Risk Assessments

There are several approaches available to assess climate change risk. These *Design Guidelines* do not prescribe a detailed methodology for Designers to follow, although it is recommended that any methodology used is aligned with *ISO 31000 Risk Management - Guidelines*. A globally recognized approach, this standard provides a generic risk management model that walks users through the steps of gathering information, assessing risk and developing a risk treatment plan. The resource list included at the end of this chapter includes a list of methodologies that are consistent with the *ISO 31000* standard.

4.3.2 Level of Effort and Detail

The required level of effort for a climate risk assessment will vary for every project. Designers should determine the required level of effort and detail based on a number of factors including the scope and scale of the project, acceptable risk thresholds, and the required level of service for the drinking water system. The availability of site-specific climate data may also influence the level of detail which is practicable for a risk assessment.

4.3.3 Risk Assessment Timeline

It is recommended that Designers complete a screening-level risk assessment during planning and conceptual design to understand site vulnerabilities and identify high-level considerations for siting and design. During preliminary design, Designers should conduct a comprehensive risk assessment to further analyze components or processes which are most at-risk due to climate change. Finally, to document decisions made, an adaptation plan should be developed and implemented to mitigate climate risks. Beyond the design stage, climate impacts and adaptation measures should be monitored and reassessed on a regular basis during operations.

4.3.4 Managing Uncertainty

Historical climate records are considered to be a reflection of “reality” and, through statistical analysis, they assist in the development of design values to address climate uncertainty. From an engineering perspective, the full ensemble of global climate models (GCMs) encompass greater uncertainty in future climate projections than those in historical records. The fact that climate models are being refined, especially with respect to projecting extreme values, creates a perceived increase in risk, which should be acknowledged and managed to ensure resilience over the full design life of the infrastructure.

Uncertainty should not prevent Water Suppliers from taking action now with regards to potential climate change impacts. Typically, engineers, planners, policy makers, and operators are already well equipped to deal with uncertainty by the very nature of their occupation. Using risk assessment as a decision-making process in the face of unknowns is not a new concept. Making decisions based on projections for long-term climate changes can be approached in the same manner.

4.3.5 Ongoing Monitoring and Updates

Climate science is an evolving discipline, where new data, models and projections are regularly published. For this reason, it is worthwhile to monitor new projections and compare them to those used in a design, adaptation planning, or operational plans. If new projections differ substantially from prior projections, it may be warranted to revisit a project climate risk assessment or adaptation plan for infrastructure, policies, or programs. A schedule can be created to evaluate updates to climate data, as it pertains to critical aspects of existing operations or new projects.

4.3.6 Reporting and Documentation

Designers should continuously document and report on their climate risk assessment process and include this documentation as part of project design reports.

4.4 Climate Change Risk Assessment Framework

The following framework is presented to guide Designers through various steps of understanding climate risks and incorporating resilience into drinking water system design. Illustrated in Figure 4-3, each step of the process is described in greater detail in the subsequent sections. Although this framework is focused on drinking water system design, it is important for Owners and Operators of drinking water systems to monitor climate risks and engage in ongoing adaptation planning.

STEP	OBJECTIVE	TIMING
Step 1: Project Definition (Section 4.5)	Determine relevant climate parameters and components to assess in risk assessment.	Project Planning
Step 2: Screening-Level Risk Assessment (Section 4.6)	Identify climate hazards.	Project Planning/Conceptual Design
Step 3: Detailed Risk Assessment (Section 4.7)	Assess the likelihood and severity of risks.	Preliminary Design
Step 4: Climate Adaptation Plans (Section 4.8)	Identify and implement measures to mitigate and manage risks.	Preliminary/Detailed Design/Operations

Figure 4-3 Climate Change Risk Assessment Framework

4.5 Step 1: Project Definition

The first step of the risk assessment process is Project Definition where climate parameters and project components to be included in the risk assessment are identified. Project Definition also includes stakeholder identification and building an understanding of organizational risk tolerance to inform the risk assessment process. The following activities are adapted from the framework presented in EGBC's *Professional Practice Guidelines for Developing Climate Change-Resilient Designs for Highway Infrastructure in British Columbia (2020)*:

.1 Characterize the project location;
.2 List project infrastructure components;
.3 Identify relevant climate parameters;
.4 Define project time horizons;
.5 Identify team members and stakeholders to be involved in risk assessment;
.6 Identify risk tolerance and level of service; and
.7 Identify non-climate design drivers.

The following sections provide additional detail on these activities.

4.5.1 Characterize the Project Location

When characterizing a project's location, Designers should assess not only the project footprint, but also the surrounding area which could impact the system. This is required to identify geographic characteristics, topography, water bodies, environmental features, and nearby infrastructure. During this stage, Designers should also consider regulatory requirements and standards which apply to the site.

4.5.2 List Project Infrastructure Components

At this stage of the process, Designers should identify key infrastructure components to be included in the project. High-level identification of infrastructure components is sufficient; details on the infrastructure design are not required at this stage. Designers should note which infrastructure components will be constructed as a part of the project, and which components, if any, will be retained or refurbished. Older and overextended drinking water infrastructure is likely to be more susceptible to climate hazards *(J. Boyle, M. Cunningham, J. Dekens, 2013)* and so it is important to include infrastructure to be retained as it will affect the overall resilience of the drinking water system.

4.5.3 Identify Relevant Climate Parameters

When identifying relevant climate parameters, Designers should consider not just parameters which could have a direct impact on the drinking water system (i.e. flooding damaging infrastructure), but also parameters which could have an indirect impact (i.e. impacts to supply chain due to climate hazards occurring in other geographic locations). Designers should ensure they are considering the full range of parameters and looking not just at annual averages, but also looking at extreme values and seasonal changes to determine how drinking water infrastructure could be impacted.

Climate parameters which may be considered include, but are not limited to:

- .1 Rainfall (intensity, duration, frequency, seasonal shifts);
- .2 Temperature (averages and extremes, heating and cooling degree days, heat waves);
- .3 Snow and ice (daily snowfall, snow depth, snowpack, timing of freshet, ice storms, rain on snow events);
- .4 Wind (average speed, gust speed, wind direction); and
- .5 Sea level (average level, high tide/king tide, storm surges).

Climate parameters may also interact resulting in climate hazards which could impact drinking water systems. For example, drought, extreme storm events, wildfire risk, etc. Furthermore, interacting climate parameters may result in cascading effects which could result in increased risk for infrastructure components.

It is important to note that certain climate phenomena are not currently well captured by climate models. Examples include lightning, freezing rain, wind gusts, tornadoes, blizzards, shortwave (UV) radiation, and air quality. If these parameters are to be included, it is recommended to consider how the factors that affect these phenomena are changing. Such an assessment should be completed by a Climate Specialist.

4.5.4 Define Project Time Horizons

The time horizons for climate projections should align with the design life of infrastructure being considered. In some cases, it may be appropriate to use more than one-time horizon to capture risks related to different types of infrastructure.

As stated by EGBC (2020), "Infrastructure with a short service life is usually subject to periodic refurbishment or replacement. This provides an opportunity to re-evaluate corresponding climate risks and adaptation measures. Risks associated with climate change for such infrastructure may be low because the climate trend has had little time to develop. However, for infrastructure components that are not eligible for replacement or refurbishment before the end of their service lives, the consequences of decisions made during the design process can be significant."

4.5.5 Identify Team Members and Stakeholders to be Involved in Risk Assessment

The team members and stakeholders to be involved in a climate risk assessment will be project specific. At a minimum, Designers should include the Owner and Operator of the drinking water system as a part of the risk assessment process.

For a detailed risk assessment it is recommended that Designers also engage with individuals from the following groups:

.1 All relevant Qualified Professionals involved in the design of the project (i.e. hydrogeological, geotechnical, structural, hydrotechnical, electrical, mechanical, civil, etc.);
.2 Operations and maintenance;
.3 If Designers do not have a strong background in climate science, they should include a Climate Specialist as a part of the risk assessment team; and
.4 If Designers are not familiar with risk assessment processes, they should include a Risk Assessment Professional as a part of their team.

In most cases, it will also be valuable to engage with individuals with knowledge and experience in one or more of the following fields:

.1 Public safety;
.2 Social impacts;
.3 Economic impacts;
.4 Environmental impacts, including watershed and ecosystem impacts;
.5 Local climate and knowledge of historical climate events;
.6 Traditional knowledge;
.7 Politics;
.8 Insurance;
.9 Community issues;
.10 Land use planning;
.11 Emergency preparedness and response; and
.12 Law and accounting.

If public engagement is a part of the project scope, it is recommended that climate change considerations be included as a part of stakeholder engagement activities. Similarly, climate change considerations should be included when consulting or engaging with Indigenous communities.

4.5.6 Identify Risk Tolerance and Level of Service

Prior to completing a risk assessment, Designers should consult with the Owner and Operator to define their risk tolerance and the required level of service for the drinking water system. Risk thresholds typically depend on the function and design life of the infrastructure, and should be discussed and agreed upon to ensure that the climate risk assessment is aligned with these thresholds.

When determining and setting these objectives, it may be helpful to consider stakeholder expectations, strategic objectives, financial risk tolerance, and risks related to not meeting the required level of service. Regulatory requirements may also inform risk tolerance, such as requirements of the *Drinking Water Protection Act* and Drinking Water Protection Regulation, as well as conditions set out in Operating Permits.

4.5.7 Identify Non-climate Design Drivers

To provide context for a climate risk assessment, Designers should consider non-climate design drivers (for example, protection of public health, preserving or enhancing the ecological services of existing watersheds, meeting population growth demands, other regulatory requirements, etc.). Although these design drivers and project objectives may not be directly included in the risk assessment, they provide important context and could inform risk prioritization and adaptation planning.

4.6 Step 2: Screening-Level Risk Assessment

Completing a screening-level risk assessment during the planning process and/or conceptual design phase of a project allows Designers to identify potential climate impacts and vulnerabilities and determine if a more comprehensive risk assessment is required. The screening-level risk assessment answers the following questions:

- .1 What climate hazards will the drinking water system be exposed to; and
- .2 Which infrastructure components or processes might be impacted by these climate hazards?

4.6.1 Climate Projections

Climate projections are generally completed by a Climate Specialist using climate models. In some cases, regional climate projections may have already been completed and Designers may be able to use these projections when undertaking a climate risk assessment. There are publicly available resources for climate data which Designers may access to inform a climate risk assessment (Section 4.9 – Suggested Resources includes resources for climate data). However, it is not recommended that Designers rely solely on these resources if they do not have appropriate knowledge and experience with interpreting climate data in relation to typical design criteria. When using climate change projections to inform design, Designers should understand the source, data accuracy, spatial resolution as well as assumptions and limitations associated with the climate data. Understanding uncertainties associated with climate data is important to enable Designers to manage this uncertainty in the vulnerability and risk assessment process (also see Section 4.3.4 on Managing Uncertainty). If Designers do not have experience interpreting climate change projections and incorporating into design, they should engage with a Qualified Professional.

4.6.1.1 Climate Modelling

There are over thirty Global Climate Models (GCMs) which are owned by leading scientific institutions around the world. Per best practice in climate science, multiple climate models (i.e. multi-model ensembles that group results from multiple climate models together) that project future changes across a range of greenhouse gas emission scenarios should be used when assessing the potential impacts of climate change. Emission scenarios represent possible GHG emission patterns over the 21st century from anthropogenic emission sources. There are currently four industry standard scenarios, called Representative Concentration Pathways (RCP), that have been established by the Intergovernmental Panel on Climate Change (IPCC). These are commonly known as:

- .1 RCP 2.6 – Assumes that GHG emissions stay consistent until 2020 when they begin to decline until 2100, where average global warming is limited to approximately ~2.0 °C in this time period;
- .2 RCP 4.5 – A future with relatively ambitious emissions reductions where CO_2 emissions increase only slightly before a decline commences around 2040, where average global warming is limited to approximately ~2.4 °C by 2100;
- .3 RCP 6.0 – A future where CO_2 emissions stabilize, where average global warming is limited to approximately ~2.8 °C by 2100; and
- .4 RCP 8.5 – A future with no implementation of policy changes to reduce emissions, and thus increasing GHG emissions into the future, where average global warming is anticipated to increase by ~4.3 °C by 2100.

Designers may select a range of emissions scenarios to consider for the time horizon of the infrastructure components. While RCP 8.5 is the worst-case scenario of greenhouse gas concentration trajectories referred to in the IPCC report, it is the general consensus among local climate change scientists that RCP 8.5 is the likely pathway given the current state of anthropogenic (human) activity; therefore, it may be most appropriate for long-range planning. As climate science continues to evolve, best practices around emission scenario selection may also change.

It is important to recognize that improvements in climate modelling and process understanding will ultimately lead to better climate change projection data. It is encouraged for Designers using this guideline to maintain awareness of the rapid evolution in climate science and technology, and always use the best available data. Relevant climate data resources are provided at the end of this chapter.

4.6.2 Identify Infrastructure Components & Operational Processes

To complete the screening-level risk assessment, the key infrastructure components for the project are identified. Operational processes, policies, and human resources may also be included in this list to capture how climate change may impact future operations (i.e. extreme weather could prevent operators from accessing the site). Designers will need to determine the appropriate level of detail when identifying infrastructure components. It may be appropriate to group components or look at some components at a system or sub-system level.

4.6.3 Identify Climate Hazards

This step of the process considers the impact of climate projections on identified infrastructure components and operational processes. If an interaction between the selected infrastructure component or process and a climate hazard is found to exist and be of significance, this interaction should be included in the risk assessment. This process is repeated until all components or processes identified by the climate risk assessment team have been considered. Each identified climate hazard is then carried forward to be further analyzed in the detailed risk assessment.

4.7 Step 3: Detailed Risk Assessment

The detailed climate risk assessment builds on the work completed as a part of the Screening-Level Risk Assessment. What differentiates the detailed risk assessment from the screening-level risk assessment is that the detailed risk assessment considers not just whether an infrastructure component is vulnerable to a climate hazard, but what the likelihood and consequences of that interaction may be.

Generally, risk can be defined as the probability (or likelihood) of an event occurring and the severity (or consequence) of impacts if that event occurred. These processes can be numerically defined, or assigned qualitative rankings based on a specific scale. Designers should work with their key stakeholders and risk assessment team to define the scales and scoring terms for probability and severity which are aligned with the owner's risk tolerance: for example, very low probability may be an estimated likelihood of less than 1%, and very high severity could be permanent damage to infrastructure and long-term service disruption. *The Strategic Climate Risk Assessment Framework for British Columbia* also provides comparable definitions for likelihood and consequence scales. Figure 4-4 shows an example of how probability and severity scores can be used to determine an overall risk score using a five-point scale for severity and probability. If a numeric scale is used for probability and severity, risk scores are the product of the two scores.

RISK = PROBABILITY x SEVERITY

It is recommended that risk scoring exercises are completed in a workshop setting with key stakeholders representing multiple disciplines. Multi-disciplinary attendance at roundtable discussions related to severity and expert guidance by Climate Specialists in the assignment of probability will help to ensure that infrastructure impacts and climate information are properly accounted for in scoring. The scoring system can be adjusted and tailored to a specific site or process on a case-by-case basis, as long as it remains consistent throughout the entire assessment.

		SEVERITY (CONSEQUENCE)				
Risk Rating		**Very Low (1)**	**Low (2)**	**Moderate (3)**	**High (4)**	**Very High (5)**
PROBABILITY (LIKELIHOOD)	**Very Low (1)**	Very Low (1)	Very Low (2)	Low (3)	Low (4)	Low (5)
	Low (2)	Very Low (2)	Low (4)	Low (6)	Moderate (8)	Moderate (10)
	Moderate (3)	Low (3)	Low (6)	Moderate (9)	High (12)	High (15)
	High (4)	Low (4)	Moderate (8)	High (12)	High (16)	Very High (20)
	Very High (5)	Low (5)	Moderate (10)	High (15)	Very High (20)	Very High (25)

Figure 4-4 Sample Risk Matrix

4.7.1 Probability Scoring

Probability scoring is based on the likelihood of occurrence of a climate event within the lifetime of a specific infrastructure component which will lead to an impact. Probability scoring is informed by climate thresholds set for different infrastructure components. These climate thresholds help Designers to identify at what point infrastructure may be impacted. Thresholds can be determined through design standards, review of event and performance history, modeling of system performance or inspection of assets. It is recommended that Designers and Climate Specialists work together to set thresholds and then use climate projections to determine the probability that these thresholds might be exceeded.

4.7.2 Severity Scoring

Severity scores are specific to risk tolerance levels and required levels of service for each drinking water system component. When evaluating severity, it may be helpful to identify sub-categories to capture different types of consequences. The following list is an example of the types of consequence sub-categories that could be used *(ICLR, 2014)*.

.1 People (health and safety, displacement, loss of livelihood, reputation, disproportionate impacts to vulnerable populations);
.2 Economic (infrastructure damage, financial impact on organization); and
.3 Environment (air, water, land, ecosystems).

4.7.3 Risk Ranking and Prioritization

The risk analysis will generate a long list of risk scores. Scoring on a numeric scale allows for a quantitative comparison of various climate impacts to determine a priority for mitigation or adaptation. For infrastructure that is categorized as a high risk, adaptation measures should be implemented immediately. As the level of risk decreases, adaptation measures generally tend to decrease. Risk-based planning focuses on minimizing the risk associated with the asset through an appropriate intervention strategy, while ensuring that any risks are managed at the minimum cost.

4.7.4 Engineering Analysis

If there are gaps in data which do not allow for an adequate assignment of risk, additional engineering analysis may need to be completed in order to better understand the probability or severity of different potential impacts. Engineering analysis may also be completed after a risk assessment is completed in order to inform risk mitigation options to be included in a climate adaptation plan or design brief.

4.8 Step 4: Climate Adaptation Plans

4.8.1 Identifying Adaptation Options

After the risk assessment is completed, a climate adaptation plan can be developed to identify actions to mitigate climate risks and reduce vulnerabilities to climate change.

As noted by *EGBC (2020)*, adaptation is not restricted only to increasing capacity or strength, but may include:

.1 Enhanced operation and maintenance practices;
.2 Different construction materials or methods;

.3 Different siting;
.4 Phasing opportunities triggered by threshold events;
.5 Further study or more detailed analysis; and
.6 Monitoring, or any number of items that could enhance climate change resilience.

The climate change adaptation plan can be incorporated into a design brief.

4.8.2 Cost-Benefit Analysis of Adaptation Options

Once a range of possible adaptation options has been identified, the Designer may prioritize a shortlist of the most appropriate options for implementation. As part of this process, it is recommended that the Designer develop a cost-benefit analysis as a form of economic evaluation, and a multi-criteria analysis where costing is difficult to quantify.

.1 Cost-Benefit Analysis: Quantifies and assesses intervention costs against economic benefits such as improved safety and reduced risk of service disruptions to enable selection of the "best" option to close a performance gap. Lifecycle cost-benefit analysis is used to determine the set of investments with the lowest Net Present Value (NPV) or other financial parameter over the analysis period; and

.2 Multi-Criteria Analysis: Prioritizes competing options where benefits and costs are less tangible to define. Criteria are selected that align with climate change objectives. A weighting to demonstrate the relative importance of these factors is selected from an overall score.

Designers and stakeholders should work together to develop adaptation plans that take a holistic approach to climate adaptation and identify which climate risks are to be addressed through design and which risks will be addressed through other measures. These decisions should be well documented and communicated to ensure all parties are aware of the adaptation measures to be taken. Though often representing higher upfront costs, investments in a more resilient design, such as one that considers a full range of climate projections, can help avoid larger future costs (in terms of maintenance, repair and replacement), and make a project more resilient to future climate and weather extremes.

4.8.3 Adaptation During Design

Designers should consider the following categories of adaptation measures that can be used in the design process:

.1 Status quo design;
.2 Flexible design;
.3 Robust design; and
.4 Low- or no-regret strategies.

These adaptation measures are not mutually exclusive, and it is likely that a combination of strategies will be employed to realize adaptation objectives.

The following sections describing these adaptation measures are excerpts that have been adapted from EGBC’s Professional Practice Guidelines for *Developing Climate Change-Resilient Designs for Highway Infrastructure in British Columbia (2020)*.

4.8.3.1 Status-Quo Design

Status-quo design recognizes that implementing no explicit adaptation measures is a valid response, provided that the reason or reasons are well documented and supported by evidence.

Situations where status-quo design may be a valid design method include the following:

.1 The risk assessment shows that the infrastructure is at no risk or low risk due to climate change; and
.2 The service life of the subject infrastructure is very short, and adaptation measures will be considered when the infrastructure is replaced or refurbished.

4.8.3.2 Flexible Design

Flexible design assumes that there will be opportunities to adapt in the future and allows for changes to be made when required. This option reduces up-front capital costs by designing the infrastructure to meet short term needs and/or probable future conditions, with planned design modifications for future scenarios. Flexible design is most appropriate for gradual changes over time, such as sea level rise or melting permafrost. Successful flexible design requires monitoring of climate, loads, and infrastructure performance, and should only be implemented if the Owner has the funds, authority, and willingness to maintain the monitoring program and implement predetermined upgrades as required.

With a flexible design approach, adaptation measures can be implemented when predefined trigger events occur. Trigger events should be defined in a way that ensures continued integrity of the infrastructure, but still signals increasing likelihood that the climate is trending toward conditions more severe than those used for initial design. For example, a trigger may be a flood level, flow rate, or rainfall intensity that reaches or exceeds a threshold value.

Flexible design involves the following steps:

.1 Base the project design on the most-probable weather or climate conditions, as opposed to the most-unfavorable conditions;
.2 Establish a course of action and design modification for every foreseeable unfavorable deviation from the most-probable weather and climate condition. Actions may increase adaptation through one or more of the following measures:
   a. Increase the infrastructure’s capacity or capacities;
   b. Reduce loads;
   c. Reduce the consequences of failure;
.3 Conduct a continuous monitoring program to determine the performance of infrastructure to evaluate its performance and response to observed changes; and
.4 Implement a plan of action to modify design and construction in response to observed climate changes.

4.8.3.3 Robust Design

Robust design seeks to ensure the proposed infrastructure will perform as expected over a range of possible future climate conditions, including the “worst-case” design scenario. This option usually results in higher initial construction costs for the infrastructure and ultimately lower vulnerability to climate change.

Some considerations for choosing the robust design approach may be as follows:

- .1 The overall cost of implementing flexible design far exceeds the additional cost of implementing robust design;
- .2 Flexible design is not an option because there are no feasible opportunities to phase in adaptation measures;
- .3 There are social or political issues that are better addressed through robust design; and
- .4 Robust design will not compromise level of service for present-day conditions.

Robust design may include, but is not limited to, the following:

- .1 Use of generous safety factors applied to loads generated using "average" projected climate values and ensuring that capacities are designed accordingly;
- .2 Capacities designed to service loads generated using "worst-case" projected design climate values; and
- .3 Redundant features added to the design to protect against failure.

4.8.3.4 Low- or No-Regret Strategies

Low- or no-regret strategies can offer benefits under a range of climate change scenarios (including current and uncertain future climates) and lay the foundation for addressing projected changes *(IPCC 2012)*. These strategies include early warning systems, sustainable land-use planning, ecosystem management and restoration, and risk communication between decision-makers and local residents to minimize the extent of negative impacts. It is recommended that Designers connect with land use planners and watershed managers to identify watershed-scale opportunities for climate adaptation (i.e. erosion prevention or natural flood control). Identifying nature-based solutions to improve watershed resilience to climate change can increase drinking water system resilience as well as provide ecosystem and community co-benefits.

4.9 Suggested Resources

Suggested resources for climate change guidance are included in Table 4-6.

Table 4-6 Available Resources for Climate Change Guidance

Category	Resource	Link
Climate adaptation	EGBC Climate Portal	https://www.egbc.ca/Practice-Resources/Programs-Resources/Climate-Sustainability/Climate-Change-Information-Portal
	ISO 14090 Adaptation to climate change: Principle, requirements, and guidelines	https://www.iso.org/standard/68507.html
	AWWA M71 Climate Action Plans – Adaptive Management Strategies for Utilities (2021)	https://doi.org/10.12999/AWWA.M71ed1

Category	Resource	Link
	Climate Change and Water, IPCC Technical Paper VI, Intergovernmental Panel on Climate Change, June 2008	https://www.ipcc.ch/publication/climate-change-and-water-2/
Climate data	Climate Atlas	https://climateatlas.ca/
	PCIC Data Portal	https://pacificclimate.org/data
	Climatedata.ca	https://climatedata.ca/
	Canadian Climate Data and Scenarios	https://climate-scenarios.canada.ca/
	Climate Normals	https://climate.weather.gc.ca/climate_normals/index_e.htm
Risk assessment	ISO 31000: Risk Management	https://www.iso.org/iso-31000-risk-management.html
	ISO 14091 Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment standard	https://www.iso.org/standard/68508.html
	PIEVC Protocol	https://pievc.ca/protocol
	Preliminary Strategic Climate Risk Assessment for British Columbia	https://www2.gov.bc.ca/gov/content/environment/climate-change/adaptation/risk-assessment
Resilient infrastructure	Envision Framework	https://sustainableinfrastructure.org/envision/use-envision/#climate-and-resilience
	USEPA Creating Resilient Water Utilities (CRWU) – Resilient Strategies Guide	https://www.epa.gov/crwu
	World Bank Group's Water Global Practice – Resilient Water Infrastructure Design Brief	https://openknowledge.worldbank.org/bitstream/handle/10986/34448/Resilient-Water-Infrastructure-Design-Brief.pdf
BC-specific resources	Drought Information (including *BC Drought and Water Scarcity Plan* and *Dealing with Drought: A Handbook for Water Suppliers in British Columbia*)	https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/drought-flooding-dikes-dams/drought-information
	Modernizing BC's Emergency Management Legislation (Sendai Framework)	https://engage.gov.bc.ca/app/uploads/sites/121/2019/10/modernizing_bcs_emergencymanagement_legislation.pdf

4.10 Climate Change Mitigation

Climate change mitigation is an approach to reduce the human-induced greenhouse gas emissions that are released into the atmosphere and limit the extent of future climate change. Although the focus of this chapter is on climate adaptation, Designers and Water Suppliers have opportunities to reduce the emissions associated with drinking water system planning, design, operation, and maintenance activities. The energy consumed to treat and pump water, alongside that used in broader operations and facilities, plays a key role in contributing to emissions. To identify where the opportunities may lie to reduce emissions and approach carbon neutrality, it is important to understand what the existing carbon footprint of the water supplier is – where and what is driving emissions. Adaptation solutions to increase system resilience need to be considered with carbon in mind to avoid any potential conflicts/trade-offs with mitigation goals. To illustrate this, for example, diesel back-up power may increase resilience to a power outage but counteracts efforts to reduce GHG emissions. Co-benefits may be realized throughout this process as some design options will provide both mitigation opportunities as well as climate adaptation. In general, utilities should seek opportunities to reduce energy use and consumption, as it can be both economical and serve to limit future climate change impacts.

If Designers are not familiar with these concepts, it is recommended that they engage with Climate Mitigation Specialists to identify and implement opportunities. Although this is by no means an exhaustive list of resources, the following Table 4-7 includes some International standards that may help to guide Designers to understand and integrate these concepts into their design.

Table 4-7 Relevant ISO Standards

Category	Relevant ISO Standards
Greenhouse gas accounting	ISO 14064-1: Greenhouse Gases – Part 1: Specification with Guidance at the Organization Level for Quantification and Reporting of Greenhouse Gas Emissions and Removals
	ISO 14064-2: Greenhouse Gases – Part 2: Specification with Guidance at the Project Level for Quantification, Monitoring, and Reporting of Greenhouse Gas Emissions Reductions or Removal Enhancements
	ISO 14064-3: Greenhouse Gases – Part 3: Specification with Guidance for the Verification and Validation of Greenhouse Gas Statements
Life cycle assessment	ISO 14040: Environmental Management – Lifecycle Assessment – Principles and Framework
	ISO 14044: Environmental Management – Lifecycle Assessment – Requirements and Guidelines
Carbon footprint	ISO 14067 Greenhouse Gases – Carbon Footprint of Projects – Requirements and Guidelines for Quantification

5 Facility Recommendations

5.1 General

This chapter provides considerations for the siting and design of drinking water system buildings, structures, and facilities (e.g. pumping stations, pressure reducing stations, and water treatment plants).

In addition to the guidelines included in this chapter, consideration should be given to the design requirements of the *BC Building Code* (BCBC) and other federal, provincial, regional and/or municipal regulatory agencies.

5.2 Site Selection

The siting of new or expanded water system facilities should be done with careful consideration to the functional, safety, and long-term needs of the proposed facility. Factors that should be considered when selecting a site for new or expanded water supply, treatment, and/or distribution works include:

.1 Zoning by-laws or restrictions for the proposed site;
.2 Isolation from non-compatible land uses including potential pollution sources that may interfere with the quality of water or interfere with the effective operation of the water system;
.3 Facility location with respect to the raw water source, the area being serviced, and proximity to associated utilities for efficient management of the water system components;
.4 Off-site utility servicing such as electrical, natural gas, communications, sanitary, and stormwater;
.5 Site access during winter and emergency conditions;
.6 Site security including emergency access, neighbouring land uses, and normal activity within the area;
.7 Long term source water availability;
.8 Proximity to areas susceptible to forest fires;
.9 Physical site conditions such as susceptibility to flooding, geotechnical issues, groundwater/aquifer characteristics or proximity to natural watershed areas;
.10 Archeological and environmental assessments and/or impacts to confirm site constraints and alteration requirements; and
.11 Adequacy of the site for future expansion.

5.3 Facility Layout

The layout of new facility sites and buildings should be done with consideration to the design of safe, efficient and cost-effective infrastructure. The Designer should consider the site topography, geotechnical issues (slope stability, dewatering during construction and post construction, and vulnerability of shallow aquifers), climate, and weather conditions to develop the most economical design. The Designer should prepare a facility layout where the various processing units are arranged in a logical progression to avoid the necessity for major pipelines or conduits to transmit water from one module to the next. The plant layout should also provide convenience of operation, accessibility of equipment for operational needs, maintenance and removal, as well as to ensure operator safety. The building layout should provide for adequate ventilation, lighting, heating and drainage, and dehumidification equipment as required, and should minimize snow drifts in exterior areas.

WTP design should consider functional aspects of the plant layout, access roads, access to the power grid, location of the backup generator, site grading, site drainage, walkways, driveways and chemical delivery and receiving areas. The plant design should also incorporate spill control features for bulk chemical off-loading areas.

Roadways for chemical deliveries should be designed to be sufficient to accommodate the largest anticipated delivery with allowance made for vehicle turning and forward exit from the site. Typically, the largest delivery would be a 27,000 L tank truck, but some chemical deliveries may be done solely through totes transported via flatbed.

Where possible, the Designer should take advantage of natural grades in arranging the various process units. Consideration may be given to the use of inter-stage transfer pumps where they are more economical (capital and operating) than extensive construction in adverse ground such as rock.

5.3.1 Site Layout

The building and site layout design should consider all functional aspects of the facility, including requirements for normal operation, anticipated maintenance activities, and future expansion. The following factors should be considered and/or addressed, as applicable, in the design:

.1 Access roads, parking, driveways, and walkways for operations;
.2 Site grading and site drainage;
.3 Facility accessibility and site mobility during all seasons;
.4 Sanitary, storm, power, and telecommunication service connections;
.5 Cross connection control and proper separation of utilities;
.6 Protection of all structures and process from flooding;
.7 Provisions for climate change resilience;
.8 Provisions for waste treatment and disposal requirements;
.9 Provisions for spill containment and management;
.10 Energy efficient design practices to utilize prevailing wind and weather conditions to minimize energy consumption with natural lighting, passive ventilation and energy recovery;
.11 Efficient routing of exposed ducting and cabling within the facility to avoid conflicts and allow ease of access for future maintenance and replacement;
.12 Proper chases or utilidors for current and future process, plumbing, ventilation, and electrical systems;
.13 Climate control of spaces based on the type of occupancy, equipment and materials such that temperature, air flow and humidity are suitable to protect people and property;
.14 Weather protection of equipment and building entrances from snow, rain and ice;
.15 Security-related issues such as site/building access controls, protection of treated/finished water components, site lighting, and alarms; and
.16 The zoning permits that may be needed.

5.3.2 Building Layout and General Considerations

The design of the building should consider the following:

.1 Adequate ventilation;
.2 Adequate lighting;
.3 Adequate heating;

.4 Adequate drainage;
.5 Dehumidification equipment, if necessary;
.6 Accessibility for equipment operation, servicing, and removal;
.7 Accessibility of drill rigs to access well heads;
.8 Flexibility of operation;
.9 Operator safety;
.10 Convenience of operations; and
.11 Placing chemical storage and feed equipment in a separate room to reduce hazards, spills and dust problems. Reference should be made to Chapter 13 – Chemical Application for further guidance on design of chemical systems.

5.3.3 Health and Safety

The building and site layout design should consider the safety of operations personnel and visitors. The design must comply with the *BC Building Code* (BCBC). The design of the building and site layout should consider the following factors:

.1 Emergency egress routes;
.2 Reducing or eliminating confined spaces;
.3 Provision of fall protection including railings, anchor points, and work zone delineation;
.4 Provision of lock-out and tag out provisions for energized equipment or potential energy hazards;
.5 Toxic gas detectors and warning signs;
.6 Noise arresters and noise protection;
.7 Vibration isolators and dampeners;
.8 Warning signs on the doors to chemical rooms;
.9 Emergency flushing/eyewash/safety shower locations and capacity (as per WorkSafeBC requirements);
.10 Provision of fire protection systems including smoke detectors and fire extinguishers;
.11 Reducing the risk of arc flash through design, including ducting and setbacks;
.12 Separation of chemical storage and handling;
.13 Manual overrides for automated controls; and
.14 Chemical spill containment and separation.

The appropriate personal protective equipment (PPE) should be provided for all personnel including; gloves, face shields, goggles, fall arrest, hearing protection, and confined space entry equipment, etc.

5.3.4 Provisions for Future Expansion

Provisions for future plant expansions should consider:

.1 Building siting and topography;
.2 Oversizing of plant piping and conveyance facilities to provide for future projected flow requirements, where treatment will not be negatively affected;
.3 Use of blind flanges for future process expansion connections;
.4 Allocation of additional space in facility superstructures;
.5 Building envelope access points for installation of future equipment;
.6 Provision for future buried or exposed electrical cables between equipment and structures;
.7 Sizing of HVAC and electrical systems (including additional space in MCC/PDC rooms);

.8 Provision of wall castings for future piping penetrations whenever pipes pass through walls of concrete structures; and

.9 Provisions for expansion of the plant waste treatment and disposal facilities, including space for installation of electrical equipment at a later date.

The Designer should review all of the above considerations regarding facility layout with both the drinking water system Owner and the operator at an early stage in the planning and design processes.

5.4 Monitoring Equipment and Laboratory Facilities

Each drinking water system should have equipment to perform the routine performance monitoring necessary to ensure proper operation of the system. Monitoring equipment selection should be based on the characteristics of the raw water source and the complexity of the treatment processes involved. Testing and monitoring should be conducted by appropriately trained individuals. Laboratory test kits which simplify procedures and the qualifications needed to conduct one or more tests may be acceptable.

Water Suppliers must conduct regulatory compliance monitoring (bacteriological) as per Section 11 of the DWPA and Section 8, Schedule A and Schedule B of the DWPR. In contrast with performance monitoring conducted at Water Supplier laboratory facilities, samples for bacteriological compliance monitoring must be analyzed by laboratories (normally third-party) which have been approved by the Provincial Health Officer. A list of approved laboratories can be found on the website of the Provincial Health Services Authority (PHSA). Laboratories may also conduct bacteriological monitoring on site for operational purposes, but these samples cannot be used to meet regulatory monitoring requirements.

Analyses conducted to determine compliance for physical and chemical parameters should be performed in a laboratory certified for analysis of these parameters. Some laboratories are voluntarily certified by the Canadian Association for Laboratory Accreditation (CALA).

Laboratory facilities (e.g. a dedicated laboratory room) is recommended for systems which conduct multiple onsite analyses. The following should be considered when designing a laboratory room:

.1 Sufficient bench space, adequate ventilation, adequate lighting, storage room, laboratory sink, and auxiliary facilities should be provided. Air conditioning may be necessary;

.2 Sample lines may be used to convey a continuous sample stream to the laboratory from the various stages of the treatment process. These sample lines should run continuously to provide representative samples and be kept as short as possible. Consideration for discharging the increased volume of wastewater should be reviewed if a continuous sample stream is to be included in the design;

.3 Sufficient glassware and general reagents should be provided to conduct all the required analyses, as well as appropriate cleaning agents. Sample and reagent storage and refrigeration should also be provided, if required;

.4 An emergency shower/eye wash station should be provided and should be located such that operators have easy access to the station. Stations not connected to a potable water system should have a minimum 15-minute flush capacity. Saline solutions should not be used;

.5 At larger treatment plants, the Designer should consider providing pilot-scale facilities, with sufficient flexibility to alter coagulation, flocculation, filtration and other process operations, to assist in determining optimum plant operating conditions. If a pilot plant is not currently being considered, providing space for future addition should be considered;

.6 Acid resistant plumbing systems from laboratory or waste drains should be used as required, based on the type of laboratory and reagents used; and

.7 Methods should be provided for verifying adequate quality assurances and for routine calibration of equipment.

Additional details, including specific analytical recommendations, can be found in Chapter 22 – Water Quality Monitoring.

5.5 Personnel Facilities

Personnel facilities should be dictated by the number of personnel expected to be working at one time. At a minimum, it is recommended that provisions be made for storage lockers and change rooms/washrooms with showers. Water efficient fixtures should be used. A lunchroom of adequate size to serve as a meeting or training room for WTP staff as well as a suitable office for WTP supervisory staff and record keeping should be provided. Whenever possible, personnel facilities should be separated from the WTP facilities, but with convenient access to the WTP. Adequate facilities should be included for shop space and storage consistent with the designed facilities.

The provision of drinking water and sanitary facilities for operators may lead to a significant increase in cost for small remote plants. In communities where such facilities may be available elsewhere, the Designer should determine whether such facilities are required and may propose alternatives. Reference should be made to Chapter 21 – Small Systems for further guidance on small system design.

The facility water supply service line and the plant finished water sample tap should be supplied from a source of finished water at a point where all chemicals have been thoroughly mixed, and the required disinfectant contact time has been achieved. Due to high disinfectant residual concentrations at the WTP, bottled water dispensers may be preferred as drinking water for personnel and visitors.

There must be no cross connections between the facility water supply service line and any piping, troughs, tanks, or other treatment units containing wastewater, treatment chemicals, raw or partially treated water.

5.6 Building Services

All buildings must conform to the *BC Building Code*. The following should also be considered for each building:

.1 Adequate and safe heating systems with controls should be provided. In many areas of the plant, sufficient heat need only be provided to prevent freezing of equipment or treatment processes. Buildings should be well ventilated by means of windows, doors, roof ventilators or other means;

.2 Walls, floors, and HVAC systems should be coated in a corrosion resistant material and protected from damage due to humidity;

.3 All rooms, compartments, pits and other enclosures below grade should have adequate forced air ventilation provided when it is necessary to enter them;

.4 Rooms and galleries containing equipment or piping should be adequately heated, ventilated, and dehumidified to prevent excessive condensation. Switches should be provided for convenient control of the forced ventilation;
.5 Buildings should be adequately lit throughout by means of natural light and artificial lighting;
.6 Control switches should be conveniently placed at the entrance to each room or area;
.7 Emergency lighting should be provided;
.8 Communications systems should be provided including connections between buildings;
.9 Power outlets of suitable voltage should be provided at convenient spacing throughout plant buildings to provide power for purposes such as maintenance equipment and extension lighting;
.10 Power outlets located on the outside of buildings may be advantageous. Ground fault interrupter (GFI) type outlets are desirable throughout (where appropriate). Outlets supplied by uninterruptible power supply (UPS) or emergency power systems should be located such that they are easily accessible during a power outage;
.11 Adequate shop space and storage for the designed facilities should be provided; and
.12 A bridge crane, monorail, lifting hooks, hoist or other adequate facilities should be provided for servicing or removing heavy and/or large equipment.

5.7 Mechanical Piping

All mechanical piping in water treatment plants should:

.1 Be designed and manufactured in accordance with ASME, AWWA or CSA standards;
.2 Use seismically appropriate pipe materials and connections for all pipes;
.3 Use compatible flanges or grooved couplings for steel pipe and equipment connections that are equal to or greater than 75 mm in diameter. Steel pipe or equipment connections that are less than 75 mm in diameter should be threaded. Similar units, flange standards and thread standards should be used throughout the facility;
.4 Use fused piping connections, and flanged equipment connections for HDPE pipe;
.5 Use socket welded or threaded piping connections, and threaded or flanged equipment connections for PVC pipe. However, threaded piping is not recommended for small diameter sodium hypochlorite piping;
.6 Use flanged piping connections and equipment connections for FRP pipe;
.7 Be appropriate for the type of liquid to be conveyed. Pipe selection will depend upon economic and corrosion rate factors, as well as the type of equipment used, and connections required. Acceptable process piping/valve materials include polyvinyl chloride (PVC), polyethylene (PE), ductile iron (DI, with proper coating), carbon steel (with proper coating) and stainless steel (with proper passivation). Special consideration is to be given to low and high pH liquids;
.8 Allow for greater potential for deflection in thin wall pipe systems;
.9 Allow for future capacities and ease of extending the piping without major disturbance to the plant;
.10 Have proper isolation through valves, spectacle blinds and pipe sections to allow for repair or replacement;
.11 Provide couplings downstream of isolation valves to allow for maintenance of piping;
.12 Allow for the possibility that piping could be installed during construction when temperature conditions could be substantially different from the design condition (for

example, piping could be installed in temperatures anywhere between 40 °C and -20 °C and substantial differences in pipe dimensions could occur). Where piping is cast-in-place, allowance should be made for differential expansion between pipe material and structures. For this reason, the use of polyvinyl chloride (PVC) pipe with cast iron mechanical joint fittings should be avoided;

.13 Be made of similar materials (e.g. pipe appurtenances); otherwise, dielectric couplings should be employed to reduce galvanic corrosion. If pipe with dissimilar materials is connected, insulation kits should be used to reduce galvanic corrosion;

.14 Be provided with drains at all low points and air valves at all high points;

.15 Include cleanouts and flushing facilities for sludge piping;

.16 Allow for proper restraint under all anticipated conditions, particularly where surges may occur, and high transient pressures could result, or where different temperatures occur seasonally. Piping stress analysis should be part of the design of all piping systems (pipe and support) involving high pressure fluids or gases, dangerous chemicals, large diameter above ground pipe, or the potential for transient or temperature derived pressure effects;

.17 Consider supply pressure and employ pressure reducing valves, where necessary;

.18 Avoid using plastic or PVC type pipe for pneumatic systems;

.19 Guard or protect from physical impact, plastic or other pipe materials that may shatter on impact, especially for essential and/or hazardous systems;

.20 Where piping connections are made between adjacent structures, use at least two flexible couplings if any possibility of settlement or differential expansion exists, unless other mitigation is provided to accommodate potential lateral deflections. Particular attention should be given to pipe bedding in areas adjacent to structures to avoid damage due to settlement;

.21 Be arranged so that all valves, flow meters, and other items which may require regular inspection or maintenance are conveniently accessible;

.22 Include sufficient couplings and flanges to allow for easy disassembly and removal of equipment;

.23 Not be subject to contamination and have watertight joints;

.24 Provide sample taps so that water samples can be obtained from each water source and from appropriate locations in each treatment unit operation, and from the finished water. Taps should be consistent with sampling needs and should not be of the petcock type. Taps used for obtaining samples for bacteriological analysis should be of the smooth-nosed type without interior or exterior threads, should not be of the mixing type, and should not have a screen, aerator, or other such appurtenance.

.25 Insulation should be provided where temperatures below 4 °C are anticipated, or a humid environment where condensation on cold pipe surfaces would be expected. Heat tracing should also be provided when there is a risk of freezing.

.26 Designed for the process water piping flow velocities listed in Table 5-1.

Table 5-1 Recommended Maximum Line Velocity

Process	Maximum Velocity (m/s)
Maximum Velocity Limited by Process Considerations	
Flocculated water	0.60
Pre-settled water	0.60
Post-settled water	0.30
Filter influent	0.20
Maximum Velocity Limited by Hydraulic Considerations	
Raw water (pumped)	3.0
Filter effluent	2.0
Wash supply	3.0
Wash drains	2.5
Treated water (pumped)	3.0

5.8 Cross Connections and Backflow Prevention

Within water facilities, considerable potential exists for cross connections between drinking and non-drinking water. Typical examples are drinking water supplies for chemical solution make-up, cooling water supplies to mechanical equipment, seal water supplies to pumps, and filter surface-wash piping. While pump seal water supplies need only be of better sanitary quality than the water pumped, it is frequently more convenient to use the treated water system to provide seal water.

For information on cross connection control, refer to relevant municipal bylaws; the BC Plumbing Code (in particular, Division B, article 2.6.2), the Canadian Standard Association's (CSA) *Selection and Installation of Backflow Preventers/Maintenance and Field Testing of Backflow Preventers (CSA Standard B64.10)*, the *AWWA Manual of Water Supply Practices M14 – Recommended Practice for Backflow Prevention and Cross-Connection Control* and/or the USEPA *Cross-Connection Control Manual, 2003.*

There are several types of backflow prevention devices available including air gaps, double check valve assemblies, reduced pressure principle devices, dual check valves, atmospheric vacuum breakers, and pressure vacuum breakers. Backflow prevention devices should be selected, installed and tested in accordance with the previously mentioned standards or codes.

For applications involving health hazards, only air gaps or reduced pressure principle devices should be used.

5.9 Piping Colour Code

To facilitate identification of piping in plants and pumping stations it is recommended that the colour scheme described in Table 5-2 is used.

Table 5-2 Piping Colour Coding

Chemical Lines	**Colour**
Alum or primary coagulant	Orange
Ammonia	White
Carbon slurry	Black
Caustic	Yellow with green band
Chlorine (gas and solution)	Yellow
Chlorine dioxide	Yellow with violet band
Fluoride	Light blue with red band
Lime slurry	Light green
Ozone	Yellow with orange band
Phosphate compounds	Light green with red band
Polymers or coagulant aids	Orange with green band
Potassium permanganate	Violet
Soda ash	Light green with orange band
Sulfuric acid	Yellow with red band
Sulfur dioxide	Light green with yellow band
Waste Lines	**Colour**
Backwash waste	Light brown
Sewer (sanitary or other)	Dark gray
Sludge	Dark brown
Other	**Colour**
Compressed air	Dark green
Gas	Red
Other lines	Light gray
Water Lines	**Colour**
Finished or potable	Dark blue
Raw or recycle	Olive green
Settled or clarified	Aqua

For liquids or gases not listed above, a unique colour scheme and labeling should be used. In situations where two colours do not have enough contrast to easily differentiate between them, a 150 mm band of contrasting colour should be on one of the pipes at approximately 700 mm intervals. The name of the liquid or gas should also be on the pipe. It is recommended to provide arrows indicating the direction of flow.

5.10 Site, Building, and Digital Security

Security measures are required to help ensure that Water Suppliers can effectively protect the drinking water supply. Design considerations should address physical infrastructure security and facilitate security related operational practices and institutional controls. Because drinking water systems cannot be made immune to all possible attacks, the design should address issues of critical asset redundancy, monitoring, response, and recovery. All public water supplies should identify and address security needs in design and construction for new projects and for retrofits of existing drinking water systems. Reference should be made to the *AWWA G430*, *Security Practices for Operation and Management* and AWWA's *Security Guidance for Water Utilities* document. To ensure highest protection to the public's drinking water, it is recommended that all water systems undertake a Security Vulnerability Self Assessment, at the very minimum, once every five years to identify any weaknesses in water system security and to determine security measures that should be implemented.

The following concepts and items should be considered in the design and construction of new water system facilities and improvements to existing water systems:

.1 Security should be an integral part of drinking water system design. Facility layout should consider critical system assets and the physical needs of security for these assets;

.2 The design should identify and evaluate single points of failure that could render a system unable to meet its design basis. Redundancy and enhanced security features should be considered to eliminate single points of failure when possible, or to protect them when they cannot reasonably be eliminated;

.3 Consideration should be made to ensure effective response and timely replacement of critical components that are damaged or destroyed. Critical components that comprise single points of failure (e.g. high volume pumps) that cannot be eliminated should be identified during design and given special consideration. Design considerations should include component standardization, availability of replacements and key parts, re-procurement lead times, and identification of suppliers, and secure retention of component specifications and fabrication drawings. Readily replaceable components should be used whenever possible and provisions should be made for maintaining an inventory of critical parts;

.4 Human access should be through controlled locations only. Intrusion deterrence measures (e.g. physical barriers such as fences, window grates and security doors; traffic flow and check-in points; effective lighting; lines of sight; etc.) should be incorporated into the facility design to protect critical assets and security sensitive areas. Appropriate and effectively operated detection should be included in the system design to protect critical assets and security sensitive areas. All cameras and alarms installed for security purposes should be connected to SCADA (Supervisory Control and Data Acquisition) where available and include monitors at manned locations. Alternative methods should be considered for primary use where there is no SCADA or SCADA support system;

.5 Vehicle access should be through controlled locations only. Physical barriers such as moveable barriers or ramps should be included in designs to keep vehicles away from critical assets and security sensitive areas. It should be impossible for any vehicle to be driven either intentionally or accidentally into or adjacent to finished water storage or critical components without being provided access by operations staff. Designated vehicle areas such as parking lots and drives should be separated from critical assets with adequate standoff distances to eliminate impacts to these assets from possible explosions of material in vehicles;

.6 Sturdy, weatherproof, locking hardware should be included in the design for the access to tanks, vaults, wells, well houses, pump houses, buildings, power stations, transformers, chemical storage, delivery areas, chemical fill pipes, and similar facilities. Hardened protective covers should be considered for padlocks or similar devices. Vent and overflow openings should be placed in secure areas. When not placed in secure areas, they should be provided with deterrence or intrusion detection equipment;

.7 Computer based control technologies such as SCADA should be secured from unauthorized physical access and potential cyber-attacks. Wireless and network-based communications should be encrypted/firewalled as a deterrence to hijacking by unauthorized personnel. Consideration should be made to designing ISA/IEC 62443-compliant automation systems, and/or including provisions for a CSMS (cybersecurity management system). Vigorous computer access and virus protection protocols should be built into computer control systems. Effective data recovery hardware and operating protocols should be employed and exercised on a regular basis. All automated control systems should be equipped with manual overrides to provide the option to operate manually. The procedures for manual operation including a regular schedule for exercising and ensuring the operator's competence with the manual override systems should be included in facility operation plans. Refer to AWWA's resources on cybersecurity (including the Cybersecurity Risk Management Tool) for more information;

.8 Real time water quality monitoring with continuous recording and alarms should be considered at key locations to provide early warning of possible contamination events; and

.9 Facilities and procedures for delivery, handling and storage of chemicals should be designed to ensure that chemicals delivered to and used at the facility cannot be released, introduced or otherwise used to debilitate a water system, its personnel, or the public. Particular attention should be given to potentially harmful chemicals used in treatment processes (e.g. strong acids and bases, toxic gases, and incompatible chemicals) and on maintenance chemicals that may be stored on-site (e.g. fuels, herbicides, paints, and solvents).

5.11 Flood Protection

Other than surface water intakes, all water supply facilities including pump stations, wells, reservoirs, and water treatment plant access roads should be protected to at least the 200-year flood elevation or maximum flood of record, and any climate risk assessments that have been completed. A minimum freeboard may also be required. Local municipal bylaws and provincial guidelines (e.g. the *BC Flood Hazard Area Land Use Management Guidelines*) should be referred to for the flood construction level. Additionally, the Riparian Areas Protection Regulation and local bylaws should be reviewed when working near a riparian area. Main switch gear electrical controls should be located above grade in areas not subject to flooding. For well floodproofing, reference should be made to the *Drinking Water Protection Act* (section 16), Drinking Water Protection Regulation (section 14) and *Water Sustainability Act* (section 63).

6 Source Water

6.1 General

This chapter provides guidance for the selection and development of source waters for use in drinking water supply and presents topics for Designers to consider when developing a new drinking water source or modifying an existing drinking water source. Development of source water infrastructure can represent a significant investment that will have long term implications to the quality and quantity of water available for use in a water system. Careful consideration of the source water alternatives (e.g. waterbody or aquifer, location, diversion infrastructure, etc.) can reduce the need for engineering or operational controls and ensure the sustainable supply of drinking water.

Provision of clean, safe and reliable drinking water begins with the source water. The term source water refers to any surface water or groundwater supply that is used to provide drinking water under the DWPA. Water Suppliers should aim to obtain source water from the best available source which is economically reasonable and technically possible. When selecting a source water, more than one water source should be evaluated, where feasible. Doing so will help allow for the best water source to be selected, and will document alternative source(s) that can be used as a back-up in cases where the chosen water supply becomes contaminated, unreliable, or otherwise unsuitable.

Prior to developing a new water source, a Water Supplier should demonstrate to the Issuing Official that the source water is appropriate for the intended use, there is adequate quantity of water available to meet current and future water demands, and that withdrawals from the water source are sustainable (see Section 6.1.2 – Source Water Quantity).

When selecting a new water source, Designers should apply a systems approach to assess the impact of seasonal variations on raw water quality and quantity, the benefits of gravity supply to the distribution system, the type and proximity of known contaminant sources, current and anticipated activities within the source area (watershed or capture zone), changing climate conditions, the effect of blending multiple source waters on water chemistry (if applicable), and accessibility to water supply infrastructure.

Consultation should be a key project phase when developing a new source water supply. The relevant First Nations should be consulted where Indigenous rights may be adversely impacted by:

.1 a proposed water supply diversion, storage and use; or
.2 construction, maintenance and operation of the supply system.

6.1.1 Types of Source Water

In B.C., drinking water sources are generally grouped into the following types of source water to assess the level of treatment required for public health protection:

.1 **Surface Water** is defined in the Drinking Water Protection Regulation as water from a source which is open to the atmosphere and includes streams, lakes, rivers, creeks and springs;

.2 **Groundwater** is defined in the *Water Sustainability Act* as water naturally occurring below the surface of the ground. In the *Guidance Document for Determining Groundwater at Risk* *of Containing Pathogens,* groundwater sources are classified based on the following categories:

a. **Groundwater at risk of containing pathogens (GARP)** is defined as any groundwater supply likely to be contaminated from any source of pathogens, continuously or intermittently. Potential sources of pathogens include sewage discharge to land, leaking municipal sewage pipes (especially force mains), agricultural waste stockpiles, runoff intrusion into poorly constructed wells, and surface water;

b. **GARP-viruses only** is defined as any groundwater supply determined to be 'at risk' of containing viruses (i.e. if the DWO has reason to believe that the source is only at risk of containing viruses, and not other pathogens). This would include water supply system wells located within 300 m of a source of probable enteric viral contamination without a barrier to viral transport or other conditions indicating possible viral contamination, therefore requiring treatment of viruses;

c. **Groundwater at low risk of containing pathogens** is defined as groundwater that is considered to be at low risk of containing pathogens as a result of a GARP assessment (i.e. no hazards were identified following a GARP Stage 1: Hazard Screening and Assessment, or the groundwater source was determined to be at low risk following a Stage 2: GARP Determination).

The *Guidance Document for Determining Groundwater At Risk of Containing Pathogens (GARP)* should be referenced when assessing microbial contamination risks to groundwater. The determination of the groundwater category (GARP, GARP-viruses only, or groundwater at low risk of containing pathogens) for a given water source is made by a DWO. This determination becomes the basis for establishing whether disinfection is required and the other measures needed to ensure that public health is protected. Water Suppliers may conduct a self-assessment in consultation with the DWO; and

.3 **Rainwater** is defined as water collected from natural precipitation from a roof or similar structure. Stormwater – precipitation runoff that flows over land and/or impervious surfaces not including roofs (e.g. streets, parking lots, roofs with public access or green roofs) – is not considered as rainwater. Any system used to collect, convey, store, treat and distribute rainwater for use is a rainwater harvesting system. Refer to Chapter 21 – Small Systems for rainwater-specific guidance.

For guidance on pathogen log reduction treatment objectives for different source water types, refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* (BC MOH, 2022).

6.1.1.1 Source Water Assessment

As part of an application for source water approval, a Water Supplier should undertake a source water assessment to understand the characteristics of the source water and threats that may affect the quality and quantity of water. A source water assessment represents only a portion of the overall water system assessment and should be completed prior to the development of source water diversion or extraction infrastructure. The methodology to be used for the source water assessment may vary based on the size, characteristics and complexity of the water system. The source water assessment should accompany an application for source water approval. The Ministry of Health has developed several tools to complete this work.

The Comprehensive Drinking Water Source-To-Tap Assessment (CS2TA) is intended to help water suppliers develop a better understanding of risks to drinking water safety and availability. This is an eight-module step-by-step assessment that evaluates the vulnerabilities that may threaten the safety and sustainability of the water supply and provides risk management actions to address them. Modules 1 and 2 are specific to the source water, while Modules 3, 4, 5 and 6 are specific to the infrastructure and management of the drinking water system. Module 7 outlines the risk assessment process, and Module 8 recommends an approach to manage and mitigate the identified risks.

A source water assessment may be comprised of CS2TA Modules 1, 2, 7, and 8, or as agreed to by the DWO or their designate.

6.1.2 Source Water Quantity

In selecting the source water to be developed, the Designer should determine the water supply requirements to meet current and future water system demands. The assessment of the source water quantity requirements can be separated into two parts, as follows:

.1 Determine the water demands required by water system customers, process water requirements and facility requirements (if applicable) based on current and future design horizons; and

.2 Verify the source water has adequate capacity to meet the water demands determined in point .1 in addition to all other authorizations with precedence, as determined under the WSA, including the environmental flow needs, and that the withdrawals from the source water are sustainable.

The quantity of water required (in point .1) should be determined based on the water system demands (consumption, bulk supply, non-revenue water, etc.), process water requirements (wash water, make-up water, sample waste, etc.), facility domestic usage, and other water demands that can be reasonably anticipated for the water system. For water system planning, the source water should be sized to supply the current and future anticipated maximum day demand (MDD), seasonal average monthly fluctuations and the total annual demand of the water system. For water systems providing fire protection, the source water(s) should have adequate capacity to replenish depleted fire suppression storage within 72 hours (or sooner if required by the local fire authority or local government having jurisdiction over the water system) while concurrently supplying the MDD of the water system. For water systems without storage (free surface or pressure tanks) the source water supply infrastructure should be sized to meet the peak hourly demand plus a suitable safety factor. Further details of source water capacity planning are provided in subsequent sections of this chapter; considerations for small water systems (including rainwater systems) are provided in Chapter 21 – Small Systems.

Water Use During Scarcity in B.C.

If **significant water shortage** (SWS) is in place under the WSA for a designated area and a **critical environmental flow threshold** (CEFT) order is in place for a water source, CEFT has precedence over water rights. A CEFT is a short-term flow threshold, below which significant or irreversible harm to the stream's aquatic ecosystem is likely to occur. Under the "**first in time, first in right**" (FITFIR) system of precedence of rights, the date of precedence establishes who is allowed their full allocation of water first during times of water scarcity or drought. Domestic users will not be prohibited from diverting and using up to 250 litres per day per dwelling for **essential household use** (EHU).

The determination of the source water availability is administered under the *Water Sustainability Act* (WSA) with consideration to all other authorized water rights on the source water and the interconnected surface water and groundwater resource. The WSA endeavours to protect BC's water supply to ensure sustainable management of the Province's water resources today and in the future. Under the WSA, a Water Supplier must hold a Water Licence to divert or use water from a surface water or groundwater source; therefore, water systems must have appropriate Water Licences for their source water supplies. Water Suppliers must apply to the Ministry of Water, Land and Resource Stewardship (WLRS) for a Water Licence for surface or groundwater use through FrontCounterBC's website (www.frontcounterbc.gov.bc.ca).

As part of the Water Licence application process, WLRS conducts a watershed-scale water balance and/or groundwater modelling to consider climate, and groundwater and surface water interaction over the anticipated lifetime of the water supply system. When water balance and environmental flow needs estimates are not available for an area, the Water Licence applicant may be required to carry out this modelling.

A Water Licence is not required for rainwater harvesting.

6.1.3 Source Water Quality

Where possible, source water for drinking water systems should be selected to obtain the highest quality water that is reasonably and economically available and should meet the provincial *Source*

Drinking Water Quality Guidelines (SDWQGs). The SDWQGs are managed and developed by the Ministry of Water, Land and Resource Stewardship as part of the *B.C. Ambient Water Quality Guidelines* (WQG). These guidelines provide maximum acceptable concentrations (MAC) and aesthetic objectives (AO) for chemical, physical and microbiological water quality parameters and apply to ambient or raw water before it is treated and distributed for potable use. Assessment of source water quality against the ambient SDWQGs is a key part of source water protection and the multi-barrier approach to drinking water safety.

The Contaminated Site Regulation (CSR), under the *Environmental Management Act*, sets out requirements for sites which may be contaminated or are known to be contaminated to ensure that groundwater quality at these sites is suitable for specified direct uses (including drinking water) and is of adequate quality to protect adjacent groundwater uses. The CSR and supporting technical guidance outlines screening and sampling methodologies to determine whether there are potential contaminants of concern (PCOCs) in the soil or within the groundwater, and sets requirements for remediation (i.e. numerical standards). Designers must check for any registered contaminated sites, or sites with current or historical activities which could reasonably be assumed to be contaminated, within 500 m of any proposed drinking water source, and should refer to the CSR and supporting technical guidance from the Ministry of Environment and Climate Change Strategy for further details and tools.

Designers need to consider source water quality parameters to determine the level of treatment required to meet the *Design Guidelines*. A source water quality assessment and monitoring program should be conducted to understand the variation in seasonal water quality conditions of a new or modified water source. When developing a new source water, the focus of the sampling program should be on understanding the challenges, risks and seasonal variations. The following Table 6-1 provides a list of parameters that should be considered. The specific parameters to test and frequency of sampling should be selected on a source-by-source basis and should consider the source water type, proximity to potential contaminant sources, current and anticipated land use in the source area, and effects of changing climate conditions.

Table 6-1 Raw Water Characterization Parameters

Field Parameter
Conductivity
Odour [a]
pH
Temperature
Turbidity
Lab Parameter
Microbial [b]
E. coli
Heterotrophic plate count
Iron and sulphate reducers/bacteria
Protozoa (*Cryptosporidium*, *Giardia*)
Total and fecal coliform
Disinfection and DBP Related
Bromide
HAA by-product formation
THM by-product formation
Tannins and lignins
Total organic carbon (TOC)
UV transmittance
Physical
Colour
Total Dissolved Solids (TDS)
Total Suspended Solids (TSS)
Chemical
Alkalinity
Calcium
Chloride
Corrosivity [c]
Cyanide
Fluoride
Hardness
Potassium
Sodium
Sulphate
Sulphide

Lab Parameter (continued)
Nutrients
Ammonia
Nitrate
Nitrite
Organic nitrogen
Phosphorus
Total nitrogen
Metal Scans
Aluminum
Antimony
Arsenic
Barium
Boron
Cadmium
Chromium
Copper
Iron
Lead
Magnesium
Manganese
Mercury
Molybdenum
Nickel
Selenium
Silver
Zinc
Uranium
Additional Tests
Radium/gross alpha beta
Organic Contaminants
Hydrocarbons [d]
Pesticides and herbicides [e]

[a] Qualitative test only. Refer to Chapter 10 – Taste and Odour Control for potential causes and mitigation of water odours.
[b] Although viruses are not commonly quantified, this hazard is assessed in groundwater during GARP determination. Refer to the *Guidance Document for Determining Groundwater at Risk of Containing Pathogens*.
[c] Refer to Chapter 12 – Internal Corrosion Control for information on corrosivity indices.
[d] Measurement of VHw6-10 (volatile hydrocarbons in water, carbon range of C6-10), BTEX (benzene, toluene, ethylbenzene and xylenes), and/or a full VOC scan may be informative depending on site-specific conditions. Refer to the *British Columbia Environmental Laboratory Manual*.
[e] Screening for specific chemicals should be based on local land use. Refer to the *Guidelines for Canadian Drinking Water Quality* for chemicals to consider.

6.2 Surface Water

6.2.1 Source Selection

Surface water sources make up over 75% of the water used for water supply systems in B.C. (*Statistics Canada, 1996*). Surface water sources are typically prone to seasonal variation in quantity and quality. Designers and Water Suppliers should develop surface sources with full knowledge of the anticipated seasonal fluctuations and climate change impacts that may impact the quality and service capacity over time; examples include temperature changes, heavy rainfall events, low rainfall or low snowpack years, anthropogenic activities, wildfires, and drought conditions. Historical water quality and hydrological data should be reviewed to determine the adequacy of the surface water source to meet the current and future needs of the drinking water system.

6.2.1.1 Quantity

The availability of surface water depends on climatic influences, environmental flow needs, existing water use rights, and future impacts of climate change. Designers should assess the capacity of the surface water source to meet the current and future water supply system demands while continuing to satisfy the existing water rights, environmental flows needs and the established minimum flow thresholds.

Source water capacity assessments can be estimated using different methods. Flow mass curves can be generated from streamflow records. Alternatively, a record can be simulated using long-term precipitation data. Where data exists, both methods may be used, and a comparison made between them. Source water source capacity assessments should:

.1 Include a statistical analysis to determine the 1/20-year return periods within a 95% confidence interval to understand natural fluctuations in water availability;
.2 Meet the maximum projected water demand of the water supply system as shown by calculations based on a 1/50-year drought or the extreme drought of record, whichever is more extreme, and include consideration of multiple year droughts and changes in expected drought frequency due to climate change;
.3 Assume a minimum design horizon of 50 years and provide a reasonable surplus for anticipated growth;
.4 Be adequate to compensate for all losses such as silting, evaporation, seepage, etc.;
.5 Be adequate to provide ample water for other authorized water users of the source while maintaining the environmental flow needs, as determined under the WSA;
.6 Use flow mass curves where streamflow data exists to estimate the minimum perennial flow on record, and future minimum flow when considering climate change impacts, and determine a drought return period;
.7 Consider all available storage in all yield calculations; and
.8 Consider climate change in future precipitation projections. Refer to Chapter 4 – Climate Change Risk Assessment and Adaptation for details on climate change planning and design practices.

Refer to the *Assessment Methods for Aquatic Habitat and Instream Flow Characteristics in Support of Applications to Dam, Divert, or Extract Water from Streams in British Columbia* and *Development of*

Instream Flow Thresholds as Guidelines for Reviewing Proposed Water Uses for further guidance on assessing surface water source capacities in B.C.

Referral to the Environmental Assessment Office (*EAO, 2019*) is required for surface water supply sources that:

.1 Divert water at a maximum rate of ≥ 10 million m^3 per year;
.2 Include modifications that will increase the original design capacities by 35% or greater;
.3 Result in changes in or about a stream, coastline or estuary and entails dredging, filling or physical disturbance of:
  a. 1,000 m or greater of linear shoreline, or
  b. 2 ha or greater of foreshore or submerged land, or a combination of foreshore and submerged land below the natural boundary of a stream, marine coastline or estuary;
.4 The modification results in an increase of 35% or greater in:
  a. The length of linear shoreline that is directly disturbed by dredging, filling or other physical action, or
  b. The disturbed area or a combination of foreshore and submerged land, below the natural boundary of a stream, coastline or estuary.

Refer to the *Environmental Assessment Act* Reviewable Projects Regulation for further details.

6.2.1.2 Quality

A source water assessment should be conducted as defined in Section 6.1.1.1 – Source Water Assessment to understand the factors, both natural and man-made, which may affect water quality in the source water. Specific considerations for surface water sources include, but are not limited to:

.1 Possible future uses of the watershed;
.2 The Water Supplier's degree of control over the watershed;
.3 Degree of hazard to the supply posed by forest fires, or agricultural, domestic, industrial, or recreational activities in the watershed, which may generate toxic or harmful substances detrimental to treated water quality or undermine the integrity of the watershed;
.4 Waste discharges (point source and non-point sources) and activities in close proximity to the intake protection zone or the watershed;
.5 Capability of the proposed treatment process to reduce contaminants to meet provincial drinking water treatment objectives;
.6 Impacts of currents, wind and ice conditions, and other contributing water sources; and
.7 Potential seiche effects on water quality in lakes.

The determination of representative source water quality should be based on obtaining samples over a sufficient period of time, recommended minimum of one year, to assess seasonal variability in the microbiological, physical, chemical and, when applicable, UV transmissivity and radiological characteristics of the water.

6.2.2 Intake Structure

6.2.2.1 Intake Location

The design objectives for selecting intake location should be to provide adequate quantities and a high and consistent quality of raw water, as confirmed by samples taken over all four seasons at the location and depth(s) of the proposed intake.

When locating the intake, the following should be considered:

.1 The minimum submergence from the top of the intake structure to the minimum recorded water level should be 3 m and the pipe and screen should comply with the *Canadian Navigable Waters Act;*
.2 Historical information on water depths at the proposed location, whether or not the source level is controlled, and, if controlled, whether historical minima occurred before or after control measures were implemented;
.3 The effect of bottom contours, subsoils and available water depths;
.4 Soil conditions including soil porosity and hydraulic conductivity;
.5 Water levels under drought conditions;
.6 Whether there is sufficient distance from shore to avoid water quality disturbances due to wave action or other shoreline disturbances;
.7 The location of present and future planned outfalls from sewage treatment plants and industrial installations, as well as any inshore pollution, especially during high runoff conditions;
.8 The optimum depth(s) to draw water of highest quality;
.9 Water quality information and data on current flows and directions, including potentially infrequent occurrences such as thermoclines or falling plume dispersions;
.10 Potential for the presence of zebra mussels and other molluscs in the source water that may impact intake performances, though these invasive mussels have not yet been found in B.C.'s waters (refer to Section 6.2.4.1 – Mussel Control); and
.11 The influence of contaminant sources.

6.2.2.2 Design of Intake Structures and Pipelines

Due to the high cost and complexity of underwater construction, as well as the impact on the environment, it is suggested that intake size be sufficient for a minimum design period of 50 years. The design of intake structures for surface water supplies should include, but is not limited to, the following:

.1 Withdrawing water from the location of optimal quality. This may include provision to withdraw water from multiple locations within the water column if quality varies significantly with depth and during seasonal events;
.2 Where frazil ice may be a problem, limiting the velocity of flow into the intake structure to less than 0.075 m/sec (during cold weather conditions) and maintaining uniform acceleration of water from inlet to intake pipe. Intake crib materials should be of low thermal conductivity, with racks of smooth materials;
.3 Top entry and side entry designs which may be evaluated on the basis that:
  a. Side entry designs are less likely to be damaged by anchors;
  b. Top entry designs provide greater clearance above the river or lake bottom, and the required inlet area can be more readily attained;
.4 Having a Ground Force Circuit Interrupter (GFCI) protection device as per the BC Electrical

Code on all submerged electrical motors;

.5 Locating river intakes in a stable reach of the channel, where erosion or deposition will not endanger the works and in such a way that the natural regime of the river will not be upset;
.6 Inspection of manholes every 305 m for pipe sizes large enough to permit visual inspection;
.7 Having separate facilities for the release of less desirable water held in storage;
.8 Where shore wells are not provided, having a diversion device capable of keeping large quantities of fish or debris from entering an intake structure;
.9 The intake design and its anchoring should take into account peak wave height and frequency and provide adequate protection against ice scouring and dragging anchors and seismic events;
.10 Identifying intakes with buoys or reflectors where in proximity to shipping or recreational activities. The Designer should be familiar with the requirements as legislated under the *Canadian Navigable Waters Act*;
.11 Using buried surface water collectors (refer to Section 6.2.2.2 – Design of Intake Structures and Pipelines); and
.12 Checking all designs for transient pressure problems and/or vortex generating tendencies, particularly if the intake pipe is long or has high design velocities.

The design of river intakes differs substantially from that for lakes in that a substantial current may exist and anchoring, bottom scouring and siltation considerations will assume greater significance. Where possible, river intakes should ideally be located well upstream of known point sources of pollution. River hydrology should be considered where the riverbed is subject to movement.

6.2.2.3 Design of Intake Screens

The following should be considered when designing an intake screen:

.1 A screen and intake structure design that does not entrain or impinge fish and meets Fisheries and Oceans Canada (FOC) requirements. Refer to the *Interim Code Of Practice: End-Of-Pipe Fish Protection Screens For Small Water Intakes In Freshwater* for intakes up to 150 L/s and consult FOC directly for larger intakes;
.2 Provision of fish ladders or fish passages on streams or rivers where stipulated by FOC;
.3 Screens should be constructed at the end of pipe, intake structure, or in-plant just prior to the raw water pumping facility;
.4 Consideration of the level of redundancy to be based on overall system redundancy, storage and access to alternate source water. Use of at least two screens operating in parallel is recommended;
.5 Mechanically cleaned screens are recommended for larger intake structures (> 150 ML/d) and fixed and mechanically cleaned screens may be used for small and medium capacity facilities;
.6 Locate intake screens and entrance ports a minimum of 0.6 m above the bottom of the streams, lake or impoundment, or as required to prevent sediments from being picked up;
.7 Consideration should be given to providing a means for backflushing or air bursting small intakes, if practical; and
.8 Coarse screens (bar and/or trash racks) may be required upstream of fine screens. Coarse screens should be constructed using 13 to 19 mm bars inclined at 30^{o} from vertical, providing 25 to 75 mm openings.

6.2.2.4 Infiltration Gallery Intake

An acceptable alternative design to a direct intake is an infiltration gallery intake. This type of intake is suitable when the riverbed is composed of gravels and rocks or if the floodplain is demonstrated to have a high-water table that is connected to the nearby watercourse. Infiltration galleries should incorporate either a standby duplicate intake or a submerged intake for use in case of problems with the stream-bed intake.

The Designer should consider the following when designing an infiltration gallery intake:

- .1 Protection from ice accumulation;
- .2 Protected against persons and domestic pollution, industrial or other harmful wastes or runoff;
- .3 Accessibility in all seasons;
- .4 Provision for backwashing and/or aeration;
- .5 The use of filter cloth;
- .6 The use of perforated or slotted plastic;
- .7 The intake opening area is sufficient to minimize inlet head loss;
- .8 Selection of backfill material in relation to the collector pipe slot size and gradation of the native material over the collector system;
- .9 The total orifice area should not exceed 18% to 20% of the total pipe wall area;
- .10 The orifices should be sized for an entrance flow velocity of 0.3 m/min or less and be adequate for the selected filter material gradation surrounding the gallery pipe/conduit in order to prevent sand from entering the piping system;
- .11 Stainless steel or concrete pipes should be installed with a minimum grade of 500:1 (sloping up toward the collector) and at depths of about 4.0 to 5.0 m below the bottom of streams or lakes; and
- .12 The depth of perforated infiltration pipes (to be located as deep as possible in the aquifer so as not to be affected by seasonal fluctuations).

6.2.3 Raw Water Storage

Raw water storage can be useful to manage the quantity and quality of the source water. Raw water storage facilities may be sized to allow retention of intermittent stream or aquifer to balance seasonal inflows with water system demands and provide standby against failure of intake facilities. Water storage facilities may be used to improve water quality by providing pre-sedimentation of solids or to avoid or reduce the impact of source water diversion during periods of poor raw water quality. Storage of source waters is regulated under the WSA and must be licenced under the Water Sustainability Regulation. Impoundments or reservoirs may be used, where authorized, to reduce peak withdrawal rates for a water system and to preserve other authorized water rights.

The Designer should be aware that changes in water quality may occur in impoundments and/or reservoirs, and the intake(s) should be designed accordingly.

Impoundments and reservoirs should be designed with the following considerations:

- .1 Should be of sufficient volume to sustain, if possible, a 1/50-year yield without significant drawdown (the volume should be confirmed by a bathymetric survey that is current within the last 20 years);

.2 Should have all necessary permits and approvals for controlling streamflow or installing a structure on the bed of a stream;
.3 Should have fish ladders or fish passages where stipulated by FOC;
.4 The hydraulic structure should be designed to meet the British Columbia Dam Safety Regulation and be in accordance with the latest version of the Canadian Dam Association's *Dam Safety Guidelines;*
.5 The site should be made as secure as is reasonably possible through the use of fencing, signage and patrolling/policing, if necessary;
.6 Minimizing seepage, including the use of liners; and
.7 Safety features for stability and spillway design should be approved by the BC Dam Safety Program.

Referral to the Environmental Assessment Office (*EAO, 2019*) is required for:

.1 Construction of a water storage reservoir:
   a. With a dam 15 m high or greater, measured in accordance with Section 1 (4) of the Dam Safety Regulation, or
   b. Containing 10 million m^3 or greater of water above the natural boundary of the streams that supply the water to the reservoir.
.2 Modifications to an existing water storage reservoir that increases the flooded area of the reservoir, as permitted under the WSA, by 20 ha or greater.

Refer to the *Environmental Assessment Act* Reviewable Projects Regulation for further details.

6.2.3.1 Facility Planning

The Designer should assess the need, location, and sizing of the raw water storage reservoir before proceeding with final design. Reservoir sizing should be determined by assessing the availability of water and the nature of upstream activities. The Designer should also consider any potential adverse effects on the water intake, storage, or treatment facilities; and should include design features to minimize the effects of fluctuating raw water turbidity and impacts to the environment.

6.2.3.2 Site Preparation

When preparing a site for an impoundment or reservoir the following should be completed:

.1 Inclusion of fencing around the reservoir;
.2 Protection from floods during construction; and
.3 Decommissioning of all wells which will be inundated, in accordance with requirements of the Groundwater Protection Regulation.

6.2.3.3 Reservoir Management

Raw water reservoirs should have a reservoir management program that identifies the current condition of the reservoir, the necessary storage capacity, and the necessary management procedures to respond to changes in reservoir conditions. Reservoirs that include a dam, as classified in the Dam Safety Regulation, must meet the requirements set out in the Dam Safety Regulation with respect to construction, monitoring, and reporting practices based on the consequence classification.

Reservoirs should be managed to avoid any difficulties with taste, odour, colour, iron, and manganese in drinking water. In-reservoir management techniques should address problems with algae, weeds, low dissolved oxygen, and loss of storage capacity.

Artificial circulation, aeration, phosphorus precipitation, sediment removal, dilution, and flushing are reservoir management techniques that should be adopted to improve water quality. Use of algaecides is not recommended due to algaecide toxicity and the potential for blue-green algae (cyanobacteria) cells to be ruptured, resulting in the release of cyanotoxins.

The reservoirs should be sized with consideration of potential climate change impacts: for example, increased frequency of droughts, changing patterns of precipitation and snowmelt, and increased water loss due to evaporation as a result of warmer temperatures, will result in changes to water availability. Warmer air temperatures may also result in increased demands on water supplies.

6.2.3.4 Off-Stream Raw Water Storage Reservoir

An off-stream raw water storage reservoir is a facility into which water is pumped during periods of good quality and high streamflow for future release to treatment facilities. Off-stream raw water storage reservoirs should be designed with the following considerations:

- .1 Water quality is protected by controlling runoff into the reservoir;
- .2 Dikes are structurally sound and protected against wave action and erosion;
- .3 Dikes and dam structures meet the relevant requirements of the Dam Safety Regulation;
- .4 Intake structures and devices meet the requirements of Section 6.2.2 – Intake Structure;
- .5 The point of influent flow is separated from the point of withdrawal to prevent short-circuiting;
- .6 Separate pipes are provided for influent to and effluent from the reservoir;
- .7 A bypass line is provided around the reservoir to allow direct pumping or gravity flow to the treatment facilities;
- .8 Redundancy with a minimum of two cells to enable one cell to be taken offline for filling or maintenance. Each cell should be sized to retain about 75% of the annual raw water needs and be sized to satisfy long-term drought conditions;
- .9 Control structures should enable the plant operator to isolate each cell, to drain each cell, and to enable the cells to be operated in series or in parallel;
- .10 Each cell should be deep enough to restrict light penetration within the depth of the reservoir to discourage the development of ideal habitats for aquatic plant growth;
- .11 Inside slopes of the cells should be armoured, where required, to prevent erosion. The impact of ice formation on winter storage should be accounted for in the design; and
- .12 Safety features should be incorporated to prevent animals or unintended human entry into the reservoir and to provide for safe egress.

6.2.4 Source Water Pre-Treatment

Pre-treatment at the intake should consider mussel control, intake chemical treatment and pre-sedimentation. For design guidance on pre-sedimentation, refer to Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification.

6.2.4.1 Mussel Control

Invasive mussels (i.e. zebra and quagga mussels) have the potential to obstruct public water supply intakes and cause loss of intake capacity, as well as contribute to taste and odour problems. These mussels have not yet been found in B.C. water supplies, although there is a high risk of their introduction to water systems. Water Suppliers should periodically assess the condition of their intakes to determine if mussels are or potentially may be present and implement a system of control.

The most accepted and currently recommended forms of chemical treatment for public water supplies are the use of oxidants such as chlorine, chlorine dioxide, potassium permanganate and ozone. Chemical dosages are typically applied at the intake through solution piping and a diffuser to prevent the formation of mussel colonies within the intake and piping. The type of chemical selected and frequency of application will depend on the type of existing chemical treatment facilities, mussel breeding season, potential for disinfection by-product formation, and other pre-treatment objectives such as taste and odour control, safety and cost. Refer to Section 6.2.4.2 – Intake Chemical Treatment.

In addition to the chemical methods described above, intake screens are also available that are manufactured with special alloys that prevent mussel growth on the intake itself.

The Designer may consider the provision of a suitable alternate intake, as periodic alternating use/zero flow conditions has been demonstrated to control mussel infestation, where economical.

Further information on zebra mussel prevention and management can be found in the AWWA Manual of Water Supply Practice *M7 - Problem Organisms in Water: Identification and Treatment.*

6.2.4.2 Intake Chemical Treatment

If it is determined that chemical treatment is warranted to address taste and odour control or the control of mussels and other nuisance organisms at the intake, the following should be considered in the design of the chemical system:

.1 Chemical treatment should be in accordance with Chapter 13 - Chemical Application;
.2 Plant safety items, including but not limited to ventilation, operator protective equipment, eyewashes/showers, cross connection control, etc., should be provided;
.3 Solution piping and diffusers should be securely anchored. Piping and diffusers should have appropriate valving and should be installed within the intake pipe or in a suitable carrier pipe;
.4 Provisions should be made to prevent chemical dispersal into the water environment outside the intake. Diffusers should be located and designed to protect all intake structure components;
.5 A spare solution line should be installed to provide redundancy and to facilitate the use of alternate chemicals;
.6 The chemical feeder should be interlocked with plant system controls to shut down automatically when the raw water flow stops;
.7 Provisions should be included for obtaining raw water samples not influenced by chemical treatment;
.8 Means to provide adequate flushing should be provided; and,
.9 When alternative control methods are proposed, appropriate piloting or demonstration studies may be required.

6.3 Groundwater

Groundwater makes up nearly 25% of the total source water used for drinking water supply in B.C. Groundwater and aquifers can be a productive source of high quality water, often requiring minimal treatment for potable use. Groundwater supplies are often utilized by small and medium-sized water systems or as a secondary source of water.

In B.C., the Groundwater Protection Regulation (GWPR), under the WSA, ensures that activities related to the use of wells and groundwater are performed in a sustainable and environmentally safe manner. The GWPR regulates minimum standards for well construction, maintenance, deactivation and decommissioning. The GWPR also identifies the types of qualified people certified to drill wells, install well pumps, and perform related services. When developing a groundwater source, the GWPR must be followed and the reference material below consulted:

- .1 *Groundwater Protection Regulation: Guidance Manual (ENV & FLNRORD, 2019);*
- .2 *Groundwater Protection Regulation Handbook (BC Groundwater Association, 2017);*
- .3 *Guidance for Technical Assessments in Support of an Application for Groundwater Use in British Columbia (ENV & FLNRORD, 2020)*; *and*
- .4 *AWWA Standard A100 – Water Wells* and *AWWA Manual M21 – Groundwater.*

This section provides a high level overview of planning and design considerations when developing a new groundwater source or modifying an existing groundwater source for a water supply system. In all cases, the requirements of the *Water Sustainability Act* and the Groundwater Protection Regulation related to groundwater protection must be met, as well as the applicable portions of the *Drinking Water Protection Act* (Sections 16 and 23), Health Hazard Regulation (Section 8, under the *Public Health Act*), Sewerage System Regulation (Section 3.1) and Municipal Wastewater Regulation (Section 82). Designers should also consult relevant Ministry of Water, Land and Resource Stewardship policies and guideline documents associated with groundwater protection requirements.

6.3.1 Source Selection

6.3.1.1 Quantity

The Designer should determine groundwater supply capacity requirements based on meeting the MDD of the water system with the largest producing well out of service. The required groundwater supply capacity can then be compared to the estimated long-term well yield capacity. The Designer should use a pumping test or hydrogeologic analysis conducted by or under the direct supervision of a Qualified Professional to estimate the long-term well yield capacity.

Water Suppliers must obtain a Water Licence prior to using a water supply well. The *Guidance for Technical Assessments in Support of an Application for Groundwater Use in British Columbia* provides guidance on the appropriate level of analysis that is required to make a decision on a Water Licence application. Water Licence applications undergo a technical review by the Ministry of Water, Land and Resource Stewardship to make sure there is enough water to not affect the existing water rights of others or harm the water supply and aquatic ecosystem. Other government agencies, affected landowners and licensees may be notified of the application and given the chance to respond; more details are provided in the *Water Applicant's Agency Resource Guide*. First Nations in the area may also be consulted.

Technical assessment requirements in support of Water Licence applications vary based on the quantity of water use and the potential to impact the availability of water to other wells, streams, and groundwater sources. The technical assessment levels range from Level 1 to Level 4, where Level 4 requires the most extensive reporting to support the application to license a water supply well. The results of a technical assessment are presented in a technical assessment report that is sealed by a Qualified Professional. A technical assessment report is intended to address the following considerations related to a new water supply well: groundwater availability and production capacity, impacts to existing users, hydraulic connection to surface waters, and other relevant issues (e.g. salt water intrusion, aquifer supply limits, flowing artesian conditions).

Pumping tests are required for Level 3 and Level 4 technical assessments. Refer to Section 6.3.1.6 – Pumping Test for more information.

Referral to the Environmental Assessment Office (*EAO, 2019*) is required for water supply wells with:

.1 Capacities of 75 L/s or greater that are operated continuously or intermittently for greater than one year; or
.2 Modifications that will increase the original design capacities by 35% or greater.

Refer to the *Environmental Assessment Act* Reviewable Projects Regulation for further details.

6.3.1.2 Quality

An assessment should be made of the factors, both natural and anthropogenic, which may affect water quality in the well and aquifer. Such an assessment may include obtaining samples over a sufficient period of time to assess the microbiological and physical characteristics of the water, including dissolved gases, and chemical and radiological characteristics. A GARP assessment should be conducted prior to the development of a groundwater supply source.

Groundwater quality monitoring should be conducted to:

.1 Show the suitability of the raw water source for potable use by comparing the results to the GCDWQ and the *Source Drinking Water Quality Guidelines*;
.2 Demonstrate the need for further treatment to meet the GCDWQ and provincial water quality objectives (i.e. *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*, Ministry of Health, 2015);
.3 Provide indications of well vulnerability to pathogens, and associated disinfection requirements;
.4 Identify other parameters that require treatment (if any);
.5 Show any changes that may occur as a result of pumping; and
.6 Provide evidence of contaminant sources that were not identifiable as part of the well siting study.

If GCDWQ values are exceeded, the hydrogeologist should indicate if this represents one or more of the following:

.1 A naturally occurring condition within the aquifer related to:
  a. The aquifer material (e.g. gypsum, arsenic, iron, manganese, uranium);
  b. Drawdown effects (e.g. hardness, dissolved solids, redox changes);
.2 Groundwater-surface water interactions (e.g. stream, river, lake, wetland or seawater

intrusion);

.3 Point-source contaminant sources (e.g. service stations, dry cleaning stores, landfills, on-site sewage systems);
.4 Non-point source contaminant sources (e.g. agriculture, road salting); and/or
.5 Inadequate well development (see Section 6.3.3 – Groundwater Source Construction-Related Contaminants).

The results of this assessment should be included in a well construction report sealed by a Qualified Professional.

6.3.1.3 Number of Wells

Ideally, a minimum of two sources of groundwater should be provided. Active wells may not be used at equal frequencies, depending on yield and water quality; less active wells should be flushed or operated for a minimum of two hours every seven days to avoid stagnation.

6.3.1.4 Siting of Wells

Siting of water supply wells must be conducted in accordance with GWPR. A desktop study should be completed prior to exploratory drilling to collect available background data from sources such as iMapBC or the BC Water Resources Atlas, GWELLS database, eLicensing, hydrogeological reports, provincial groundwater monitoring data, Environmental Monitoring System Data and geological mapping. The local Environmental Health Officer should be consulted with on the location of the proposed well. The well siting study should consider:

.1 Topography and drainage, including climate change impacts;
.2 Accessibility of the site by the drill rig and equipment;
.3 GARP hazard screening and assessment;
.4 Aquifer type;
.5 Aquifer hydraulic properties and distribution;
.6 Potential well depth;
.7 Geology mapping;
.8 Existing water well records;
.9 Existing monitoring well records;
.10 Beneficial confining units;
.11 Baseline/background groundwater quality;
.12 Expected groundwater flow directions and groundwater flow divides;
.13 Proximity and potential connection to surface water and potential to deplete the surface water or impact stream baseflow;
.14 Proximity and potential connection to contaminant sources;
.15 Existing allocation restrictions and environmental flow needs of the potentially connected surface water;
.16 Impacts from a nearby controlled dam;
.17 Proximity to the coastline and potential for saltwater intrusion;
.18 Land uses in source water zones;
.19 Risk of encountering flowing artesian conditions (refer to Section 6.3.1.7.3 – Flowing Artesian Wells);
.20 Distance from existing production wells, both private and domestic; and
.21 Cost of transmission and pumping of the groundwater.

6.3.1.4.1 Contaminant Setbacks

Well setbacks from contamination sources must also be considered in the siting of the well. Under Section 8 of the Health Hazards Regulation (HHR), Part 1 of the Sewerage System Regulation (SSR), Section 82 of the Municipal Wastewater Regulation, and the Section 18 of the GWPR, wells must have at least the horizontal setbacks from sources of contamination as defined in Table 6-2; however, for larger community water wells, larger setbacks may be required as determined by the size of the capture zone. In addition to these setbacks, the Designer should review local municipal bylaws.

Table 6-2 Well Setbacks from Possible Contamination Sources

Setback [2]	Contamination	Reference
6 m	Private dwelling	Health Hazards Regulation
15 m	Domestic sewage holding tank	Sewerage System Regulation
30 m	Any probable source of contamination	Health Hazards Regulation
30 m	Sewage system, including septic tank with daily flow less than 22.7 m^3/day	Sewerage System Regulation
50 m	Shorelines or saltwater body	GWPR Handbook
60 m	Discharge from municipal wastewater with maximum daily flow between 22.7 m^3/d and 37 m^3/d	Municipal Wastewater Regulation
60 m	High pumping rate community well [1] - sewage system, including septic tank with daily flow less than 22.7 m^3/day	Sewerage System Standard Practice Manual
60 m	Underground stormwater infiltration facility	GWPR Handbook
90 m	Discharge from a municipal wastewater system with a maximum daily flow equal to or greater than 37 m^3/day and the well is within a **confined** aquifer	Municipal Wastewater Regulation
90 m	High pumping rate community well [1] in an unconfined aquifer - sewage system, including septic tank with daily flow less than 22.7 m^3/day	Sewerage System Standard Practice Manual
120 m	Any cemetery or dumping ground, unless contamination of the well would be impossible because of the physical conformation	Health Hazards Regulation
300 m	Discharge from a municipal wastewater system with a maximum daily flow greater than 37 m^3/day and the well is within an **unconfined** aquifer	Municipal Wastewater Regulation

1. High pumping rate community well - for the purpose of determining horizontal setbacks, this means a well or well group serving more than 500 people or if it is pumped for more than three months at a rate of more than 190 L/min.
2. Larger setbacks may be required as determined by the size of the capture zone.

In addition to the setbacks defined above, water supply wells should be hydraulically up-gradient from potential sources of contamination, where possible. Well capture zones should not encompass potential sources of contamination. Separation distances should be established by a Qualified Professional based on the time of travel to the well, the type of aquifer, depth of the well and the persistence of the contaminant source. Future land use and long term wellhead protection should also be a factor when selecting a suitable location. Land uses of concern include:

- .1 Agricultural sources (runoff from pastures or feed lots, fertilized fields, manure storage areas and intensive pesticide use areas);
- .2 Landfills or waste management facilities;
- .3 Cemeteries;
- .4 Archaeological and culturally significant areas;
- .5 Bulk storage of liquids (service stations, dry cleaners, bulk plants, heating oil);
- .6 Roads and highways (road salt runoff, accidental chemical releases);
- .7 Mines and quarries (stored mine water, acid mine drainage, heavy metals from tailings, mine dewatering activities);
- .8 Wastewater treatment facilities; and
- .9 Industrial activities (manufacturing or processing facilities).

The *Guidance Document for Determining Ground Water at Risk of Containing Pathogens* (GARP) by the BC Ministry of Health should be referred to when assessing the level of potential risk that a groundwater source may become, or may already be, contaminated by pathogens. EGBC's Professional Practice Guidelines *Assessment of Groundwater at Risk of Containing Pathogens (GARP)* should also inform groundwater assessments.

6.3.1.4.2 Hydraulic Setbacks

Water supply wells should be sited to minimize impacts to existing groundwater users and the proposed wells must be sited so that that the horizontal setback distance is not less than 15 m from any part of the proposed wells to an existing water supply well, in accordance with the GWPR (section 18). In situations where large quantities of groundwater are required, it may be necessary to locate new wells within different catchment areas to avoid exceeding the aquifer recharge rate or causing stream depletion.

Proximity to streams and lakes can affect a well's vulnerability to pathogens. The degree of interaction between well field pumping and stream base flows should be addressed through well location, casing length, monitoring of groundwater and streamflow responses, and water quality monitoring.

6.3.1.5 Exploration Program

A groundwater supply exploration program will help to confirm the quantity and quality of groundwater available within a target area. A Qualified Professional should lead this type of work. The program scope will be determined based on the desktop study and by previous testing work within the area, potential supply sources and water supply requirements.

The minimum test hole diameter should be 150 mm in areas that have not been previously investigated to allow for pumping tests. Depending on the well setting and goals of the investigation, test holes with a minimum diameter of 200 mm may be more appropriate, as larger diameter pumps are often required to test at higher pumping rates. If a 150 mm diameter test well is used, it can be retained as a monitoring well or equipped with a pump and used as a backup or lower rate production well.

During construction of each exploration well, a detailed log must be made in accordance with the GWPR. Preliminary water quality sample(s) should be taken and analyzed for the full suite of health and aesthetic related parameters to confirm the presence of suitable water quality (refer to Table 6-1). If the well has not been developed, turbidity can affect the analytical results of unfiltered samples. Filtered samples may be more appropriate for turbid samples collected at this early stage of exploration.

The completion of exploratory wells allows for the assessment of aquifer characteristics, and will ultimately allow for proper production well design, spacing of wells and pump selection.

The GWPR must be followed for the siting and construction requirements for water wells. Specific requirements concerning the casing and annular seal, setbacks, driller and assessor qualifications, and yield assessment should be consulted prior to any intrusive work. Refer to the *Guidance for Technical Assessments in Support of an Application for Groundwater Use in British Columbia*.

6.3.1.6 Pumping Test

A pumping test is a type of flow test that is used to estimate well performance, well yield, the zone of influence of the well and aquifer characteristics. A pumping test is generally required to support a Water Licence application as part of the technical assessment. This technical assessment should also meet the requirements consistent with the level of proposed pumping and aquifer type. Refer to the *Guidance for Technical Assessments in Support of an Application for Groundwater Use in British Columbia (Version 2)* for more information.

In a pumping test, the well is pumped under controlled conditions and the water level in the well and other nearby wells is measured over time to determine drawdown. Pumping tests are commonly used to:

- .1 Determine the maximum long-term yield for a well (i.e. specific capacity of the well after 100 days of pumping);
- .2 Assess the impacts of the proposed well on neighbouring wells or water bodies; and
- .3 Obtain aquifer properties, such as permeability and boundary conditions.

Additional details about pumping tests can be found in *Guide to Conducting Pumping Tests* by the Province of British Columbia, Agriculture and Agri-Food Canada, and the British Columbia Groundwater Association.

6.3.1.7 Additional Considerations

6.3.1.7.1 Saltwater Intrusion

Saltwater intrusion can occur due to either natural processes or anthropogenic activities. As per Section 58 of the WSA, a person must not operate a well in a manner that causes intrusion of saline groundwater or saltwater into an aquifer.

Areas at highest risk of saltwater intrusion include locations:

- .1 Close to the coast;
- .2 Where there is a low to moderate slope;
- .3 On peninsulas or in areas with a limited source area for groundwater recharge;
- .4 Where there is a high density of wells;
- .5 Where there are high rates of pumping from a single well or from multiple wells in a coastal

area;

.6 Where the static (non-pumping) groundwater level is at or below sea level; and
.7 In fractured bedrock aquifers due to heterogeneity and the linear nature of fracturing.

Best practices when planning or developing a water supply well in areas at high risk of saltwater intrusion include, but are not limited to:

.1 Well siting: Avoid drilling in locations immediately adjacent to the coast. The GWPR Handbook recommends drilling at least 50 m beyond the coast;
.2 Well depth: Avoid drilling excessively deep within areas proximal to the coast. The depth to the freshwater-saltwater interface varies locally;
.3 Well alteration: Avoid using technologies such as hydrofracturing in areas < 100 m from the coast to reduce the risk of opening fractures that are directly connected with the sea;
.4 Well testing: Avoid pumping at higher flow rates or for longer than is necessary;
.5 Well monitoring: Monitor for specific conductivity or salinity during drilling. If there is a significant increase in the measurements during drilling, consider stopping, and testing the chloride concentration of the groundwater. If a saline zone has been encountered it may be necessary to seal the well below a certain depth;
.6 Closing unstable or unused wells;
.7 Qualified Professional: Consult a Qualified Professional to help assess saltwater intrusion risk and plan for and interpret water quality test and monitoring results.

Saltwater intrusion is indicated by elevated concentrations of chloride and high electrical conductivity of groundwater compared to average conditions in the area. These salinity indicators are easy to measure. Groundwater wells with the following characteristics may be considered to be affected by saltwater intrusion, according to the *Best Practices for Prevention of Saltwater Intrusion*:

.1 Chloride concentration greater than 150 mg/L;
.2 Specific conductivity greater than 1000 µs/cm; and
.3 TDS greater than 700 mg/L.

For coastal British Columbia, a groundwater well should only be pumped if it is capable of producing water of this quality or better.

If a well is severely impacted by saltwater intrusion, it may be necessary to discontinue using it for a period of time, and use alternate sources, to give the well time to recover, or the well may need to be decommissioned permanently. Refer to the WSA for the regulations regarding well operation and saltwater intrusion.

The Designer should refer to *Best Practices for Prevention of Saltwater Intrusion,* and advisories for coastal areas for further guidance on saltwater intrusion (located here: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/information-for-well-drillers-well-pump-installers/well-drilling-advisories).

6.3.1.7.2 Subsurface Filtration (Riverbank Filtration)

Subsurface filtration is a naturally occurring process that filters surface water as it passes through river or lakebed sediments, lake/riverbank substrate, and into an aquifer before being drawn up by a well. Subsurface filtration is best suited to systems that are located adjacent to rivers with reasonably good surface water quality and that plan to use subsurface filtration as one component of their treatment process. For certain systems, subsurface filtration can be an efficient, cost-effective pre-treatment option to improve water quality or control the extent of sudden changes in raw water temperature and quality after a storm event; however, only certain subsurface conditions provide improved quality.

The Designer should consider the type of bed and aquifer material present, the dynamics of groundwater flow, and the potential for scouring of riverbed materials at any potential riverbank filtration site. The degree to which any particular contaminant will be removed via bank filtration depends on site-specific conditions and may vary over time. A similar raw water characterization as for surface water may apply. Subsurface filtration must be demonstrated through one of the acceptable methods described in the Ministry of Health's *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*:

.1 Well/surface water separation;
.2 Subsurface filtration study; or
.3 Demonstration of performance

A subsurface filtration study or demonstration of performance must be conducted by a Qualified Professional.

Sampling frequency and analysis should be developed to assess the water quality and effectiveness of the subsurface filtration process; turbidity sampling intervals are specified for pathogen log reduction credit maintenance in the Ministry of Health's *Guidelines for Pathogen Log Reduction Credit Assignment.* Both the *Guidelines for Pathogen Log Reduction Credit Assignment* and *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia* should be referenced if proceeding with subsurface filtration.

6.3.1.7.3 Flowing Artesian Wells

The provincial regulatory requirements for controlling flowing artesian wells are outlined in Section 77 of the *Water Sustainability Act.* EGBC has issued a *Flowing Artesian Wells and Excavations Practice Advisory* to provide direction on responsibilities for anticipating and managing flowing artesian conditions during well design and construction. Additionally, the Ministry of Environment and Climate Change Strategy has published *Flowing Artesian Wells,* which provides general guidance for working with flowing artesian wells.

If artesian conditions are encountered when constructing or supervising construction of a well, the qualified well driller or Qualified Professional must ensure the artesian flow is controlled and advise the well owner (and the land owner, if applicable) of the steps taken to do so. If the flow cannot be controlled, the person responsible for drilling the well should advise the Ministry of Water, Land and Resource Stewardship Regional Hydrogeologist and must comply with any directions given.

A flowing artesian well is considered "under control" when the entire flow is through the production casing to the wellhead and the flow can be stopped or directed indefinitely without leaking on the surface of the ground and with no leakage into any other aquifer penetrated by the well.

Pre-screening the geology and hydrogeology of a project site minimizes the chance that uncontrolled flowing artesian conditions will be encountered unexpectedly during borehole drilling or while excavating in soil or rock. When artesian conditions are anticipated based on pre-screening, alternate well design practices should be applied to control the artesian flow.

The well driller should take precautions to prevent a well from flowing out of control, particularly in areas that have a history of flowing wells. The Ministry of Water, Land and Resource Stewardship maintains a database of artesian wells on its Well Drilling Advisories website (https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/information-for-well-drillers-well-pump-installers/well-drilling-advisories) that should be reviewed.

6.3.2 Well Construction

In B.C., the construction of a new well is regulated under the GWPR. The well driller must be certified and ensure that the well is constructed to meet the minimum requirements as defined in the GWPR. A well identification plate and a well construction report is required for all new wells. If the well is to be decommissioned, a well decommission report is required at that time as defined in the GWPR. All wells should be straight and meet plumbness requirements, as specified by the AWWA.

6.3.2.1 Casing

Well casings should be designed as follows:

- .1 Materials should be new or like new and:
    - a. Approved or certified by the Canadian Standards Association (CSA), Underwriters' Laboratories of Canada, ASTM International, or NSF International;
    - b. Strong enough to withstand pressures or forces exerted on them during installation and well operation;
- .2 The well and casing diameters should be based on the intended use (production or observation well), anticipated flow rates, pumping equipment specifications, wellhead completion appurtenances, and screen-liner requirements;
- .3 The well casing should protrude at least 0.3 m above the ground surface, and the ground should be sloped away from the well to prevent ponding of water around the well;
- .4 Production well diameters for water supply wells should be a minimum of 200 mm, to provide sufficient size for pumps and monitoring devices, and contingency for possible future liner installation;
- .5 Well casings with 150 mm diameter may be suitable for monitoring wells and smaller capacity water supply wells;
- .6 Well casing may be constructed of steel or HDPE. PVC (minimum DR 21) should only be used when approved by the Issuing Official and should be of NSF 61 certified material. In all cases, the casing material should have a minimum weight and thickness to withstand the forces it is subject to;
- .7 HDPE casing material may be considered in applications where permeation by hydrocarbons or degradation of other PVC or steel materials may occur; and
- .8 The use of any nonferrous material as well casing is subject to the approval of the Issuing Official.

6.3.2.2 Casing Vent

Provisions should be made for venting the well casing to the atmosphere. The vent should terminate in a downturned position, at or above the top of the casing or pitless unit, no less than 300 mm above grade or floor, in a minimum 38 mm diameter opening covered with a 24 mesh, corrosion resistant screen. Consideration should also be given to install the screen above the snow levels. The pipe connecting the casing to the vent should be of adequate size to provide rapid venting of the casing. Where vertical turbine pumps are used, vents into the side of the casing may be necessary to provide adequate well venting; installation of these vents should include a fine mesh vermin screen. Venting of wells located inside a pump house must ensure that the vent is directed outside the building to prevent the build-up of harmful gasses inside the pump house building.

6.3.2.3 Well Cap

The well cap is a secure cap or lid that prevents vermin, contaminants, debris or other foreign objects or substances from entering the interior of the production casing and includes a sanitary well seal. Part 4 of the GWPR must be followed when designing a well cap. The following should be considered:

.1 All wells, temporary or permanent, should be effectively located/sealed against the entrance of water and contaminants;
.2 Venting and electrical penetrations to be above the 1:200 flood elevation or highest historic flood level, whichever is highest; and
.3 At all times during the progress of work, the contractor should provide protection to prevent tampering with the well or entrance of foreign materials.

6.3.2.4 Surface Seal

Surface seals are installed in the annular space around the outside of the outermost casing and between multiple casings and extend up to or just below the surface of the ground. Surface seals are intended to:

.1 Prevent the entry of contaminants and foreign matter;
.2 Be permanent, watertight and continuous;
.3 Be reinstated and extended to within 0.3 m of the ground surface when disturbed by pitless unit installation or extension above the finished grade surface; and
.4 Be made of non-toxic materials.

Division 3 – Surface Seals of the GWPR includes detailed surface seal requirements.

6.3.2.5 Water Level Measurement

Provisions should be made for monitoring and measurement of water levels in the completed well. This is typically done using pressure transducers or sounding tapes in sounding tubes within stilling wells or conduits inside the well case.

6.3.2.6 Pitless Unit or Pitless Adaptor

The pitless unit or adaptor is a device attached to a casing for the underground conveyance of water from the well. Pitless units or adaptors should be installed below the frost line.

Pitless units should:

.1 Be shop-fabricated from the point of connection with the well casing to the unit cap or cover;
.2 Be welded to the well casing;
.3 Be of watertight construction throughout to prevent entrance of contaminants;

.4 Be of materials and weight at least equivalent and compatible to the casing;
.5 Have a field connection to the lateral discharge from the pitless unit of threaded, flanged or mechanical joint connection; and
.6 Terminate at least 300 mm above final ground elevation or 1 m above the 200-year flood level or the highest known flood elevation, whichever is higher.

The design of the pitless unit should make provision for:

.1 Access to disinfect the well;
.2 An access tube within which water levels can be independently measured;
.3 Facilities to measure water levels in the well;
.4 A cover at the upper terminal of the well that will prevent the entrance of contamination;
.5 A contamination-proof entrance connection for electrical cable;
.6 An inside diameter as great as that of the well casing, up to and including casing diameters of 300 mm, to facilitate work and repair on the well, pump, or well screen.

6.3.2.7 Pumps

Pump specifications for a newly designed well should be based upon analysis of the hydraulic testing results, the recommended pumping rates (i.e. short and long-term) and pump intake setting. Factors that should be included in the selection of an appropriate pump size include:

.1 Well and/or casing diameter;
.2 Recommended pumping rate for sustainable well operation;
.3 Calculated or observed water level from pumping test(s);
.4 Total dynamic head and vertical lift requirements;
.5 Friction/head losses;
.6 Service pressure; and
.7 Long-term power requirements.

The design criteria for well pumping stations generally follow those presented for raw surface water pumping in Section 18.3 – Raw Water Pumping Stations. Water supply wells should be equipped with either submersible or vertical turbine line shaft pumps. Well pumps are required to be installed by a certified pump installer as defined in the GWPR.

Oversizing a pumping system will result in an excessive pumping rate. In turn, the excessive pumping rate can cause critical fracture zones to de-water, resulting in sudden declines in pumping levels and potential damage to the well or pump.

Line shaft pumps and submersible pumps are two common types of well pumps.

.1 Line shaft pumps should:
    a. Have the casing firmly connected to the pump structure or have the casing inserted into a recess extending at least 13 mm into the pump base;
    b. Have the pump foundation and base designed to prevent water from coming into contact with the joint;
    c. Be water lubricated. If oil lubricated pumps are proposed, food grade lubricant should be used;
.2 Submersible pumps should:
    a. Be water lubricated;

b. Not have mercury seals. Mercury seals are not permitted;
c. Have the top of the casing effectively sealed against the entrance of water under all conditions of vibration or movement of conductors or cables; and
d. Have the electrical cable firmly attached to the riser pipe at 6 m intervals or less.

In addition, the following special considerations apply for well pumping stations:

.1 Provide a pump pedestal for dry mounted vertical turbine pump assemblies and large diameter inline submersible pump assemblies (i.e. greater than 200 mm diameter discharge). The pump pedestal should be designed to support the full weight of the pump and riser piping and to prevent load transfer to the well casing(s);
.2 A water-tight seal should be provided between the pump base plate (or submersible discharge head) and the pump pedestal, and between the well casing and the pump discharge column to prevent the entrance of contaminants;
.3 Provide for adequate means for removal of the pump for maintenance purposes including crane pad laydown area, roof hatch access, or lifting equipment and riser pipe decoupling appurtenances.
.4 A flow measurement device should be provided.

6.3.2.8 Well Riser and Discharge Piping

Well piping systems – including riser, column and/or discharge pipes as applicable – should:

.1 Be designed to minimize friction loss;
.2 Have control valves and appurtenances located above the pump house floor;
.3 For pitless units, include a buried well isolation valve located adjacent to the well casing;
.4 Be protected against the entrance of contamination;
.5 Be equipped with a check valve in or at the well, a shutoff valve, a pressure gauge, and a means of measuring flow;
.6 Be equipped with a smooth nosed sampling tap located at a point where positive pressure is maintained, but before any treatment chemicals are applied. The sample tap should be at least 0.5 m above the floor to facilitate sample collection;
.7 Avoid the use of return pipes that permit water to be recirculated down the well, which could cause contamination of the well;
.8 Where applicable, be equipped with an air release-vacuum relief valve located upstream from the check valve, with exhaust/relief piping terminating in a down-turned position at least 0.5 m above the floor and covered with a 24-mesh corrosion resistant screen;
.9 Include provision to permit future testing of the well, including a means to pump to waste in case of poor water quality during the test;
.10 Be valved to allow isolation of the well for test pumping and control of each well;
.11 Have all exposed piping, valves and appurtenances protected against physical damage and freezing;
.12 Be properly anchored to prevent movement and be properly supported to prevent excessive bending forces;
.13 Be protected against surge or water hammer;
.14 Conform to the latest standards issued by the ASTM, AWWA and NSF/ANSI, where such standards exist, or in the absence of such standards, conform to applicable product standards;
.15 Be constructed so that it can be disconnected from the well or well pump to allow the well

pump to be removed;

.16 In particular, the riser piping (submersible pump application) or column piping (vertical line-shaft pump application) inside the well should:

a. Be constructed with fittings, brackets, tape or other appurtenances which meet NSF/ANSI Standard 61 *Drinking Water System Components – Health Effects*, where applicable;

b. Be capable of supporting the weight of the pump, piping, water and appurtenances, and be capable of withstanding the thrust, torque and other reaction loads created during pumping. The actions of fatigue from repeated starting and stopping of the pump should be considered when choosing pipe and fittings;

c. Be fitted with guides or spacers to center piping and well pump in the casing; and

d. Be constructed of non-corrosive materials.

6.3.2.9 Dug Wells

Dug wells are typically not recommended. Their shallow depth makes them vulnerable to contamination and higher fluctuations in water level due to drought or local changes in drainage.

However, in some instances dug wells can provide water, for example, when a shallow aquifer is the only viable potable water source. The GWPR must be followed when constructing a dug well. Additional information can be found in the brochure *Best Practices for Dug Wells.*

6.3.3 Groundwater Source Construction-Related Contaminants

Inadequate well development and flushing following construction may result in high turbidity or detection of chemical residuals used in the well drilling process. Collecting initial water quality samples at the end of the pump test will help ensure that sample results reflect the water quality in the aquifer and are not the result of well construction. A damaged or poorly designed screen may also result in high turbidity levels observed in a water supply well.

The Designer should be aware of the risks posed by certain construction materials and practices. Low-level detection of organic contaminants may be the result of residuals associated with well development and construction. It is possible to introduce organic contaminants such as tetrahydrofuran and 2-butanone (components in PVC glue) and toluene (a component in lubricants) during well construction. Such construction-related contamination, even in very small concentrations, may require increased water quality monitoring and/or treatment.

High turbidity in a new well or spring is often an indicator of one or more consequential issues, including:

.1 **Poor source development:** Inadequate well cleaning following construction may result in high turbidity and indicate the need to redevelop the source;

.2 **Iron or manganese:** These common inorganic contaminants will cause turbidity and, in most cases, require treatment to remove them from newly developed sources if they exceed the GCDWQ MACs and/or aesthetic objectives; and

.3 **Groundwater under the direct influence of surface water.** High turbidity measured in wells developed close to lakes, rivers, and springs may indicate direct surface water influence. A GARP Assessment should be completed.

6.3.4 Commissioning of a New Well

Commissioning of new wells should take place following connection to the distribution system and installation of all well appurtenances. Operation and performance of all well system components should be checked against the system design. During commissioning, further yield and time-drawdown data may be collected to support calculated sustained yields and predicted pumping levels, and/or to confirm groundwater quality results. These results may be used to finalize the operational groundwater monitoring plan.

The water level and water quality responses of each well should be clearly documented during the commissioning process. A recommended procedure for a multiple well system is as follows:

- .1 Operate the first well for one to three days or until steady state drawdown is achieved;
- .2 Turn on and operate the remaining wells with continued monitoring of water level changes in all wells; and
- .3 After all wells have been turned on, operate the system for a period of time that is sufficient to confirm all of the predicted parameters.

All new production wells or well fields should be monitored closely during the initial year of operation. The water level, flow rate and water quality data should be reviewed by a qualified hydrogeologist, and recommendations made for adjustments or further monitoring as warranted.

Upon completion, all wells should be disinfected with a chlorine solution to remove microbial pathogens that may have been introduced during well construction. As per Section 30 of the GWPR, ‘the person responsible for drilling, altering, developing or rehabilitating a water supply well must, promptly after performing the activity, disinfect the groundwater in the well to destroy micro-organisms introduced by the activity.’ This can be completed by following the *Water Well Disinfection Using the Simple Chlorination Method* or AWWA methods (i.e. AWWA C654).

When following the AWWA method, chlorine should be applied to ensure that a concentration of 50 mg/L is present in the well for a period of twelve hours. Dosage should be computed on the basis of the water required to provide mixing throughout the entire well volume. Effective disinfection requires that a conductor pipe is used to pump the solution to the bottom of the well. After sufficient holding time, the chlorinated water should be circulated within the well casing and pump column, and then the well should be pumped to waste to remove the chlorinated water. Bacteriological evaluation should be conducted to verify disinfection.

Disinfection agents are potentially hazardous compounds. Proper storage, training, and handling are required for all disinfection compounds.

6.3.5 Wellhead Protection

The *Well Protection Toolkit* (Ministry of Environment and Climate Change Strategy, Ministry of Health and Ministry of Municipal Affairs, 2004) outlines a six-step process for the development and implementation of a well protection plan to prevent contamination of well water supplies. Protecting source water through a well protection plan is one of the barriers in the multi-barrier approach to drinking water protection.

The *Well Protection Toolkit* presents the well protection planning process through the following six steps:

- .1 Form a community planning team;
- .2 Define the well protection area;
- .3 Identify potential contaminants;
- .4 Develop management strategies;
- .5 Develop contingency plans; and
- .6 Monitor results and evaluate the plan.

A source water assessment comprised of selected *Comprehensive Source-to-Tap Assessment* (CS2TA) modules is also recommended to inform well protection plans. Refer to Section 6.1.1.1 – Source Water Assessment for further details on CS2TA guidance and other considerations for groundwater protection measures that may be employed to ensure the long term integrity of the water supply well. In some instances, a regional-level aquifer based protection plan may be warranted to protect the ground water supply.

6.3.6 Observation or Monitoring Wells

It is recommended that a municipal well field completion include a provision for routine surveillance of water levels and water quality in both the pumping well and the host aquifer. Monitoring wells are defined as a class of well under the GWPR: they are used for collecting water samples and monitoring the water depth in the aquifer. The GWPR requires that all permanent monitoring wells have construction and decommissioning reports, however these are not required for temporary monitoring wells. The *Guidance for Technical Assessments in Support of an Application for Groundwater Use in British Columbia* should be referred to for further direction on observation wells.

The required number and location of monitoring wells should be based on hydraulic testing results. The distance should be determined based on the aquifer type by a Qualified Professional. At least one monitoring well should be located at the mid-point of all production wells for surveillance of long term and seasonal water level responses within the aquifer.

If applicable, a monitoring well should be located between the pumping well(s) and any perceived contaminant risk. Where dewatering of domestic wells is of concern, a monitoring well resembling the domestic well design should be established between the pumping well(s) and the domestic well(s) of concern. Alternatively, the nearest domestic wells may be incorporated into the well field monitoring strategy.

Monitoring wells should be:

- .1 Equipped with an automatic logging pressure transducer;
- .2 Constructed in accordance with the requirements for permanent wells if they are to remain in service after completion of a water supply well, and;
- .3 Protected at the upper terminal to preclude entrance of foreign materials.

6.3.7 Deactivating or Decommissioning Wells

An open or unused well is a potential liability to any well field and to the well owner. A well must be decommissioned (taken permanently out of service) within five years of being deactivated. The GWPR describes the requirements for deactivating or decommissioning a well.

When a water supply well is decommissioned, a well decommission report must be completed. The requirements of the report are defined in Schedule 4 of the GWPR.

7 Pre-sedimentation, Coagulation, Flocculation and Clarification

7.1 General

This chapter describes design considerations for drinking water treatment processes which reduce suspended and colloidal solids in water: pre-sedimentation, coagulation, flocculation and clarification. The selection of a particular treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

7.1.1 General Design Considerations

When selecting and sizing pre-sedimentation, coagulation, flocculation and clarification processes, the Designer should:

.1 Determine the required throughput (volume of water to be treated);
.2 Evaluate the raw water quality, including temperature, turbidity, total suspended solids, pH and other parameters affecting the performance of the process;
.3 Determine the key components to be removed and the target performance required. In general, sedimentation processes are well suited for high turbidity surface waters while dissolved air flotation is well suited for surface waters with lighter particles, such as those with high concentrations of algae or organic carbon. Consideration should also be given to the use of pre-sedimentation;
.4 Determine the type, concentration, and dosage of coagulants and flocculants, and the required reaction times;
.5 Consider the impact of upstream and downstream processes;
.6 Determine the optimum surface loading rate (also called overflow or hydraulic loading rate) and size of clarification unit(s) based on findings from the points above;
.7 Consider the following recommended minimum provisions:
   i. Provide a minimum of two units of each coagulation, flocculation, and sedimentation tank (or two clarifiers) where possible. Where only one tank is available, sufficient finished water storage or provisions to produce water should be provided to maintain a continuous supply of water while the tank is out of service;
   ii. Allow units to be taken out of service without disrupting operation. Drains or pumps should be sized to allow for dewatering in a reasonable period of time;
   iii. Allow measurement and modification of flows to each train or unit;
   iv. Permit operation of the units either in series or in parallel where softening is performed, and in other circumstances where clarification is performed;
   v. Minimize hydraulic head losses between units to allow future process changes without the need for re-pumping; and
   vi. Be started manually following shutdown.

7.2 Pre-sedimentation and Hydrocyclones

Pre-sedimentation may be required for source waters with high suspended solids, turbidity, and/or organics. Pre-sedimentation may be performed seasonally, such as during spring freshet, or continually during the year for increased clarification and/or filtration efficiency. Coagulants and/or oxidizing agents may also be added.

When designing pre-sedimentation systems, the following should be considered:

.1 Pre-sedimentation basins should have hopper bottoms or continuous mechanical sludge removal mechanisms, and arrangements for dewatering. The design should provide a means of maintaining and cleaning basins without interruption;
.2 The inlet should be designed so that incoming water is dispersed across the full width of the line of travel as quickly as possibly. Short-circuiting should be prevented;
.3 Provisions should be provided to bypass the pre-sedimentation basins; and
.4 Sufficient detention time should be provided to meet target effluent water quality. As a general guideline, three hours detention is the minimum recommended period. However, this should be confirmed through bench or pilot testing.

Hydrocyclones can be used as an alternative to pre-sedimentation to remove suspended solids using centrifugal force. Hydrocyclones are effective in removing suspended particles from water where the specific gravity (density) of the particles is heavier than the water; removal efficiency increases as particle density increases. Raw water enters at the top of the cone-shaped separator, creating a vortex. The centrifugal forces cause the denser particles to separate to the bottom. Hydrocyclones are pre-manufactured and often proprietary equipment; for further guidance, the manufacturer should be consulted.

7.3 Coagulation

Coagulation refers to the combined processes of rapid mixing and chemical precipitation of dissolved and particulate matter from water through “particle destabilization”. Particle or charge destabilization occurs by neutralizing the negatively charged particles in the water by adding inorganic salts (positively charged metal ions such as aluminum and iron) or organic polymers.

Enhanced coagulation refers to the process in which coagulant is added to optimize the removal of natural organic matter, with the goal of reducing or eliminating DBP formation. Enhanced coagulation is now nearly ubiquitous in conventional water treatment, as turbidity removal alone is no longer the primary focus of surface water treatment facilities.

Sweep coagulation refers to the process in which a sufficiently high concentration of coagulant is added to precipitate metal hydroxides, which enmesh floc particles into larger agglomerates during flocculation.

Flocculation is the process following coagulation which uses gentle stirring to bring suspended particles together so they will form larger aggregate particles, called flocs. Organic polymers are often used at this stage to provide bridging of floc particles, which tends to form even larger floc agglomerates.

The targeted floc type and characteristics depend on the type of downstream process employed. The floc characteristics will depend on the types of colloidal and/or suspended solids in the water; water temperature and pH; the type and dosages of coagulants and coagulant/flocculant aids (if used); the rapid mixing procedures; flocculation methods, intensities, and time; and overall flow regime through the system.

Consideration should be given to optimizing chemical feed point locations. This may including provision of multiple injection locations for the coagulant, coagulant/flocculant aid, and/or pH adjustment chemicals in relation to the rapid mixing process, residence time, and chemical reaction rates. Alternatively, validation of the optimum chemical reaction times and efficiencies may be determined through bench scale or pilot testing.

The type of coagulant and coagulant/flocculant aid polymers selected depend upon a number of factors including incoming water quality, downstream unit treatment processes, treatment objectives, and economics. Designers should consider pilot and bench scale testing, comparable industry practice, and treatment equipment vendor requirements or conditions when selecting coagulation chemicals. For example, use of polymers may not be compatible with certain filtration processes such as polymeric hollow fibre membranes.

7.3.1 Rapid Mix Unit

The rapid mix unit is where coagulant(s) and raw water are subject to a short duration, high intensity mix to encourage coagulant dispersion and hydrolysis reactions (for metal salts). The rapid mix unit can either be a separate process tank or an in-line mixing system. The following should be considered:

.1 The detention time in the mixing zone should be minimized and limited to under 30 seconds;
.2 The detention time (t) and mixing intensity (G value) are dependent on the chemicals added, water temperature, pH, and other water quality parameters. Jar testing should be conducted to determine system specific values. Table 7-1 can be referred to as guidance for design values;
.3 Powered mixers are generally preferred. Static mixers should only be considered where flow is relatively constant and high enough to maintain the required turbulence for chemical reactions to occur. The Designer should be aware that minor reductions in flow through static mixers may significantly reduce the mixing efficiency delivered. This may reduce operational flexibility and chemical reaction efficiency, particularly at low throughputs; and
.4 The rapid mix process should be placed as close to the flocculation zone as possible.

Table 7-1 Coagulation Design Values (ACWWA Water Supply Guidelines, 2020)

Mixer Type	Mixing Intensity (G value) (s^{-1})	Detention Time, t (s)	Gt
In-line mixers	700 to 1,500	0.5 to 1.0	500 to 1,500
In-line sidestream pump mixer	700 to 1,500	0.5 to 1.0	500 to 1,500
In-line mechanical mixer	3,000 to 5,000	0.5 to 1.0	2,000 to 3,000
Paddle-type rapid mixer	600 to 1,000	10 to 60	6,000 to 25,000

7.3.2 Coagulant Chemical Injection

The following should be considered when designing coagulant chemical injection:

.1 Chemicals injected to a rapid mix unit should be injected at a point closest to the inlet of the unit;
.2 Flocculant aids should not be injected into a rapid mix unit unless an additional rapid mix unit for the flocculent aid is provided;

.3 The Designer should be aware that solids-forming reactions may plug the chemical injector/diffuser and should make appropriate provisions for removal and cleaning;
.4 Coagulant and flocculant aid concentration and detention times should be derived from jar/pilot testing;
.5 The nozzle velocity of a chemical injector into a rapid mix unit should not exceed 3.0 m/s;
.6 3 to 5 minutes detention time should be allowed between coagulant addition and upstream chemical addition, or as otherwise demonstrated through pilot testing. This includes chemicals used for alkalinity or pH adjustment, powdered activated carbon (PAC) and potassium permanganate ($KMnO_4$); and
.7 Primary coagulants should not be mixed using in-line devices such as pumps, weirs, valves, etc., as they do not provide controlled mixing.

7.3.3 Enhanced Coagulation

Disinfection by-products (DBPs) are the result of reactions between disinfectants and natural organic matter (NOM). Reducing NOM, as measured by total organic carbon (TOC), can reduce DBP formation.

Enhanced coagulation refers to removal of TOC by adding sufficiently high concentrations of coagulant and is recommended for treatment plants using surface water or GARP. Generally, TOC removal requires higher coagulant concentrations than for turbidity removal. Coagulants including alum, iron salts, polyaluminum chloride, and cationic polymers have been shown to be effective for enhanced coagulation. If aluminum-based coagulants are used, the Designer should take steps to reduce the amount of residual aluminum below the relevant Health Canada operational guidance value for finished water, particularly for water with elevated pH.

Table 7-2 shows recommended TOC removal prior to the point of continuous disinfection in relation to the source water alkalinity and TOC concentrations. Generally, TOC removal becomes more difficult as alkalinity increases and TOC decreases. In higher alkalinity waters, pH depression to a level at which TOC removal is optimal (e.g. pH between 5.5 and 6.5 for alum) is more difficult and is not be easily achievable. Use of pH control can improve TOC removal, however, it will also impact downstream processes. These impacts should be carefully considered before pH control can be implemented. Potential impacts include:

.1 A lower alum dose resulting in a low amount of sludge produced at the plant;
.2 A lower settled-water pH, which will require a higher dose of alkaline chemicals such as lime to increase the pH of the finished water to levels acceptable per local regulations or as needed for corrosion control;
.3 Increased TDS in the finished water due to acid and caustic addition; and
.4 Increased operating costs arising from pH adjustment.

Table 7-2 TOC Removal Requirement by Enhanced Coagulation (From Alberta 2012, Table 2.2)

Influent TOC (mg/L)	Alkalinity (mg/L as $CaCO_3$)		
	0-60	60-120	>120
0-2	No action	No action	No action
2-4	40%	30%	20%
4-8	45%	35%	25%
>8	50%	40%	30%

7.4 Flocculation

Flocculation is the process of enhancing agglomeration of small floc particles into larger flocs, which are more easily settleable, floatable and/or filterable. This is done by gently stirring through hydraulic or mechanical methods. The mixing should be thorough enough to provide opportunities for the particles to collide but also gentle enough to prevent the flocculated particles from breaking apart.

Flocculation aids may also be used. Flocculation aids are secondary coagulation chemicals which assist in floc formation, including organic charged and neutral compounds, and activated silica.

7.4.1 Basin Design

The following should be considered in flocculation basin design:

.1 A minimum of two separate flocculation tanks should be provided where possible so that maintenance can be performed without disrupting plant operation;
.2 Each tank should be divided into at least two stages (i.e. series compartments) with tapered flocculation (i.e. diminishing velocity gradient) to prevent short-circuiting and floc destruction;
.3 A drain and/or pumps should be provided for dewatering and sludge removal;
.4 The inlet and outlet of each tank should be designed to minimize short-circuiting and floc destruction;
.5 A superstructure (enclosure or cover) over the flocculation basin is recommended to prevent ingress of rainfall, dust or other debris; and
.6 To assist in observing floc formation, effective size, and density, consideration should be given to providing access and adequate lighting.

7.4.2 Detention Time and Flow through Velocity

The detention time for flocculation depends on the raw water characteristics (including water temperature, turbidity, colour, etc.) and downstream treatment processes. A summary is provided in Table 7-3.

Table 7-3 Flocculation Detention Time

Downstream Process	Water Temperature	Flocculation Detention Time [1]
Sedimentation	Summer temperatures	25 – 30 min
	< 5 °C	30 – 40 min or more
Flotation	Summer temperatures	5 - 10 min
	< 5 °C	20 or more
Direct filtration	All	≤ 15 min

[1] Even shorter times may be adequate for coagulation/flocculation for membrane filtration. However, if the flocculation time prior to membrane filtration is too short, or control of pH, alkalinity and buffering capacity of the water is inadequate when using aluminum based coagulants, dissolved aluminum concentrations in the permeate may exceed the GCDWQ operational guideline and/or may prematurely foul the membrane.

7.4.3 Mixing Equipment

Mechanical mixing equipment with paddles driven by variable speed drives is preferred. External, non-submerged motors and bearings are recommended. All submerged parts should be corrosion resistant for long-term use in coagulated water. When designing mixing equipment, the key parameters to consider include:

.1 G value: velocity gradient, also called mixing intensity or root mean square velocity (in s^{-1});
.2 t: residence time within flocculation chamber(s) (in s); and
.3 Gt: The product of velocity gradient and residence time (dimensionless).

The following should be considered regarding the G and Gt values:

.1 Generally, G values of 10 to 80 s^{-1} are needed for flocculation. However, the G value is temperature dependent. The mixing should be sufficient to allow particles to collide but gentle enough to prevent floc shearing. The peripheral speed of paddles should range from 0.15 to 0.9 m/s;
.2 Lower velocity gradients should be applied for fragile colour floc. Higher velocity gradients are needed for flocculated suspended material (turbidity) or where direct filtration is the next downstream process; and
.3 Optimum G and Gt should be determined by pilot testing. Jar testing can also be used if the volume, paddle size and speed are known.

Mixing can also be done hydraulically using baffles. Design of the baffles should take into consideration the flow range, provide a sufficient G value and also consider the Gt. Baffles or hydraulic flocculators should only be used in systems where anticipated flow variations are small.

7.4.4 Location

When selecting the location of the flocculation basin, the Designer should consider:

.1 Placement of the flocculation basin as close to the downstream process as possible;
.2 Flocculated water should never be pumped between the flocculation basin and downstream process as this will break the floc;

.3 The velocity of the flocculated water through the piping or conduits to the downstream process should be no less than 0.15 m/s and no greater than 0.45 m/s. Changes in direction of the piping or conduits should be minimized to prevent turbulence; and

.4 Polymer flocculation aids and activated silica should not be subjected to high shear mixing. Provisions should be made for separate addition downstream of coagulant mixing. A delay period of 3 to 5 minutes detention time between processes is recommended.

7.5 Clarification

Clarification is the process that allows separation of particles by gravity settling or flotation for removal and typically precedes filtration. Clarification technologies can be divided into five general categories: horizontal flow sedimentation basins, upflow clarifiers, adsorption clarifiers, ballasted sand processes and flotation processes.

7.5.1 General Settling Tank and Clarifier Design Considerations

7.5.1.1 Surface Loading Rate

The key parameter in sedimentation basin design is the surface loading rate, also known as overflow rate or hydraulic loading rate. Surface loading rate is measured as a velocity as shown in the equation below. This equation is applicable to both horizontal sedimentation basins and upflow clarifiers.

$$Surface\ Loading\ Rate\ (V_o)\left[\frac{m}{h}\right] = \frac{Flow\ of\ Water\ (Q)\left[\frac{m^3}{h}\right]}{Surface\ area\ of\ settling\ basin\ (A)[m^2]}$$

Particles with a settling velocity (Vs) greater than the surface loading rate (Vo) will settle out, while other particles will settle at a ratio of $\frac{Vs}{Vo}$. Reference values for settling velocities of selected floc types are shown in Table 7-4. The optimum surface loading rate depends on the technology chosen, the target performance in terms of suspended solids (measured as turbidity), the nature of flocculated material, and temperature. Bench or pilot testing is recommended to determine the settling velocities of particles as velocities are impacted by water type, temperature, chemistry and the presence of different coagulation chemicals, and other environmental conditions.

Table 7-4 Settling Velocity of Selected Floc Types (Crittenden et al., 2012)

Floc Type	Settling Velocity (m/h) at 15 °C
Small fragile alum floc	2 – 4.5
Medium-sized alum floc	3 – 5
Large alum floc	4 – 5.5
Heavy lime floc (lime softening)	4.5 – 6.5
Iron floc	2 – 4
Polyaluminum chloride (PACl) floc	2 – 4

7.5.1.2 Basin Design

The following general basin design considerations should be made for clarification processes:

.1 A minimum of two trains should be provided. Where only one sedimentation basin is available, sufficient finished water storage or provisions to produce water without sedimentation should be provided to maintain a continuous supply of water while the basin is out of service;
.2 Basins, piping and appurtenances should be constructed from corrosion resistant materials;
.3 Open ports, submerged ports, and similar entrance arrangements are required. A baffle should be constructed across the basin close to the inlet end and should project below the water surface such that influent water is distributed evenly across the entire basin and at uniform velocities;
.4 Basins should be designed such that short circuiting does not occur;
.5 Outlet weirs or submerged orifices should be designed to:
  a. Not exceed discharge velocities of 250 m^3/day/m of the outlet launder or orifice circumference;
  b. Have a maximum submergence depth of 1.0 m;
  c. Not exceed a submerged orifice entrance velocity of 0.15 m/s. The use of submerged orifices is recommended in order to provide a volume above the orifices for storage when there are fluctuations in flow;
.6 An overflow weir or pipe should be provided to establish the maximum water level desired on top of the filters. The overflow should discharge by gravity with a free fall at a location where the discharge can be observed;
.7 A superstructure to house the sedimentation units is recommended;
.8 Basins should be designed with a drain or sump;
.9 Bottom slopes should be no less than 8% sloping toward the drain, if mechanical collection is not installed;
.10 Mechanical sludge collection is recommended, and bottom slopes may be less than <1% in this case. Flat bottoms are recommended for travelling siphon or scraping mechanisms. Where sludge hoppers are used, the hopper design should be consistent with the flow characteristics of the sludge produced; and
.11 Handrails should be provided around the basins and ladders should be provided for access into the basins.

7.5.1.3 Sludge Systems

When selecting a sludge system, the Designer should consider the following factors:

.1 The type of sedimentation technology chosen and the provision of high-rate settlers;
.2 The nature and quantity of suspended solids in raw water;
.3 Coagulant(s) and coagulation/flocculation aid(s) used; and
.4 Climate (ice formation).

Further information on system specific sludge removal requirements are provided in Chapter 14 – Waste Residuals Handling and Treatment. General considerations for sludge removal systems include:

.1 Sludge pipes should be not less than 75 mm in diameter and arranged to facilitate cleaning;
.2 The entrance of sludge withdrawal piping should be designed to prevent clogging. Designers should be aware that sludge loadings may be unevenly distributed in the tank. Specifically, conventional (horizontal) sedimentation basins may have significantly higher sludge concentrations at the basin inlet than elsewhere;

.3 Valves should be located on the outside of the tank for accessibility. All valve operators which are not within buildings should be tamper proof with provision for locking;
.4 Operators should be able to observe and sample sludge withdrawn from the unit;
.5 Flushing lines should be provided to backflush sludge lines; and
.6 Sludge disposal should be by an approved method.

7.5.1.4 Superstructure

A superstructure (i.e. cover or enclosure) over the settling tank/clarifier should be provided. The following should be considered:

.1 A cover may be adequate if there is no mechanical equipment in the tank(s) and adequate monitoring is provided under all expected weather conditions;
.2 Roof drainage should also be provided and should not discharge into the tank;
.3 Consider the potential for ice formation within the settling tank which may fall and damage submerged equipment if the water level is dropped; and
.4 Consider Brownian motion, particularly for tanks that are located outdoors. When the surface of the tank is warm, and the bottom is cold, thermal currents occur. This results in settled solids moving back into the supernatant.

7.5.1.5 Health and Safety

Relevant municipal, provincial and federal regulations should be adhered to. This includes:

.1 Provision of ladders, ladder guards, railing, handholds and entrance hatches where applicable, including on the inside walls of basins above the water level;
.2 Consideration of confined space requirements;
.3 The incorporation of fall arrest systems that are easily accessible;
.4 Tank openings that are curbed and covers that have a locking device; and
.5 Consideration for a sealable, small opening into tanks for venting and testing purposes.

7.5.2 Horizontal Sedimentation

Horizontal sedimentation basins rely on gravity to remove solids. Water to be treated moves horizontally and sedimentation occurs over the length of the basin. Gravity sedimentation is best suited for source waters that experience high turbidity and suspended solids. Flocculation is necessary prior to gravity sedimentation to develop floc that will settle. Gravity sedimentation is generally less effective on lower throughputs.

7.5.2.1 Turbulence and Stability

Flow characteristics (i.e. laminar or turbulent flow) and stability need to be considered when designing horizontal sedimentation basins. Flow characteristics are determined by the dimensionless Reynolds number. Stability is characterized by the Froude number (Fr). Design criteria for Re and Fr are provided in Table 7-5. A large Reynolds number indicates high turbulence; a low Froude number implies that the water flow is not dominated by horizontal flow, and back-mixing may occur.

Reynolds number is determined by the following equation.

$$Re = \frac{v_f R_h}{\nu}$$

Where Re = Reynolds number based on hydraulic radius, dimensionless
v_f = average horizontal fluid velocity in tank (m/s)
R_h= hydraulic radius, $\frac{A_x}{P_w}$ (m)
A_x = cross-sectional area (m^2)
P_w = wetted perimeter (m)
ν = kinematic viscosity (m^2/s)

Froude number is determined by the following equation.

$$Fr = \frac{{v_f}^2}{gR_h}$$

Where Fr = Froude number, dimensionless
v_f = average horizontal fluid velocity in tank (m/s)
R_h= hydraulic radius (m)
g = acceleration due to gravity, 9.81 m/s^2

A summary of the design criteria for horizontal settling basins is shown in Table 7-5.

Table 7-5 Horizontal Sedimentation/Settling Tank Design Criteria

Parameter	Typical Values	Notes
Surface loading rate	< 1.0 to 2.4 m/h	Low rates should be used for colour removal and high rates for turbidity and suspended solids removal. Rate may need to be reduced by 15 -25% in plants smaller than 10,000 m^3/d to maintain desired performance. Sizing should consider the lowest water temperature.
Mean horizontal flow velocity	0.3 to 1.1 m/min	
Max water entrance velocity	0.6 m/s	Flow straightening baffles should be considered as a part of the inlet.
Water depth	3 to 4.5 m	
Length to width ratio	Min 4:1	
Water depth to length ratio	Min 1:15	
Weir loading	9 to 13 $m^3/(m \cdot h)$	
Detention time	2 – 4 h	
Froude number (Fr)	Fr > 10^{-5}	From Kawamura, 2000
Reynolds number (Re)	Re < 20,000	From Kawamura, 2000

The water exiting the settling basin should be uniformly collected by either a submerged pipe (orifice) or across a weir positioned perpendicular to the flow direction. The velocity of the exit flow will depend on the individual design. Submerged orifices are recommended to provide a storage volume in the sedimentation tank above the orifices to accommodate fluctuations in flow. Submerged orifices should not be located more than 1 m below the water level. An overflow for each tank should be provided when submerged orifices are used.

7.5.2.2 Inlets and Outlets

Inlets and outlets should be designed to distribute water evenly across the basin and minimize short-circuiting. Velocities should be kept uniform.

An inlet zone should be allowed for in the design with a perforated baffle plate to provide flow straightening. The inlet zone will provide an area of varying turbulence based on the influent flow, which provides mixing for the flocculant aid. The flow straightening baffle wall straightens the flow to reduce the turbulence within the sedimentation zone to ensure the required Reynolds and Froude numbers are achieved.

Drainage systems that allow the basin to drain within a reasonable time period (ex. 8 h) should be provided.

7.5.2.3 Sludge Systems

Settled particles form a sludge at the bottom of the basin which must be removed. The sludge system should include the following components:

.1 Sludge collection – ensure collection of sludge throughout basin;
.2 Sludge removal – piping to remove sludge from the basin or clarifier; and
.3 Sludge disposal – waste sludge should be disposed appropriately per regulations.

Sludge collection systems should provide full tank coverage. A summary of the different sludge collection system types and design considerations for conventional sedimentation tanks is shown in Table 7-6.

Table 7-6 Sludge Collection Systems and Design Considerations

Sludge Collection System Type	Design Considerations
Manual sludge removal	- Tank bottom should be sloped toward inlet (1:100). - Flushing lines should be provided.
Travelling siphon or scraping mechanisms	Tank bottom should be flat.
Pumping from sludge hoppers	Hopper design should be consistent with flow characteristics of sludge.

7.5.3 Tube or Plate Settlers

Tube and plate settlers are used to reduce the vertical sedimentation path of the floc particles and thereby reduce the settling time required.

Tube settlers use multiple adjacent tubular channels which increase the effective settling surface area. The tubes help accumulate smaller particles until the particles become large enough to move down the tube uniformly. Tube settlers are typically sloped at 60°. The size and shape of the tubes vary by manufacturer.

Plate settlers (also known as lamella settlers) use a series of inclined plates, typically angled at 55° to 60°. Solids fall to the plate surface, where they slide down by gravity.

There are two different design approaches for tube or plate settlers:

.1 A lamella plate clarifier is typically a rectangular tank with upflow characteristics. Plates or tubes are installed across the complete surface area; and
.2 Horizontal flow tanks typically have the tubes or plates located at the outlet end of the basin, where the flow goes up to discharge over the weir or launder collection area.

When designing tube or plate settlers, the design criteria from Table 7-7 should be considered.

Table 7-7 Tube or Plate Settling Design Criteria

Parameter	Typical Value	Note
Surface loading rate	Tube settlers < 4.8 m/h Plate settlers < 1.2 m/h	Assumes effective settling area is the footprint area (i.e. before the plates or tubes are installed).
Incline angle of tube or plate settlers	55 to 60°	Tube settlers are typically angled at 60°.
Distance between tube or plate	50 mm	
Average flow velocity	0.15 to 0.2 m/min	Typical values for alum floc.
Recommended entrance velocity	0.6 m/min	
Weir loadings	3.7 to 7.5 $m^3/m \cdot h$	

Additional consideration should be given to:

.1 Settling velocity and characteristics of suspended solids;
.2 Sludge removal equipment to be installed under the settler unit;
.3 Spacing of launders to be installed above the settler unit which meet weir loading criteria;
.4 Provisions for cleaning and/or removal of plates or tubes and sludge removal. Flushing lines with appropriate backflow prevention device should be provided;
.5 Drain piping from settler units should allow for quick flush of settler units to prevent flooding;
.6 The support system should be able to carry the weight of the settler modules when the basin is drained plus any additional weight to support maintenance personnel and equipment; and
.7 Provisions should be made to allow the water level to be dropped, and a water or air jet system for cleaning the settler modules.

7.5.4 Ballasted Flocculation and Separation

Ballasted flocculation is a high rate settling process that uses heavy particles (ballasts) to seed floc formation and accelerate the flocculation and sedimentation processes. A means to clean and recycle the sand ballast for reuse in the process should be provided. Ballasted flocculation systems are proprietary and much of the design criteria relies on equipment supplier input.

The surface loading rates of ballasted flocculation systems are very high, typically between 20 to 50 m/h. The detention time for flocculation and sedimentation is very short because of the high surface loading rates. This allows ballasted systems to have smaller spatial footprints than conventional systems. Due to the very short detention time, the overall reaction time to influent quality changes is very short, which is why the process is best suited to treat surface water with a consistent water quality. This process is very effective at removing high turbidity and has also been shown to effectively remove *Giardia lamblia* cysts, but not *Cryptosporidium* oocysts.

The Designer may consider ballasted flocculation, particularly for situations where space is limited, for the clarification process in the main treatment train or where backwash water is to be clarified before recycling. However, ballasted flocculation should not be used upstream of membrane filtration. The effluent of ballasted flocculation and sedimentation processes always contains a polymer residual, and during influent quality fluctuations, the polymer dosage is increased to compensate for the short reaction times. The residual polymer has led to filter blinding on some sites.

7.5.5 Adsorption Clarifiers

Adsorption clarifiers are proprietary systems that use a combination of hydraulic flocculation, roughing filtration, and rapid rate filtration. Flocculation occurs as the coagulated water passes through the granular media, which is often a buoyant plastic media. The agglomerated flocs are then adsorbed by the media.

Adsorption clarifiers are more applicable for higher quality surface waters with low turbidity, iron, manganese and colour. The following general guidelines should be considered in evaluating adsorption clarifiers:

- .1 The surface loading rate of adsorption clarifiers are typically in the range of 19.5 to 25.5 m/h;
- .2 The flocculation time provided in these systems is generally limited, which may be a concern at low water temperatures;
- .3 Air scour should be provided to clean the filters; and
- .4 Pilot testing should be conducted.

7.5.6 Upflow Clarifiers

Upflow clarifiers provide coagulation, flocculation, and sedimentation in a single unit. The common types of upflow clarifiers are solids contact and sludge blanket clarifiers. These are often proprietary settling units that have their basic sizes and associated equipment pre-established by the manufacturers based on flow.

Solids contact clarifiers have an inverted cone in the centre which contains the zone of coagulation and zone of high solids concentration. Raw water is drawn into the mixing zone where coagulation and flocculation take place. Water then passes into the settling zone, where the solids settle to the bottom and clarified water flows over a weir. The solids are drawn back into the mixing zone to recirculate the large floc.

Sludge blanket clarifiers also include an inverted cone within the unit. The coagulated and flocculated water enter the bottom of the clarifier and passes through a suspended layer of previously formed floc. The cone shape of the clarifier decreases the rise rate of the water from the bottom to the top as the cross-sectional area increases. When the rise rate of the water equals the downward velocity of the solid particle, the particle becomes suspended. As the water containing flocculated solids passes through this sludge blanket, the particles agglomerate to form large floc that eventually falls to the bottom of the clarifier.

These clarifiers should be considered where water characteristics (particularly temperature) and flow rates are relatively constant, and operation is continuous.

Table 7-8 Upflow Clarifier Design Criteria

Parameter	Typical Value	Note
Surface loading rates	1.2 to 2.4 m/h	Surface loading rates up to 6.0 m/h can be used. Supporting data such as calculations or bench/pilot testing results should be used to justify rates higher than 2.4 m/h. Higher rates are attainable in clarifiers that include plate or tube settlers. When selecting loading rates, low rates are preferable for colour removal and higher rates for turbidity removal.
Flocculation and mixing time	≥30 minutes	If applicable, flocculation equipment should be adjustable, and the clarifier design should provide for coagulation in a separate chamber or baffled zone within the unit.
Detention period	2 – 4 hours	
Weir loading	≤120 L/min/(m of weir length)	From 10 States Standards (2018).

In addition to the design criteria in Table 7-8, the following factors should be considered in evaluating proprietary clarifiers:

.1 Clarifiers should be designed for the maximum uniform flow rate and should be adjustable to accommodate changes in flow and water characteristics;
.2 Effective mixing devices should be provided to ensure good mixing of the previously formed sludge particles and the newly coagulated/flocculated water, and to prevent solid deposition in the mixing zone;
.3 Some proprietary clarifiers may require coagulant to be added in a separate rapid mix unit upstream of the clarifier to ensure even coagulant distribution;

.4 Overflow weir or orifices should be provided so that the water on the surface of the clarifier unit does not travel more than 3 m horizontally to the collection trough. Weirs should be adjustable. The design of the weirs and orifices should produce uniform rise rates for the entire surface area of the tank;
.5 Recirculation impellers should have an adjustable speed ratio of 1 to 4;
.6 Rake speed should be variable from 0.3 to 4.0 m/min;
.7 The design should allow sludge recirculation to continue when raw water flow stops;
.8 Adequate piping should be provided with suitable sampling taps located to permit the collection of samples from various depths of the units. Sampling taps should be located at the sludge withdrawal level and preferably spaced at 0.6 m intervals from the basin bottom to 0.6 m below the effluent level;
.9 The raw water inlet valve should be of the slow opening type, operating over not less than one minute to prevent disruption of the floc blanket; and
.10 Discharge from blow-off outlets and drains should be treated as wastewater.

7.5.6.1 Sludge Systems

In addition to the sludge removal system described in Section 7.5.1.3 – Sludge Systems, an internal or external sludge concentrator should also be provided to produce a concentrated sludge with minimum water content. Solids concentration of waste sludge should be greater than or equal to 3% by weight. Total water losses should not exceed 5%.

For sludge blanket clarifiers that decant into concentrator cones, sludge should be removed through 50 mm hoses. Because the sludge blanket forms in the middle of the clarifier, it has a higher water content and is less thick compared to sludge that settles at the bottom. The water on top of the sludge blanket also provides hydraulic head to help push the sludge through the hose.

7.5.6.2 Enclosure

A clarifier should either by located within the plant or covered with a separate cover that allows personnel to visually inspect the treatment. Appropriate weather proofing of equipment and consideration for ice blockage of orifices should be provided if the proposed clarifier is open top.

7.5.7 Dissolved Air Flotation

Dissolved air flotation (DAF) involves the use of microbubbles to remove floc particles. The bubbles are generated by saturating a recycled stream of water with pressurized air. The saturated recycle stream then enters a proprietary DAF nozzle where it is depressurized to form microbubbles, also known as whitewater. The bubbles bind to the flocculated particles and float them to the surface, where they are removed by a surface scraper system. The clarified water flows under a baffle wall or through a plenum, which then flows up to the overflow weir, which maintains the hydraulic level within the DAF tank.

The DAF process is effective at treating waters with high colour, low turbidity, high natural organic matter, or high algae content. The detention time and loading rates depend on the water being treated, the contaminants being removed, chemicals used, and the design of the DAF process. Designers may also consider using DAF on a seasonal basis (i.e. during algae blooms) because of its fast start-up time.

Table 7-9 DAF Design Criteria

DAF Design Criteria	Typical Values	Note
Conventional DAF surface loading rate	10 to 12 m/h	Conventional DAF has also demonstrated significant removal of *Giardia lamblia* cysts.
High rate DAF surface loading rate	20 to 40 m/h	Performance of high rate DAF should be confirmed with pilot studies.
Tank length	≤ 12 m	Length to width ratio typically between 1 – 2.
Tank depth	1.5 to 3.0 m	Greater depths should be used for high algae loads.
Air saturated recycle flow ratio	Between 5 to 12% of inlet flow	
Saturation pressure	415 to 725 kPa (60 to 105 psi)	
Bubble diameter	Between 10 and 100 µm	

In addition to the design criteria listed in Table 7-9, the following should be considered:

.1 Flow velocities should be limited to prevent scouring of the float from below;
.2 An inlet baffle should be provided to create a contact zone to provide sufficient floc/bubble contact time without short circuiting;
.3 The angle of the baffle should be between 60° to 90°, depending on loading rate;
.4 The air flow should be adjustable, and the air injection designed to ensure an even distribution of air across the inlet baffle;
.5 The recycle flow should be introduced at such a location to ensure even distribution of the released air at the tank influent;
.6 The clarified water should be collected at the bottom of the clarifier; and
.7 An overflow pipe or weir should be provided to control the water level in the DAF unit.

8 Filtration

8.1 General

This chapter describes design considerations for filtration treatment processes which remove particulate matter from water by passing the water through porous or non-porous filter media, such as granular media or membranes. The selection of a particular filtration treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

Filters should be designed to achieve individual filter effluent turbidity that meets the *Guidelines for Canadian Drinking Water Quality* and the BC Ministry of Health's *Guidelines for Pathogen Log Reduction Credit Assignment*, other than during the filter ripening period when the effluent should be directed to waste (filter-to-waste).

To meet the provincial dual treatment objective, a filtration process should be assigned pathogen log reduction credits. Pathogen log reduction credit assignment is based on the specified filtration treatment process being fully operational and the applicable pathogen log reduction credit assignment criteria being met. Refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* for more information.

Acceptable filtration processes for pathogen log reduction credit assignment include:

.1 Rapid rate gravity filtration, which includes inline filtration, direct filtration, and conventional filtration;
.2 Slow sand filtration;
.3 Membrane filtration, which includes microfiltration, ultrafiltration, nanofiltration and reverse osmosis;
.4 Biologically active filtration;
.5 Diatomaceous earth filtration;
.6 Cartridge filtration; and
.7 Subsurface filtration, see Section 6.3.1.7.2 – Subsurface Filtration (Riverbank Filtration) for more information.

Pressure filtration - which is not eligible for pathogen log reduction credits - is also discussed within this chapter because it may be used as pre-treatment or for some types of contaminant-specific treatment (for example, iron and manganese removal). Bag filters may be used as pre-treatment but are also not assigned pathogen log reduction credits.

8.1.1 Filtration Selection

The application of any type of filtration should be supported by water quality data representing a reasonable period of time (i.e. seasonal) to characterize variations in water quality. Pilot treatment studies may be required to demonstrate the applicability of the proposed filtration method. Pilot testing guidance can be found in Chapter 3 – General Design Guidance.

The most appropriate filtration technology will vary depending on source water quality, the availability of skilled operators, land and energy requirements, costs, availability of replacement parts for proprietary technology, and other resource considerations. For all filtration facilities, filter-to-waste capability should be provided in anticipation of a less-than-optimum filtered water quality at the start of a filtration cycle. Table 8-1 provides treatment limitations for the different types of filtration technologies given source water quality. Pre-treatment processes can allow for greater levels of coliform, colour, or turbidity than listed below.

Table 8-1 General Source Water Limitations for Filtration Technologies

Filtration Technology	Turbidity (NTU) [1]	Total Organic Carbon (mg/L) [2]	Total Coliform (#/100 mL) [1]	Colour (TCU) [1, 2]
Conventional filtration	<3,000	No limit	< 5,000 – 20,000	< 75
Direct filtration	< 15	< 3	< 500	< 40
In-line filtration	<5		< 500	< 5
Slow sand filtration [3]	< 10	< 2 [6]	< 800	< 5
Diatomaceous earth filtration	< 5		< 50	< 5
Pressure filtration [4]	**DO NOT USE FOR PATHOGEN LOG REDUCTION CREDIT**			
Cartridge filtration [3]	< 5		See [5]	See [5]
Membrane filtration [7]	See [5]	< 2	See [5]	See [5]

[1] Recommended water quality limitations are derived from a combination of sources, including Washington State (2019) and Alberta Environment and Sustainable Resource Development (2012).
[2] Higher TOC and colour values may be treatable based on specific pre-treatment technologies and unit processes.
[3] These limits are for applied filter turbidity. The treatment process can handle higher source water turbidity values if additional pre-treatment is provided.
[4] Pressure filters may be used for iron and manganese removal but will not be assigned any pathogen log reduction credits.
[5] Special studies are required to determine limitations, which are equipment specific.
[6] Higher TOC values require pilot testing. Application of ozone (≤ 1 mg/L) or other oxidants (i.e. potassium permanganate) upstream of filter may improve biodegradability of organics.
[7] NF and RO membranes may be used to treat high TOC and colour source waters.

Applicable to all treatment design, the Designer should consider how the design will affect the classification of the treatment system under the Environmental Operators Certification Program (EOCP) and inform the water supplier of the necessary operator certification level and training requirements.

8.1.2 Preliminary Design

During the preliminary design phase, Designers should conduct a historical summary of meteorological conditions and of raw water quality with special reference to fluctuations in quality, and possible sources of contamination. The following raw water parameters should be evaluated:

- .1 Colour;
- .2 Turbidity;
- .3 Bacterial concentration;
- .4 Microscopic biological organisms, which can include *E. coli*, total coliform and fecal coliforms;
- .5 Temperature;
- .6 Total solids;

.7 pH;
.8 Alkalinity;
.9 General inorganic chemical characteristics; and
.10 Additional parameters as necessary.

The preliminary design phase should also including developing a draft description of methods and work to be done during a pilot plant study or, where appropriate, an in-plant demonstration study.

8.2 Rapid Rate Gravity Filtration

Rapid rate gravity filtration, including in-line, direct, and conventional filtration, is primarily used to remove turbidity after coagulation and flocculation in large water treatment plants. Numerous texts and standards cover the design of rapid rate filtration in detail, including:

.1 *AWWA Standard B100: Standard for Granular Filter Media* (AWWA 2016a);
.2 *Water Treatment Plant Design: Ch. 9. High-Rate Granular Media Filtration* (AWWA/ASCE 2012b);
.3 *Recommended Standards for Water Works. Section 4.3.1 Rapid Rate Gravity Filters* (Ten State Standards 2018); and
.4 *Integrated Design and Operation of Water Treatment Facilities* (Kawamura 2000).

Designers should review these references and other resources as part of their evaluation of rapid rate filtration for any source. Deep bed rapid rate gravity filters generally refers to rapid rate gravity filters with filter material depths equal to or greater than 1,200 mm. For these systems, filter media sizes are typically larger than those listed in Section 8.2.8 – Filter Media. Final filter design should ideally be based on pilot plant studies.

8.2.1 Types of Rapid Rate Gravity Filtration

The pre-treatment process used prior to filtration can further classify rapid rate filtration as follows:

.1 **In-line filtration** - includes a short period of coagulation and rapid mixing prior to filtration. It does not include extended flocculation with the use of basins or clarification. In-line filtration should only be used to treat water sources with low turbidity and low concentrations of natural organic matter;
.2 **Direct filtration** - includes coagulation and flocculation prior to filtration without prior solids removal through clarification. Nonetheless, direct filtration systems should be designed such that a solids separation process could be installed at a later date; and
.3 **Conventional filtration** - includes coagulation, flocculation, and clarification prior to filtration.

Figure 8-1 illustrates a typical flow diagram for in-line, direct and conventional filtration. Refer to Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification for design of chemical mixing, flocculation and clarification. Additionally, refer to Chapter 13 – Chemical Application for design of chemical systems.

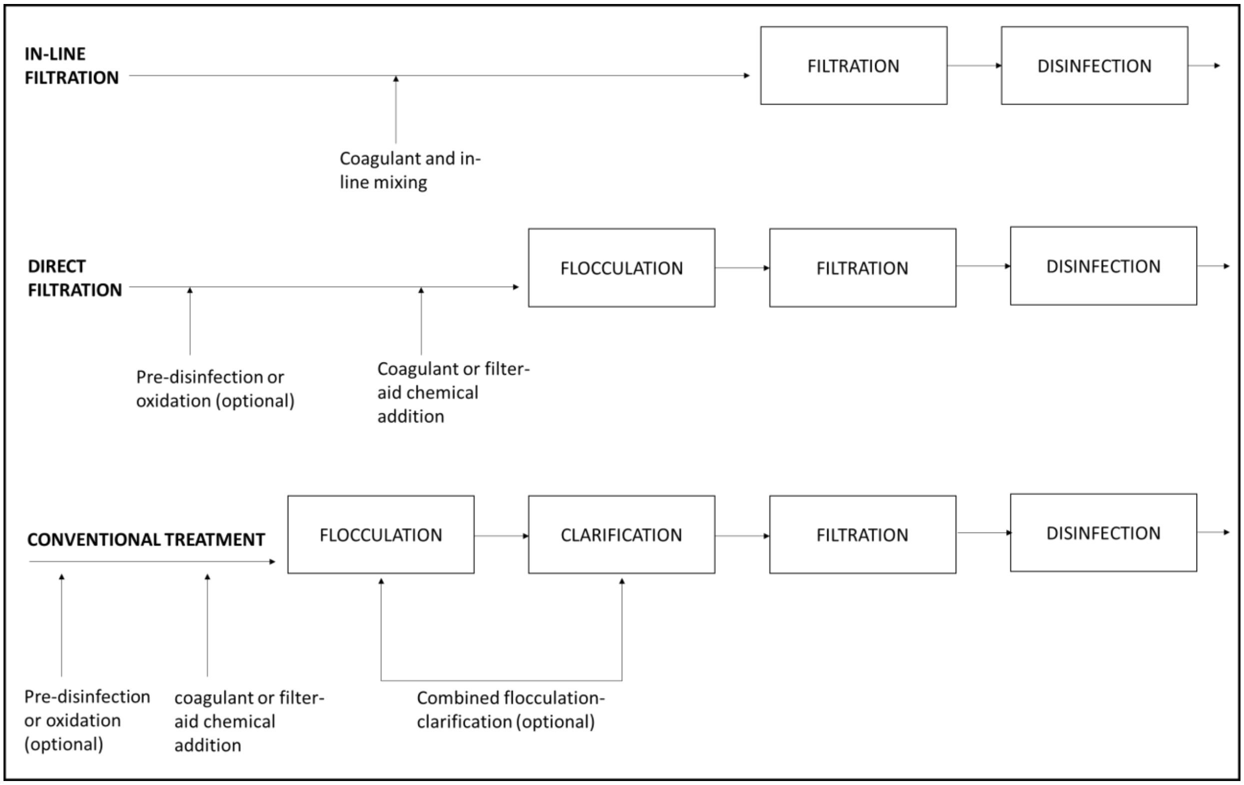


Figure 8-1 Typical flow diagram of rapid rate filtration systems

8.2.2 Rapid Media General Design Considerations

8.2.2.1 Number and Redundancy

The Designer should consider the following when deciding the number of filters in the plant:

.1 A minimum of two filtration units should be provided for redundancy;
.2 Where only two units are provided, each unit should be capable of meeting the facility design capacity (normally the projected maximum daily demand) at the approved filtration rate;
.3 Where more than two filter units are provided, the filters should be capable of meeting the plant design capacity at the approved filtration rate with the largest filter removed from service;
.4 The number of filters and area of each filter bed should be designed such that the filtration rate can remain the same or not increase substantially (less than 10% gradual change in hydraulic loading) during the backwashing of the filters to prevent the possibility of turbidity breakthrough; and
.5 Where declining rate filtration is provided, the variable aspect of filtration rates, and the number of filters should be considered when determining the design capacity for the filters.

8.2.2.2 Structural Details and Hydraulics

The filter structure should be designed with the following considerations:

.1 Effluent piping designed hydraulically for flows of up to 50% in excess of the filtration design capacity to accommodate potential peak demands, provided that the water quality is not compromised;
.2 Effluent piping arranged to prevent backflow of air into the filter;
.3 Vertical walls within the filter;
.4 No protrusion of the filter walls into the filter media;
.5 Covered by superstructure;
.6 Head room to permit normal inspection and operation;
.7 Minimum depth of filter box of 2.5 m;
.8 Minimum water depth over the surface of the filter media of 900 mm;
.9 Trapped effluent to prevent backflow of air to the bottom of the filters;
.10 Prevention of floor drainage to the filter with a minimum 100 mm curb around the filters;
.11 Prevention of flooding by providing overflow;
.12 Maximum velocity of treated water in pipe and conduits to filters of 0.6 m/sec;
.13 Cleanouts and straight alignment for influent pipes or conduits where solids loading is heavy, or following lime-soda softening;
.14 Wash water drain capacity to carry maximum flow;
.15 Walkways around filters, to be not less than 600 mm wide;
.16 Safety handrails or walls around all filter walkways; and
.17 Construction to prevent cross connections and common walls between potable and non-potable or filtered and unfiltered water. Tanks containing untreated or partially treated water should not be located adjacent to a structure containing treated water with a single wall separation. Refer to Chapter 5 – Facility Recommendations for cross connection and backflow prevention considerations and Chapter 17 – Water Storage for considerations for water storage tanks.

8.2.2.3 Appurtenances

The following appurtenances should be provided for every filter:

.1 Influent and effluent sampling taps;
.2 An indicating loss of head gauge or transmitter;
.3 Indicating flow meter and flow control to each filter/train;
.4 For surface water or GARP with two or more filters, on-line turbidimeters should be installed on the effluent line from each filter such that:
   a. All turbidimeters should consistently determine and indicate the turbidity of the water in NTUs;
   b. Each turbidimeter should report to a recorder that is designed and operated to allow the operator to accurately determine the turbidity at least once every 5 minutes;
   c. Graphical display capability should be provided for turbidity data;
   d. Turbidimeters on individual filters should be designed to accurately measure low-range turbidities and have an alarm that will sound when the effluent level approaches 0.3 NTU. The readout should be data-logged continuously and should be connected to SCADA systems;
   e. It is recommended that turbidimeters be placed in a location that also allows measurement of turbidity during filter to waste;
   f. Reference should be made to Chapter 22 – Water Quality Monitoring for further guidance on turbidity monitoring;

.5 A flow rate controller capable of providing gradual rate increases when placing the filters back into operation;
.6 Wall sleeves providing access to the filter interior at several locations for sampling or pressure sensing;
.7 A 25 to 38 mm pressure hose equipped with a shutoff nozzle or valve and storage rack at the operating floor for washing filter walls;
.8 Automatic shutoff valves on each filter effluent to prevent the filters from draining down after the plant is shut off; and
.9 Access to particle counting equipment (portable or online) may be considered as a means to enhance monitoring and overall treatment operations.

8.2.3 Filter-to-Waste Provisions

Water treatment plants should be designed with a filter-to-waste provision. Refer to Section 5.8 – Cross Connections and Backflow Prevention for considerations and resources.

Piping for filter-to-waste is to be designed at full filter flow capacity and include precautions to prevent backflow from the filter-to-waste stream to any component of the potable water supply system.

During the filter-to-waste mode, the filter may be operated at high hydraulic loading rates and wasted water turbidity should be measured daily until it reaches an acceptable level.

8.2.4 Rate of Filtration

The rate of filtration should be determined through consideration of such factors as:

.1 Raw water quality;
.2 Degree of pre-treatment provided;
.3 Filter media;
.4 The total required area of the filter bed;
.5 The available hydraulic loss during filtration;
.6 The anticipated terminal head loss prior to turbidity breakthrough in the filter bed;
.7 The anticipated filter run;
.8 Water quality control parameters;
.9 Competency of operating personnel; and
.10 Other factors as necessary.

For traditional dual media filter designs, a maximum filtration rate of 14.8 m/h is recommended. In any case, the filter rate should be proposed and justified by the Designer prior to the preparation of final plans and specifications. For all filter designs, filtration rates greater than 14.8 m/h should be confirmed through pilot testing. Pilot testing in cold water conditions is also advisable to establish acceptable rates.

8.2.5 Flow Control

There are three basic modes of filtration control:

.1 Constant rate filtration:
   a. Constant rate filtration is the most commonly used method. In this method, the rate of filtration is maintained by a flowmeter and a modulating butterfly valve on the effluent side. As the head loss increases in the media, the valve is gradually opened to maintain

the pre-determined filtration rate;

.2 Declining rate filtration:

a. In declining rate filtration, filter influent enters a specially designed manifold to provide an equal head to all filters. As such, filtration rate declines with increasing head loss in the media. This method requires a special care in start-up of filters and limits operating flexibility which can be a significant issue for larger plants; and

.3 Influent flow splitting:

a. In influent flow splitting, filter influent flow into each filter is maintained by an adjustable weir at the entrance of the cell. As head loss increases, the cell water level will rise within the cell. Filtration is terminated when the water level reaches an elevation below the influent weir to prevent flooding.

For all methods, flow control should provide equal flow distribution among the individual filters and accommodate rising head loss through each individual filter run. The Designer should consider cost, complexity and reliability when selecting a control strategy.

8.2.6 Head loss and Control

.1 Filters should be designed with a maximum permissible head loss typically in the range from 0.3 m (clean bed) to 2.5 m. Excessive head loss can cause air binding and/or channeling and deterioration of filter performance;

.2 Filters should be designed to have at least 1.0 m of water above the media and in the case of high rate filtration, this value should not be less than 1.5 m. Filters may be designed with significantly different values on a site-specific basis;

.3 Some elements of filter design are proprietary in nature, and the performance of designs which deviate significantly from these guidelines should be demonstrated based on relevant references and/or piloting; and

.4 Filter run times should be designed between 12 and 72 hours and, where possible, should be between 24 and 48 hours. Longer filter run times may be considered provided that it is adequately demonstrated that it will not result in adverse impacts on water quality, and operation and maintenance of the filter.

8.2.7 Backwash Water Troughs

Backwash water troughs should be constructed to have:

.1 The bottom elevation above the maximum level of expanded media during washing;

.2 A 50 mm freeboard at the maximum rate of wash;

.3 The top edge of each trough to be at the same elevation (adjustable weirs are recommended);

.4 Spacing so that each trough serves the same number of square meters of filter area;

.5 Trough spacing of 1.8 to 3 m for dual media with anthracite or granular activated carbon (GAC);

.6 Troughs should be located so that they do not obscure observation of filters or affect accessibility; and

.7 Maximum horizontal travel of suspended particles to reach the trough not to exceed 1.0 m.

8.2.8 Filter Media

All filter materials should meet the current applicable AWWA standards for filtering materials and storing and handling information, including *AWWA B100 – Granular Filter Media* and *AWWA B604 – Granular Activated Carbon*. The selection of media type, size (effective particle size and uniformity coefficient), distribution, depth and L/d ratio (L=depth, d=filter media effective particle size) should be such that, in operation, the filter reaches its design terminal head loss at approximately the same time as either turbidity or colour breakthrough occurs, based on whichever is the controlling process parameter. The media selection also depends on the concentration and type of suspended solids to be removed by the filter. Media selection is complex and should, therefore, only be undertaken by competent professionals.

Filter media is typically clean silica sand or other natural or synthetic media free from detrimental chemical or bacterial contaminants and having the following characteristics, unless otherwise demonstrated by pilot testing or comparable reference installation:

- .1 Typically, a total depth between 600 and 760 mm;
- .2 A uniformity coefficient of the smallest material greater than 1.65;
- .3 A minimum depth of 300 mm of media with an effective size range no greater than 0.45 mm to 0.55 mm;
- .4 Types of filter media:
  - a. Anthracite - filter anthracite should consist of hard, durable anthracite coal particles of various sizes. Blending of non-anthracite material is not acceptable. Anthracite should have an:
    - i. Effective size of 0.45 mm - 0.55 mm with uniformity coefficient not greater than 1.65 when used alone;
    - ii. Effective size of 0.8 mm - 1.2 mm with a uniformity coefficient not greater than 1.7, when used as a cap;
    - iii. Effective size for anthracite used as a single media on potable groundwater for iron and manganese removal only should be a maximum of 0.8 mm (effective sizes greater than 0.8 mm may be approved based upon on-site pilot plant studies or other demonstration);
    - iv. Specific gravity greater than 1.4;
    - v. Acid solubility less than 5%;
    - vi. A Mohs scale of hardness greater than 2.7;
  - b. Sand Filter – sand should have:
    - i. An effective size of 0.45 mm to 0.55 mm;
    - ii. A uniformity coefficient of not greater than 1.65;
    - iii. A specific gravity greater than 2.5;
    - iv. An acid solubility less than 5%;
  - c. High Density Sand - high density sand should consist of hard, durable, and dense grain garnet, ilmenite, hematite, magnetite, or associated minerals of those ores that will resist degradation during handling and use, and should:
    - i. Contain at least 95% of the associated material with a specific gravity of 3.8 or higher;
    - ii. Have an effective size of 0.2 to 0.3 mm;
    - iii. Have a uniformity coefficient of not greater than 1.65;
    - iv. Have an acid solubility less than 5%;
  - d. Granular Activated Carbon (GAC) - granular activated carbon as a single media may be considered for filtration only after pilot or full-scale testing. The design should include

the following:

i. The media should meet the basic specifications for filter media as given in .1 through .3 above. Alternate media sizes may be allowed where pilot or full-scale tests have demonstrated that treatment goals can be met under all conditions;
ii. There should be provisions for a free chlorine residual and adequate contact time in the water following the filters and prior to distribution (see Chapter 11 – Disinfection);
iii. There should be means for periodic treatment of filter material for control of bacterial and other growth;
iv. Provisions should be made for removal/replacement or regeneration; and

e. Other media types or characteristics may be considered based on experimental data and operating experience.

8.2.9 Filter Underdrains and Strainer Systems

The underdrain system (or filter bottom) should provide an even rate of filtration over the entire area of the filter and, if used, uniform distribution of backwash water and/or scouring air. Underdrain systems come in many forms including perforated pipe, false bottom with strainers, nozzle based, block underdrain, precast concrete underdrains, folded plate underdrain, and some proprietary types.

The selection of an underdrain design will be dependent on filter size, filter media characteristics, and the type of filter washing system implemented. Departures from these standards may be acceptable for high rate filters and for proprietary bottoms. Porous plate bottoms should not be used where iron or manganese may cause clogging or with waters softened by lime.

The design of manifold-type collection systems should:

.1 Minimize loss of head in the manifold and laterals;
.2 Ensure an even distribution of wash water and an even rate of filtration over the entire area of the filter;
.3 Provide the ratio of the area of the final openings of the strainer systems to the area of the filter at about 0.003 (typical range 0.0015 – 0.005);
.4 Provide the total cross-sectional area of the laterals at about twice the total area of the final openings;
.5 Provide the cross-sectional area of the manifold at 1.5 to 2 times the total area of the laterals;
.6 Lateral perforations without strainers should be directed downward;
.7 Allow for cushioning of the air inflow surge at blower start-up as well as even distribution of air scouring over the whole floor area; and
.8 Depending on the underdrain design, support media may be required. Refer to Section 8.2.10 – Support Media.

8.2.10 Support Media

Support media for underdrains, when required, should conform to the following criteria:

.1 Torpedo sand - A 76 mm layer of torpedo sand should be used as a supporting media for filter sand where supporting gravel is used, and should have:
a. an effective size of 0.8 mm to 2.0 mm;
b. a uniformity coefficient < 1.7; and

.2 Gravel - gravel, when used as the supporting media, should consist of cleaned and washed, hard, durable, rounded silica particles and should not include flat or elongated particles. The coarsest gravel should be 62 mm in size when the gravel rests directly on a lateral system and should extend above the top of the perforated laterals. Not less than four layers of gravel should be provided in accordance with the following size and depth distribution:

Size (mm)	Depth (mm)
62 – 38	125 – 200
38 – 19	75 – 125
19 – 12	75 – 125
12 – 5	50 – 75
5 – 2.5	50 – 75

Reduction of gravel depths, number of layers, and other size gradations, along with substitution of support media type may be considered with justification when proprietary filter bottoms are specified.

8.2.11 Surface Wash or Subsurface Wash

Surface or subsurface wash facilities are required except for filters used exclusively for iron, radionuclides, arsenic or manganese removal, and may be accomplished by a system of fixed nozzles or a revolving-type apparatus. All devices should be designed with:

.1 Provisions for water pressures of at least 310 kPa (45 psi), with a typical range of 483-690 kPa (70-100 psi);
.2 A properly installed vacuum breaker or other approved device to prevent back siphonage if connected to the filtered or finished water system;
.3 The following provides a typical flow range for different types of wash:
   a. Fixed nozzles: 7.5-10 m/h;
   b. Revolving single arm: 1.2-1.75 m/h;
   c. Dual arms: 3.25-3.75 m/h; and
.4 Air wash can be considered based on experimental data and operating experiences.

8.2.12 Backwash

Provisions should be made for washing filters as follows:

.1 A minimum backwashing rate of 37 m/h, consistent with water temperatures and specific gravity of the filter media. A rate of 50 m/h or a rate necessary to provide for a 25-50% expansion of the filter bed is recommended. A reduced rate of 25 m/h may be acceptable for full depth anthracite or granular activated carbon filters; for systems using air scour see Section 8.2.13 – Air Scouring;
.2 Filtered water should be used for backwashing and provided at the required rate by a minimum of two backwash water pumps (one duty and one standby). The use of high-pressure sources with pressure reducing valves is not recommended as failure of pressure reducing valves may disrupt filter media which would then need to be re-stratified;
.3 Backwash water pumps in duplicate unless an alternate means of obtaining backwash water is available;

.4 Provision for water pressures of at least 310 kPa (45 psi) or as specified by the manufacturer;
.5 Sufficient volume of water should be provided for backwashing all filters every 24 hours. An equivalent volume of equalization may be required for plants that store their backwash prior to treatment and/or ultimate disposal;
.6 Not less than 15 minutes wash of one filter at the design rate of wash, and a minimum 10 minutes of backwash water for systems that use air scour;
.7 A backwash water regulator or valve on the main backwash water line to obtain the desired rate of filter wash with the backwash water valves on the individual filters open wide;
.8 A flow meter, preferably with a totalizer, on the main backwash water line or backwash waste line, located so that it can be easily read by the operator during the washing process;
.9 Design to prevent rapid changes in backwash water flow;
.10 Backwash should be operator initiated; alternatively, automated systems should be operator adjustable; and
.11 Appropriate measures for cross connection control and prevention against back-siphonage if connected to the treated water system.

8.2.13 Air Scouring

Air scouring can be considered in place of surface wash, with the following criteria:

.1 The air should be free from contamination. Oil-free compressors should be used;
.2 Air flow should be 0.9 - 1.5 $m^3/min/m^2$ of filter area when the air is introduced in the underdrain; a lower air rate should be used when the air scour distribution system is placed above the underdrains;
.3 A method for avoiding excessive loss of the filter media during filter backwashing should be provided;
.4 Air scouring should be followed by a fluidization wash sufficient to re-stratify the media;
.5 Air scour distribution systems should be placed below the media and supporting bed interface; if placed at the interface the air scour nozzles should be designed to prevent media from clogging the nozzles or entering the air distribution system;
.6 Piping for the air distribution system should not be flexible hose (which may collapse when not under air pressure) nor a relatively soft material (which may erode at the orifice opening with the passage of air at high velocity);
.7 Air delivery piping should not pass down through the filter media nor should there be any arrangement in the filter design which would allow short circuiting between the applied unfiltered water and the filtered water;
.8 Consideration should be given to maintenance and replacement of air delivery piping;
.9 The backwash water delivery system should meet the requirements in Section 8.2.12 – Backwash; however, for systems with air scour, backwash rates of 5-10 m/h and 20-25 m/h are common for typical depth and deep bed filters respectively;
.10 The filter underdrains should be designed to accommodate air scour piping when the piping is installed in the underdrain; and
.11 Air scouring controls should allow the operator to control the air flow rates and duration. Rate of flow indicators for air and water should be provided.

8.3 Slow Sand Filtration

Slow sand filtration refers to the process in which water is gravity filtered at very low rates through a sand bed in which a biologically active layer forms on the top of the media. This biologically active layer is commonly referred to as a *Schmutzdecke*. The use of this technology should require prior engineering studies to demonstrate the adequacy and suitability for the specific raw water supply. Extensive raw water quality and piloting data should be obtained and should cover a period of at least one year to capture all of the seasonal water quality fluctuations. Pilot testing should meet the requirements of Section 3.6 – Pilot Test Recommendations.

8.3.1 Number and Redundancy

Refer to Section 8.2.2.1 – Number and Redundancy.

8.3.2 Structural Details and Hydraulics

Slow sand filters should be designed so as to provide:

.1 A cover;
.2 Headroom to permit normal movement by operating personnel for scraping and sand removal operations;
.3 Adequate access hatches and access ports for handling of sand and for ventilation;
.4 An overflow at the maximum filter water level;
.5 Protection from freezing;
.6 Means for cleaning and/or scraping of sand; and
.7 Filter-to-waste (a minimum two days flow should be considered).

8.3.3 Filter-to-Waste Provisions

During the filter ripening period, following the start-up of a new filter or a re-built filter bed, filtered water may be of very poor quality. The ripening period typically ranges from about one week to several months. The filters will not meet the minimum performance requirements during the ripening period and the water produced during this period should be wasted. Water treatment plants should be designed with this filter-to-waste provision. Precautions should be made to prevent backflow from the filter-to-waste stream to any component of the potable water supply system.

During the filter-to-waste mode, the filter may be operated at high hydraulic loading rates and wasted water turbidity should be measured daily until it reaches the acceptable level.

8.3.4 Rates of Filtration

The permissible rates of filtration should be determined by the quality of the raw water and should be on the basis of experimental data derived from the water to be treated. The nominal rate may be 0.04 to 0.40 m/h, with somewhat higher rates acceptable with the demonstration of effective performance. Water supply to the *Schmutzdecke* should maintain adequate dissolved oxygen (DO > 6 mg/L), as metals can be mobilized under low DO conditions.

8.3.5 Filter Media

All filter materials should meet the current applicable AWWA standards for filtering materials and storing and handling information and the following should be considered:

.1 Filter sand should be placed on graded gravel support layers (see Section 8.3.6 – Support Media).
.2 Sand bed depth should be generally between 1 - 1.3 m at the start of operation, although deeper beds may be used if desired;
.3 The effective size should be between 0.15 mm and 0.30 mm. Larger sizes may be considered; a pilot study may be required;
.4 The uniformity coefficient should not exceed 2.5;
.5 The sand should be cleaned and washed free from foreign matter and dust/fine particles to avoid long start-up times; and
.6 The sand should be re-bedded when scraping has reduced the bed depth to no less than 480 mm. Where sand is to be reused in order to provide biological seeding and shortening of the ripening process, re-bedding should use a “throw over” technique whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

8.3.6 Support Media

The supporting gravel should be similar to the size and depth distribution provided for rapid rate gravity filters, refer to Section 8.2.10 – Support Media.

8.3.7 Underdrains

Design of the underdrains should consider the following:

.1 Each filter unit should be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water;
.2 The underdrains should be placed as close to the floor as possible and spaced so that the maximum velocity of the water flow in the underdrain will not exceed 0.23 m/sec;
.3 The maximum spacing of laterals should not exceed 1.0 m if pipe laterals are used;
.4 The underdrain system should ensure uniform flow through the overlying sand bed by having a uniform distribution and sufficient number of collection orifices. The designed head loss within the underdrain pipe should be negligible relative to head loss through the orifice. The diameter and spacing of the underdrain pipes and the diameter of the orifices should be determined using hydraulic calculations. The recommended drain orifice diameter is 6.35 mm;
.5 Air release holes or slits should be included at the top near the midpoint of the main drain and each lateral. Alternatively, slotted drainpipe may be used where the width of the slots is in the 2-4 mm range, provided the head loss through the slots is determined to be much greater than the laterals and main drains; and
.6 Underdrains material should be PVC or other noncorrosive material meeting *NSF/ANSI Standard 61: Drinking Water System Components – Health Effects*.

8.3.8 Depth of Water on Filter Beds

Influent water should be introduced to the supernatant water with enough clearance above the sand to prevent turbulence scouring of the sand surface. Design should provide a depth of at least 1.8 to 2.0 m of water over the sand. Head loss should be between 0.1 m (i.e. clean bed) and 2.0 m (i.e. final bed).

8.3.9 Control Appurtenances

Each filter should be equipped with:

.1 Influent and effluent sampling taps;
.2 An indicating loss of head gauge or other means to measure head loss;
.3 An indicating rate-of-flow meter. A modified rate controller that limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or a flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only if other options are not viable and requires approval;
.4 Provisions for filtering to waste with appropriate measures for cross connection control;
.5 An orifice, venturi meter, or other suitable means of discharge measurement installed on each filter to control the rate of filtration;
.6 An effluent pipe designed to maintain the water level above the top of the filter sand; and
.7 A movable weir plate that can be raised or lowered during operation to control tailwater. Refer to Section 8.3.11 – Tailwater Control.

8.3.10 Scraping and Ripening

Slow sand filters should be scraped as required based on filter breakthrough or maximum head loss. After scraping, the de-watered filter should be backfilled with treated water. Provision should be made in the design to backfill the filter through the underdrain system; backfilling from the top can result in entrapment of air bubbles which may cause air binding and disruption of the flow. Slow sand filters should be allowed to ripen for enough time to ensure the target filtered water turbidity levels are achieved.

The frequency of scraping and ripening duration will vary with sand depth and raw water quality and can be more accurately determined during piloting. Filter harrowing (raking) as an intermediate maintenance activity between scrapings may prolong the life of the media and considerations to allow harrowing should be made during design of the filter basin and piping.

Slow sand filters should be operated to waste after scraping or re-bedding during a ripening period until the filter effluent turbidity falls to consistently below the water quality treatment objectives.

8.3.11 Tailwater Control

Filter effluent water (also called tailwater) passes through a finished water storage tank, normally located adjacent to the slow sand filter. Weirs are recommended over effluent control valves to control the tailwater elevation in the finished water storage.

The design of the system should have a movable weir plate that can be raised or lowered during operation. Immediately after scraping the filter, it is recommended that the water level is raised by 0.3 m to dissipate the kinetic energy of the influent flow and prevent disruption of the filter bed.

This can be achieved by increasing the head loss through the filter via raising the tailwater elevation. The weir plate should be adjustable enough so that it can be lowered to the elevation of the surface of the sand bed once the head loss across the sand bed is greater than 0.3 m.

8.4 Membrane Filtration

This section provides general design criteria that apply to all membrane systems. Membrane filtration systems are typically proprietary technologies with fiber and module designs differing significantly between manufacturers. As such, the manufacturer should be consulted for specific design requirements.

Membrane systems are classified based on their approximate pore size ranges. These categories are as follows:

.1 Microfiltration (MF): > 0.1 µm pore size (typically 0.1 - 10 µm);
.2 Ultrafiltration (UF): 0.01 - 0.1 µm pore size;
.3 Nanofiltration (NF): 0.001 –0.01 µm pore size; and
.4 Reverse osmosis (RO): 0.0001 µm pore size.

Where µm = micrometre = 1×10^{-6} metres = 1×10^{-3} millimetres.

Many membranes, especially those used in ultrafiltration, are also characterized in terms of molecular weight cut-off (MWCO), which is defined as the molecular weight where 90% of removal across the membrane occurs. MWCO is measured in Daltons (atomic weight units) and is used where measurement in microns is insufficient to accurately describe removals of dissolved constituents.

Membrane filtration systems are used in a range of drinking water treatment applications, including the removal of fine particles through ultrafiltration (UF) and microfiltration (MF) to the removal of solutes through reverse osmosis (RO) and nanofiltration (NF). In B.C., UF and MF are the most commonly used membrane systems for drinking water applications. NF and RO are less commonly found. Current RO applications are typically limited to brackish groundwater, seawater sources, and membrane softening.

Membrane replacement represents a major component in the overall cost of water production. The life expectancy of a particular membrane under consideration should be evaluated during the pilot study or from other relevant available data. Membrane life may also be reduced by operating at consistently high fluxes.

Numerous texts and standards cover the design of membrane filtration in detail, including:

.1 *Membrane Filtration Guidance Manual* (USEPA 2005);
.2 *AWWA B110: Standard for Membrane Systems* (AWWA 2016c); and
.3 *AWWA Manual M53 Microfiltration and Ultrafiltration Membranes for Drinking Water* (AWWA 2016d).

For pathogen log reduction credit assignment, the Designer should refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* and the latest edition of the USEPA Membrane Filtration Guidance Manual or ANSI/NSF Standard 419.

8.4.1 Pre-treatment

Depending on the source water, pre-treatment requirements for membrane treatment may be considered. Generally, the feed water should be very low in organic and inorganic colloidal substances, metal oxides (particularly iron and manganese), and biological substances to minimize premature fouling of the pores. In addition, most membranes will not tolerate high/low pH water or free chlorine. A number of pre-treatment unit processes that may be evaluated for integration with membrane filtration systems include:

.1 **Pre-screening:** Pre-screening of any membrane system to protect the membranes from damage by debris. The required screen size and/or strainer should be dictated by the requirements of the membrane manufacturer (typically 50 – 500 µm);

.2 **Oxidation:** Oxidation to be integrated with membrane processes to assist with organics, including both total organic carbon (TOC) and dissolved organic carbon (DOC), and taste and odour reduction. It is recommended that the oxidation process be introduced as far upstream of the membrane process as possible. However, the possibility of DBP formation should be reviewed.

The Designer should obtain agreement for the use of a particular oxidant from the membrane manufacturer. In the case of using oxidation for the removal of divalent iron and/or manganese, sufficient contact time should be allowed for chemical reaction completion and precipitate formation upstream of the membrane filter;

.3 **Adsorption:** Adsorption processes are normally used downstream of the membrane process for removal of organics (TOC and DOC) and taste and odour causing compounds. When carbon adsorption processes are considered upstream of membrane processes, pilot tests should be carried out for the specific membrane and carbon grade to assess the potential reduction in membrane life due to the presence of abrasive carbon fines. When biological filtration is planned upstream of membrane filtration, optimization of pilot biological filtration over a minimum period of 4 months should be conducted before commencing membrane pilot work on the biological filter effluent; and

.4 **Coagulation:** Coagulation upstream of the membrane process is not typically needed for effective pathogen removal. In some cases, this is implemented for pin floc formation. Coagulant use may lead to additional expense and residuals handling costs and may require conditioning of the raw water to be effective. Where coagulant is needed, such as for example, for colour or dissolved organic carbon removal, the coagulation process will add additional solids loading and may plug the membrane pores, leading to extra cleaning requirements. Furthermore, the use of coagulant needs to be optimized to prevent high dissolved aluminum concentrations in the treated water. Where coagulation is needed for a substantial part of the operating year, operating cost and life cycle analysis should be evaluated and understood for the system.

When pre-treatment is required, the Designer should consider the effects of upstream processes on the membrane system. For example, many membranes have restricted tolerance for exposure to chlorine, the use of which may be needed for mussel or taste and odour control. Other processes such as biological filters and contactors can significantly affect membrane cleaning requirements and life. Many of these processes are difficult to pilot accurately. The Designer should consider the applicability and reliability of pilot results and consider placing these processes downstream in the treatment train where possible.

8.4.2 Number and Redundancy

Since most membranes are modular in nature, redundancy should be provided such that any component failure critical to continued operation should have a means for back-up, replacement or repair in sufficient time so as not to interrupt the system water supply demand. The following considerations may be incorporated into the design:

.1 A minimum of two trains with 100% capacity each. Alternatively, isolatable membrane modules to be provided;
.2 A minimum of one redundant feed, suction, and cleaning pumps (installed or shelf spare) is provided;
.3 When determining the total amount of membrane area and number of membrane trains to meet system demands, the effect of the following should be considered:
   a. Membrane age;
   b. Irreversible fouling;
   c. Reduction in membrane area due to fibre plugging/repairs;
   d. Low temperature;
   e. Train out of service;
   f. Changes in source water quality;
.4 When a train is off-line for cleaning, the remaining trains will need to be capable of operating at a higher flux rate for the duration of the cleaning cycle in order to meet system demands. Where possible, this should be avoided as operating at high flux rates may significantly accelerate deterioration of the membrane performance. The need for redundant trains and equipment should also be considered when selecting the number and size of trains;
.5 Provision for future expansion should be considered in the anticipation of population growth;
.6 Automated monitoring and control systems should be provided with back-up power and operational control systems consisting of the following:
   a. Dual running PLCs with synchronized programs and memory, or spare PLCs loaded with the most current program;
   b. Spare input/output (I/O) cards of each type;
   c. A minimum of two human machine interfaces (HMI); and
   d. Backup power.

8.4.3 Membrane Configurations

Membrane systems come with a wide variety of configurations depending on membrane type and material, and mode of filtration. This section only provides a general overview of the commonly used membrane systems in drinking water applications. The Designer is responsible for ensuring that the selected membrane system meets the design and manufacturer’s operating requirements for the particular application.

Membranes come in different shapes and geometries which include, but are not limited to: hollow fibre, multi-bore fibre, tubular, flat sheet, and spiral-wound. Hollow-fibre and tubular membranes are the most commonly used type in MF/UF drinking water treatment applications, with tubular membranes being more common in small systems due to its low packing density and niche on tolerance of high cross-flow velocity (MWH, 2005). Flat sheet membranes in a spiral-wound configuration are most commonly used for NF and RO drinking water treatment applications.

A membrane system is further defined by the direction of filtration through the membrane, as follows:

.1 **Dead-end:** In dead-end filtration, the feed stream is directed toward and perpendicular to the membrane surface, as such water is filtered in the same direction as the feed.
   - This often results in a greater solids accumulation during the filter run and lower average flux values, when compared to that achieved in crossflow filtration; and

.2 **Crossflow**: In crossflow filtration, the feed stream is directed parallel to the membrane surface, and water is filtered in a perpendicular direction from the feed.

Each of the above membrane types can be bundled into a several membrane modules to meet the desired demand. The membrane modules are typically configured into two systems and Table 8-2 provides a comparison of the two systems.

.1 Low Pressurized Filtration System:
   a. Low pressure membrane systems use pressurized vessels to house the membrane, such that a positive pressure is applied to the feed side of the membrane to provide the driving force for the liquid to permeate through the membrane. External membranes can have either an “inside-out” or “outside-in” flow path. “Inside-out” means the feed water is conveyed into the centre of the membrane (lumen) and is filtered through the membrane surface on the channel inside diameter (ID), whereas outside-in has the feed water conveyed to the outside of a membrane fibre with filtrate passing through the membrane surface on the fibre outside diameter (OD); and

.2 Submerged Filtration System:
   a. Submerged membrane systems combine both the raw feed and membrane modules in one tank with an outside-in flow path. A negative pressure or suction is applied to the permeate side of the membrane to provide the driving force for the liquid to permeate through the membrane.

Table 8-2 Low Pressurized Filtration Compared to Submerged Filtration

Parameters	Low Pressurized Filtration Systems	Submerged Filtration Systems
Pressure	Upstream positive pressure pump (HGL)	Downstream pump (suction)
Flow configuration	Typically, dead-end	Typically, crossflow, leading to less fouling and less backwashing
Footprint	Slab on grade skids	In-slab tanks

8.4.4 Membrane Materials

Membranes can be made from either organic polymers or inorganic materials. Material selection depends on the type of membrane, quality of water and the desired finished water quality. Properties of various membrane materials are provided in Table 8-3.

Table 8-3 Properties of Various Membrane Materials

Material	pH Range	Tolerance to Chlorine (mg/L)	Maximum Temperature (°C)
Cellulose acetate [1]	3 to 6	~1	180
Polyamide [1]	2 to 12	<0.1	80
Polysulfone [1]	1 to 13	~100	150
Polyvinylidene fluoride [1] (PVDF)	2 to 10	>100	75
Aluminum oxide [2], SiC, TiO_2 (ceramic)	0 to 14	>100	>100

Note: [1] Organic; [2] inorganic

While organic membranes are more commonly used in water treatment, inorganic membranes resist compaction, high temperature, and extreme pH values and can operate under a broad range of temperatures. The major drawback of inorganic membranes is their high density and cost.

Membranes can consist of hydrophilic or hydrophobic materials (AWWA, 1992), which can have an effect on fouling; material selection should be considered with the type of feed water.

8.4.5 Rates of Filtration

The design flow rate per membrane train is a function of the total membrane surface area in the module and the flux rate selected. In determining the design flow rate, the Designer should consider:

- the loss of feed water used for backwashing and chemical cleaning;
- the lost production while a unit or train is out of service for chemical cleaning; and,
- the filtration flux (which is governed by the transmembrane pressure (TMP), fouling mechanism of the membrane, as well as its surface area).

The Designer should sufficiently size the membrane system to consider the above factors and meet the desired output. The flux rate should be selected in consultation with the membrane manufacturer and the characteristics of the source water being treated in order to achieve operation at a stable flux rate. Optimum flux rates should be selected based on pilot results considering the required design production rates with both cold and warm water. Cold water can significantly reduce the flux rate of a membrane system; hence the seasonal demands should be carefully evaluated.

Table 8-4 presents typical operating conditions of membrane systems. As the presented parameters are highly application specific, unique operating conditions should be developed through pilot testing and consultation with the manufacturer.

Table 8-4: Typical Design Criteria (sourced from Atlantic Canada)

Design Parameter	Microfiltration	Ultrafiltration	Nanofiltration	Reverse Osmosis
Flux rate (L/m^2/h)	34-170	34-170	14-34	10-34
Transmembrane pressure, TMP (kPa)	20-600	30-700	310-1,000	2,000-10,000
Recovery	90-98%	85-95%	60-75%	50-60%
Temperature range (°C)	0-35	0-35	0-35	20-35
Cleaning frequency (days)	14-90	14-90	14-180	30-360

Recovery is defined as:

$$Recovery = \frac{net\ filtrate\ production}{total\ feed} \times 100\%$$

Where net filtrate production is total filtrate production less the filtrate used for backwashing and discharged as filter-to-waste.

Membrane cleaning for reversible fouling is typically achieved through frequent backwashing and routine recovery chemical cleaning. The frequency of cleaning is highly dependent on the feed water type, filtration flux, as well as proprietary aspects of the chosen membranes. Backwashing typically occurs 1 to 4 times per hour to maintain a sustainable flux up to a certain TMP. When TMP becomes too high to maintain, recovery chemical cleaning is conducted to restore membrane permeability. The typical frequency for chemical cleaning is provided in Table 8-4. Removal rating refers to the molecule cut-off size that a membrane can reject, typically represented in microns and/or molecular weight in Daltons (Da). Refer to Section 8.4.8 – Backwash and Chemical Cleaning for further discussion on cleaning.

8.4.6 Integrity Testing

Membrane systems should be designed with a means to directly measure membrane integrity to validate the filtration efficacy (i.e. confirming the extent of membrane tears or holes remain below certain threshold to satisfy the prescribed treatment credits). Integrity testing is a requirement if the membrane process is to be considered for pathogen log reduction credits (refer to the *Guidelines for Pathogen Log Reduction Credit Assignment*). An integrity testing program should be developed in accordance with the latest edition of the USEPA's *Membrane Filtration Guidance Manual* or the guidance set out in *ANSI/NSF Standard 419 – Public Drinking Water Equipment Performance - Filtration*.

There are two basic types of integrity testing:

.1 Continuous indirect integrity testing:

a. Indirect integrity testing methods using water quality parameters such as turbidity, particle counts, DOC and/or conductivity should be routinely performed and should be on-line where possible. A filter-to-waste option should be considered in the event of a membrane integrity breach. An alarm should be provided with continuous indirect integrity testing; and

.2 Periodic direct integrity testing:

a. Direct integrity tests are typically conducted through a pressure decay test, vacuum hold, bubble point, marker solution or sonic testing.
   i. NF/RO is typically used for solids reduction, not for pathogen removal; as such, direct integrity testing is not normally provided. In the absence of direct integrity testing for NF/RO membranes, molecular markers such as Rhodamine WT or dyes may be considered with justification.

b. The required frequency of direct integrity testing will depend on the quality of the influent raw water and the robustness of the membranes. In any case, a direct integrity test should be conducted immediately following a clean-in-place (CIP) to ensure none of the fibers or seals were damaged by the cleaning solutions.

The direct integrity test upper control limit must be identified in the integrity testing program. If the upper control limit is exceeded, the direct integrity test will be reported as “failed” and the affected unit must be removed from service for further diagnostics and repairs. The plant operation manual should indicate how operators will be notified of a failed direct integrity test, how the test results data are to be saved, and any automatic shutdown procedures resulting from the failed test.

8.4.7 Filter-to-Waste Provisions

Depending on the membrane technology used, a means to filter-to-waste may be required for on-line testing during production in the event of a membrane integrity breach. Refer to Section 8.2.3 – Filter-to-Waste Provisions for general design considerations.

8.4.8 Backwash and Chemical Cleaning

The Designer should consider that chemical cleaning of membranes is required at regular intervals to slow the deterioration of available flux due to permanent fouling. Failure to apply cleaning chemicals in an optimal manner can lead to rapidly declining membrane performance and a need for early membrane replacement. Backwashing (back-pulsing) and chemical cleaning frequencies, durations and procedures should be obtained from the membrane manufacturer, based on pilot study data or similar application data.

Chemical cleaning, also known as clean-in-place (CIP), is a cleaning process in which membranes in a water treatment system are not removed from their housings (pressure vessels) or the system and are cleaned by being exposed to cleaning solutions. This is typically done using a pre-defined soaking period to dissolve the foulant rather than recirculating the cleaning solution through the cleaning system and membranes. Membrane cleaning chemicals may be highly aggressive and excessive cleaning may shorten effective membrane life. The membrane manufacturer should provide appropriate cleaning instructions to balance performance, degradation and the costs of cleaning for each specific installation.

The Designer should consider the following while designing backwash and chemical cleaning systems:

.1 The objective of the chemical cleaning process should be to restore the membrane performance to the same flux at the same transmembrane pressure (TMP) and temperature as the original design;
.2 To ensure a successful cleaning operation, cleaning chemicals should be matched to the nature of site-specific foulants and membrane material limitations.
.3 Cleaning chemicals should be NSF/ANSI Standard 60 certified;
.4 The ability to soften/demineralize and heat the water used to make up membrane cleaning solutions should be provided where required;
.5 The membrane treatment system and chemical cleaning processes should be separated using a double block and bleed arrangement. Care should be taken in the cleaning process to prevent contamination of both the raw and finished water system.
.6 Chemical cleaning systems should be designed to allow easy draining and flushing between uses to avoid cleaning solutions from being in contact with the piping systems for long periods of time;
.7 Chemical cleaning equipment should be located as close as possible to the membrane units;
.8 Provision for neutralization should be included for the spent cleaning chemicals for the membrane system. Chemical waste neutralization can be conducted in-situ or in a dedicated tank, depending on the application; and
.9 A means to flush the system to waste following chemical cleaning should be provided to prevent contamination of finished water.

8.4.9 Monitoring Equipment

8.4.9.1 *Flow Metering Systems*

Flow meters should be provided to directly or indirectly continuously monitor:

.1 The main raw water supply line (or individual train raw water supply lines) to measure the feedwater volume entering the membrane system and for flow pacing of any pre-treatment chemicals;
.2 Individual permeate lines from each membrane train to measure the filtration rate and volume of each train, and pace post disinfection chemicals;
.3 Individual reject or concentrate lines from each train to measure the flow rate and volume of waste stream water for calculating the overall recovery rate of the train;
.4 Individual backwash lines (or use of the permeate flow meters) to measure the backwash flow rate and volume;
.5 The combined filter effluent line and/or the distribution main header leaving the plant;
.6 Dosing of pre-treatment chemicals; and
.7 Total raw and filtrate flow for determination of system/unit production rate and recovery.

8.4.9.2 *On-line Metering*

The Designer should consider the following while designing on-line metering:

.1 An on-line turbidimeter should be provided on the common feed water line to the membrane trains;
.2 The filtrate from each membrane unit (synonymous with “train”, “skid”, and “rack”) should be independently monitored on a continuous basis when operating. On-line turbidimeter instruments should therefore be provided on the permeate discharge from each membrane train;

.3 The provision of particle counters may be considered on a per train basis. Sample point connections should be provided at each rack or cassette for connection of a portable particle counter to aid in troubleshooting in the event of a fibre breakage; and

.4 Provisions should be made for pH and chlorine residual measurement, either on-line or at convenient sample points, on each membrane CIP tank to monitor the cleaning solution concentrations. When protein fouling from biofilm on the membrane requires the use of protease enzyme solutions, strength measuring techniques, as recommended by the manufacturer, should be applied.

8.4.9.3 *Other Monitoring Systems*

Additional considerations for other monitoring systems include:

.1 Pressure gauges and transmitters should be provided on each membrane train to measure transmembrane pressures for monitoring the rate of fouling and to initiate chemical cleaning, and backpulse pressures to avoid over pressurization and damage to the membrane fibres; and

.2 Direct integrity testing results should be continuously monitored and recorded.

8.4.9.4 *Alarms*

Systems should be provided with alarms, communication systems, and automatic shutdown processes. At a minimum, the following alarms should be provided:

.1 High raw and filtrate turbidity;
.2 Pump failure;
.3 Direct integrity test failure (upper control limit exceedance);
.4 High TMP;
.5 Program Logic Controller (PLC) failure;
.6 Membrane unit shutdown;
.7 Clear well level high and low;
.8 Equipment failure;
.9 High and low chlorine residual;
.10 Low chemical level;
.11 Power failure; and
.12 Building low temperature.

8.4.10 Ancillary Equipment

The Designer should specify or ensure that the membrane manufacturer contractual commitment includes the following ancillary equipment:

8.4.10.1 *Feed Water or Permeate Pumps, Blowers & Compressors*

Where pumps, air blowers and compressors are employed, the number of duty pumps, air blowers and compressors required will depend on the number of process trains selected and the anticipated range of flows. A standby unit should be available for any process train in the event one of the duty units is out of service for maintenance or repair. For small systems with adequate storage, the use of “shelf-spares” in place of standby units may be considered acceptable. The Designer should also consider the efficiency of pumping and blower equipment, as these are energy intensive processes and operation may be continuous or semi-continuous.

8.4.10.2 *Isolation Valves & Unions*

The size of the individual modules is such that it is often impractical to isolate individual membrane modules. Instead, isolation valves are to be provided to isolate individual trains and membrane assemblies, or subsections of the membrane assemblies.

8.4.10.3 *Piping and Automated Valves*

Some membrane systems operate over a wide range of pressures and have a significant number of automated valves. Select piping materials, restraints, and actuator speed controls suitable for the intended materials, service and to prevent water hammer. The Designer should ensure that the valves and piping are suitable for a wet and chlorine-heavy environment. Valves and actuators should be suitable for multi-cycle operation rather than modulation/shut-off only, where required.

8.4.10.4 *Chemical Feed Systems*

Chemical feed systems should have standby pumping units. Refer to Chapter 13 – Chemical Application for the storage and safe handling of chemicals. The Designer should also consult the manufacturer regarding the design of HVAC systems, the provision of means for access to, removal of and repair of membrane modules, valves and instrumentation.

8.4.11 Cross Connection Control

Cross connection control considerations should be incorporated into the system design, particularly with regard to chemical feeds and the waste piping used for membrane cleaning (particularly clean-in-place), the waste stream and concentrate. Refer to Section 5.8 – Cross Connections and Backflow Prevention for backflow prevention options and resources.

8.4.12 Residuals

The Ministry of Environment and Climate Change Strategy should be consulted, as early as possible, when considering the use of membrane technologies, to determine environmentally acceptable options for disposal of waste streams from both pilot scale and full-scale membrane plants. Neutralization of the cleaning solutions should be provided, either directly in the process tank where the CIP has taken place, or the solutions should be transferred into a holding tank to ensure sufficient time for neutralization and monitoring prior to disposal. Refer to Chapter 14 – Waste Residuals Handling and Treatment for reference to residuals handling.

8.5 Biological Filtration

Biological treatment within a filter (i.e. a biofilter) at a drinking water treatment facility is an operational practice of managing, maintaining, and promoting biological activity on granular media in the filter to enhance the removal of organic and inorganic constituents before treated water is introduced into the distribution system. This section is specific to aerobic biofiltration. Anaerobic/anoxic biofiltration is not widely used in B.C., however, it may be used for specific dissolved contaminants including nitrate, perchlorate, selenite, chromate and VOCs. Aerobic biofiltration is typically used for the removal of iron, manganese or ammonia. Refer to the *Ten States Standards* for further details (policy statements) on anoxic biofiltration and biofiltration for groundwater.

Typical objectives of biofiltration include the following:

.1 Reduction of specific inorganic contaminants and/or natural organic matter;
.2 Increased disinfectant stability;
.3 Taste and odour (T&O) control;
.4 Reduction of substrates for microbial regrowth in the distribution system; and
.5 Control of disinfection by-product (DBP) precursors.

Naturally occurring biomass is allowed to accumulate by limiting or eliminating the pre-disinfectant residual, most commonly chlorine, in the filter influent or in the backwash water. For biological degradation of organics and inorganics to take place in aerobic biofilters, there needs to be sufficient oxygen in the filter influent to maintain the biomass. Design of biologically active filters should ensure that aerobic conditions are maintained at all times. Bio-filters that are taken off-line or put in standby can turn anoxic leading to water quality and taste & odour issues.

Biological filtration may include the use of ozone as a pre-oxidant to break down more complex organic matter into biodegradable organic matter. If ozone is placed upstream of a granular media filter, some recalcitrant organics may be degraded to more readily biodegradable compounds. Additionally, the dissolved oxygen concentration in the filter influent will be elevated. Typically, any filter downstream of ozonation will be an aerobic biological filter.

It is important to note that biological activity within a filter can have adverse effects on turbidity and microbial pathogen removal, head loss development, filter run times and distribution system corrosion. To mitigate these effects, consideration should be given to providing regular and frequent backwashing cycles as described in Section 8.5.6 – Backwash.

Biofiltration uses media to provide surface area onto which bacteria can adhere and grow. Common media includes sand, anthracite, granular activated carbon (GAC) and expanded clay. GAC media may be used to support denser biofilms due to its high surface area and tends to provide greater biological activity than sand or anthracite in cold water application. In very cold water conditions (< 5 °C) the metabolic rate and biological activity can slow to very low rates.

8.5.1 Filter Design

Biofilters are typically rapid rate gravity filters in surface water treatment plants where the primary objective is particle control. In such filters, biological treatment is always the secondary objective. Design criteria presented in Section 8.2 – Rapid Rate Gravity Filtration for rapid rate gravity filters should be applied with consideration for filtration rate, media type and depth to support the biological activity and particle capture. Pressure filtration should not be used for biological filtration, except where biological filtration is targeting specific contaminants for removal (e.g. iron, manganese).

8.5.2 Empty Bed Contact Time

Constituent removal is strongly impacted by the length of time that the water is in contact with the microbial community in the filter. Empty bed contact time (EBCT) is defined as the volume of the filter bed occupied by the media (including porosity volume) divided by the flow rate. Empty bed contact time should be determined by a pilot study based on treatment objectives. Filter media depths greater than 760 mm may be allowed if supported by the results of a pilot study. A longer empty bed contact time may be required when the water is cold (e.g. less than 15 °C). Empty bed contact times typically range between 5 and 20 minutes.

8.5.3 Media Selection

Sand, anthracite, and granular activated carbon (GAC) can be used as filter media for aerobic biofiltration. Granular activated carbon media is commonly used due its large surface area to volume ratio. Use of media with an effective size of less than 0.45 mm should be avoided.

8.5.4 Filter Bottoms and Strainer Systems

Filter bottoms with small openings may be prone to clogging. Porous plate bottoms should not be allowed. Evidence that the proposed filter bottom has successfully been used in the past with biofilters or pilot testing of the proposed underdrain may be required. Section 8.2.9 – Filter Underdrains and Strainer Systems also applies for biological filtration.

8.5.5 Pre-treatment

Pre-treatment prior to biofiltration such as coagulation, clarification, filtration or water pre-conditioning should take into consideration the effect on the downstream biofilter performance.

Chemical addition (such as ozone or peroxide) upstream of a rapid rate filter may promote biological activity on the granular filter media and increase the dissolved oxygen concentration; however, sufficient mixing and reaction time should be provided to avoid adverse effects on the microorganisms. Additional chemicals may be added to promote biological oxidation, biological activity, or reduce head loss. Refer to Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification for design considerations.

If performance of the biofilter is not meeting desired goals, testing for a DO, ORP or micronutrient limitation should be conducted. DO, pH and micronutrient dosing may be applied to achieve optimum conditions for biofiltration (i.e. phosphoric acid for phosphorus, ammonia for nitrogen, etc.). If head loss is significant, a low dose of a pre-oxidant should be considered. Designers may refer to *Biofiltration Guidance Manual for Drinking Water Facilities* by the Water Research Foundation for more information.

8.5.6 Backwash

Backwashing design should follow Sections 8.2.12 – Backwash and Section 8.2.13 – Air Scouring, and include the following:

.1 The ability to add chlorine or other approved chemicals to the backwash;
.2 Backwash air scour system;
.3 Filter-to-waste piping; and
.4 Backwash waste residuals management.

The particular backwash strategies can have a significant effect on the performance of a biofilter. Combined air and water backwash is often used to provide sufficient scouring energy to detach excess biomass from the media surface, while sub-fluidization has been used to shorten the filter ripening time after backwash. Non-chlorinated backwash water is usually needed to preserve high levels of biological activity after backwashing. Filter effluent may have decreased biological stability (i.e. increased heterotrophic plate counts) and may require treatment.

8.5.7 Monitoring and Control

In addition to the laboratory equipment listed in Section 5.4 – Monitoring Equipment and Laboratory Facilities, test equipment for the following parameters should be provided for online measurements:

.1 Dissolved oxygen concentration at the influent and effluent of the filter;
.2 Oxidation-reduction potential; and
.3 Temperature.

Test equipment for the following parameters can be provided for offline measurements:

.1 Biological indicator organisms (total coliform, heterotrophic plate count, etc.);
.2 The contaminant targeted for biological treatment; and
.3 Additional parameters as required.

Biofiltration and the associated pre- and post-treatment and residuals treatment may require advanced operator skill and training. Consideration should be made for the EOCP classification of the water treatment plant design and the resulting Operator certification that will be required.

8.6 Diatomaceous Earth Filtration

The use of diatomaceous earth filters may be considered for application to surface waters with low turbidity and low bacterial contamination. The Designer should refer to the *AWWA Manual of Water Supply Practices M30 – Precoat Filtration* and the *Guidelines for Pathogen Log Reduction Credit Assignment* for more information on the design and pathogen log reduction credit assignment criteria for diatomaceous earth filtration processes.

8.6.1 Conditions of Use

Diatomaceous earth filters should not be used for the following conditions:

.1 Colour removal for high total colour exceeding 5 TCU;
.2 Turbidity removal where either the gross quantity of turbidity is high (exceeds 5 NTU), or the turbidity exhibits poor filterability characteristics; and
.3 Filtration of waters with high algae counts.

8.6.2 Types of Filters

Pressure or vacuum diatomaceous earth filtration units will be considered for approval. However, the vacuum type is preferred as it permits observation of the filter surfaces: this allows the operator to determine whether there is proper cleaning, damage to a filter element, and adequate coating over the entire filter area.

8.6.3 Treated Water Storage

Treated water storage capacity in excess of normal requirements should be provided to:

.1 Allow operation of the filters at a uniform rate during all conditions of system demand at or below the approved filtration rate, and;

.2 Guarantee continuity of service during adverse raw water quality conditions without by-passing the system.

8.6.4 Number of Units

At least two units should be provided. Where only two units are provided, each unit should be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters should be capable of meeting the plant design capacity at the approved filtration rate with the largest filter removed from service.

8.6.5 Pre-coat

.1 Application - A uniform pre-coat should be applied hydraulically to each septum by introducing a slurry to the tank influent line and employing a filter-to-waste or recirculation system; and

.2 Quantity - Pre-coat should use 0.98 kg diatomaceous earth/m^2 of filter area, or an amount sufficient to apply a 3.175 mm-thick coating.

8.6.6 Body Feed

A body feed system to apply additional amounts of diatomaceous earth slurry during the filter run is required to avoid short filter runs or excessive head losses.

.1 Quantity - The rate of body feed is dependent on raw water quality and characteristics, and should be determined in the pilot plant study;

.2 Operation and maintenance can be simplified by providing accessibility to the feed system and slurry lines; and

.3 Continuous mixing of the body feed slurry is required.

8.6.7 Filtration

.1 Rate of filtration - The recommended nominal rate is 2.4 m/h, with a recommended maximum of 3.7 m/h; however, filtration rates should be confirmed through pilot testing. The filtration rate should be controlled by a positive means;

.2 Head loss - The head loss should not exceed 210 kPa (30.5 psi) for pressure diatomaceous earth filters, or a vacuum of 38.1 cm of mercury (-51 kPa or -7.4 psi) for a vacuum system;

.3 Recirculation - A recirculation or holding pump should be employed to maintain differential pressure across the filter when the unit is not in operation in order to prevent the filter cake from dropping off the filter elements. A minimum recirculation rate of 0.24 m/h should be provided;

.4 Septum or filter element - Filter elements should be structurally capable of withstanding maximum pressure and velocity variations during filtration and backwash cycles and should be spaced such that no less than 2.5 cm is provided between elements or between any element and a wall; and

.5 Inlet design - The filter influent should be designed to prevent scour of diatomaceous earth from the filter element.

8.6.8 Backwash

A satisfactory method to thoroughly remove and dispose of spent filter cake should be provided.

8.6.9 Appurtenances

The following should be provided for every filter:

.1 Sampling taps for raw and filtered water;
.2 Loss of head or differential pressure gauge;
.3 Rate-of-flow indicator, preferably with totalizer;
.4 A throttling valve used to reduce flow rates below normal during adverse raw water quality conditions;
.5 Evaluation of the need for body feed, recirculation, and any other pumps, in accordance with Chapter 18 – Pumping Facilities;
.6 Provisions for filtering to waste with appropriate measures for backflow prevention, refer to Section 5.8 – Cross Connections and Backflow Prevention; and
.7 A continuously monitoring turbidimeter with recording on each filter effluent, as required for the assignment of pathogen log reduction credit.

It is recommended that the following be provided:

.1 A 2.54 - 3.81 cm diameter pressure hose and storage rack at the operating floor for washing the filter;
.2 Access to particle counting equipment as a means to enhance monitoring and overall treatment operations; and,
.3 A flow rate controller capable of providing gradual rate increases when placing the filters back into operation.

8.7 Cartridge and Bag Filtration

Cartridge filtration is a pressure-driven physical separation process that removes particles greater than 1 µm using a porous filtration medium. Cartridge filters are typically made of a semi-rigid or rigid wound filament that is housed in a pressure vessel in which water flows from the outside of the cartridge to the inside. Cartridge filtration systems can be constructed with either single or multiple filters within one pressure vessel.

Cartridge filtration is ideally suited for small drinking water systems with low flow requirements. The use of cartridge filters should be limited to source water (or pre-treated influent) having a maximum turbidity of 5 NTU and maximum colour of 5 TCU. To reduce the frequency of filter replacement, cartridge filters are typically used in series with decreasing pore sizes.

When using cartridge filters of appropriate pore size, these filters can effectively remove particles from water in the size range of *Cryptosporidium* oocysts (2-5 microns) and *Giardia* cysts (5-10 microns). Cartridge filters with a rating of ‘1 micron absolute’ may be eligible for pathogen log reduction credits; refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* for more details.

It should be noted that the particulate loading capacity of these filters is low, and once expended, the cartridge filter should be discarded and replaced. With this in mind, the operational and maintenance cost of cartridge replacement should be considered during system design.

Cartridge filters can be supplied with media for removal of specific water quality parameters, such as activated carbon for taste and odour control, or oxidizing/catalytic media for iron, manganese or hydrogen sulphide removal.

Bag filters are typically constructed of a woven bag or fabric filtration medium that is placed in a pressure vessel. As water flows from the inside of the bag to the outside, contaminants are filtered out of the water. Bag filters are not eligible for pathogen log reduction credits but may be used as pre-treatment for other unit processes.

Refer to the latest edition of the USEPA's *LT2ESWTR Toolbox Guidance Manual* for system design and operation.

8.7.1 Design Guidelines

The following items should be considered in evaluating the applicability of cartridge filtration:

.1 The filter housing and cartridge filter should demonstrate a filter efficiency of at least 3-log reduction in *Cryptosporidium* or surrogate particles size 1 micron and above. Demonstration of higher log removals may be required depending on raw water quality and other treatment steps to be employed. Recommended methods for filtration efficiency demonstration include:
   a. *Cryptosporidium* removal evaluation in accordance with the procedures specified in NSF/ANSI Standard 53 *Drinking Water Treatment Units – Health Effects* or equivalent. These evaluations should be conducted by NSF or by another third-party organization that is accredited to certify equipment to NSF/ANSI Standard 53 in Canada;
   b. The *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* procedure specified by the EPA/NSF Environmental Technology Verification Program;
   c. The challenge testing procedure for cartridge filters presented in Chapter 8 of the *Long Term 2 Enhanced Surface Water Treatment Rule Toolbox Guidance Manual*;
   d. "Non-consensus" live *Cryptosporidium* challenge studies that have been designed and carried out by a third-party agent recognized for interim evaluations. At the present time uniform protocol procedures for live *Cryptosporidium* challenge studies have not been established;

.2 The design flow should be determined in consultation with the manufacturer specifications and confirmed with pilot testing;

.3 Pilot testing may be required with a full-scale filter element at the design maximum flux, and should be set up to provide an assurance of practical filter element life;

.4 System components coming into contact with water, such as filter housing, bags, cartridges, membranes, gaskets, and O-rings, should be certified to *NSF Standard 61 Drinking Water System Components – Health Effects* or equivalent;

.5 The flow rate through the treatment process should be monitored with a flow valve and meter. The flow rate through bag/cartridge filters should not exceed the maximum flow rate verified by filtration efficiency testing;

.6 Pressure gauges and sampling taps should be installed before and after the bag or cartridge filter. The pressure differential across the cartridge filter should not exceed the manufacturer's rating;

.7 An automatic air release valve should be installed on top of the filter housing;

.8 Frequent start and stop operation of the bag or cartridge filter should be avoided. To avoid this frequent start and stop cycle the following options are recommended:
  a. A slow opening and closing valve ahead of the filter to reduce flow surges;
  b. Reduce the flow through bag or cartridge filters to as low as possible to lengthen filter run times;
  c. Install a recirculating pump that pumps treated water back to a point ahead of the bag or cartridge filter. Care should be taken to make sure there is no cross connection between finished water and raw water;

.9 A minimum of two bag or cartridge filter housings should be provided for water systems that provide water continuously. Each of the housings should be able to provide the full rated flow of the water treatment plant;

.10 A pressure relief valve should be incorporated into the bag or cartridge filter housing; and

.11 A plan of action should be in place should water quality parameters fail to meet GCDWQ or other applicable treated water standards.

8.7.1.1 Design of Pre-treatment for Cartridge and Bag Filtration Systems

Pre-treatment prior to cartridge or bag filtration is strongly recommended to extend cartridge life. Examples of pre-treatment include media filters, and larger pore cartridge/bag filters. The following should be considered when designing pre-treatment:

.1 The location of the raw water intake should be optimized to provide the best water quality, and may be moved to avoid the need for pre-treatment;

.2 Particle count analysis can be used to determine what level of pre-treatment should be provided. It should be noted that particulate counting is a 'snapshot' in time and that there can be seasonal variations such as algae blooms, lake turnover, spring runoff, and heavy rainfall events;

.3 Chlorine or another disinfectant may be added at the head of the treatment process to reduce/eliminate the growth of algae, bacteria, etc., on the filters. The impact on disinfection by-product formation should be considered;

.4 A filter-to-waste component is strongly recommended for pre-treatment pressure sand filters. At the beginning of each filter cycle and/or after every backwash of the pre-filters a set amount of water should be discharged to waste before water flows into the cartridge filter. Filter to waste should be provided for the final filter(s) and a set amount of water should be discharged to waste after changing the filters;

.5 If pressure media filters are used for pre-treatment, they should be designed according to Section 8.8 – Pressure Filtration;

.6 A sampling tap should be provided ahead of any treatment so a source water sample can be collected; and

.7 The filtration and backwash rates should be monitored so that the pre-filters are being optimally used.

8.7.2 Operations

The following operations criteria should be considered for cartridge and bag filters:

.1 Cartridge and bag filters should be replaced before the differential pressure exceeds the manufacturer’s rating. If unspecified by the manufacturer, 103 kPa (15 psi) should be considered as the maximum differential pressure. It should be noted that bag filters do not load linearly. Additional observation of the filter performance is required near the end of the filter run;

.2 Maintenance (O-ring replacement) should be performed in accordance with the manufacturer's recommendations;

.3 Sterile rubber gloves and a disposable face mask covering the nose and mouth should be worn when replacing or cleaning cartridge or bag filters; and

.4 Every time cartridge or bag filter vessels are opened for maintenance, the filter system should be properly disinfected, and the filter vessel water should be run to waste until disinfectant residual has been purged from the filter vessel.

8.8 Pressure Filtration

Pressure filtration is typically used in situations where an ion-selective media is used (e.g. iron and manganese removal systems) and for systems that do not require coagulation (due to the potential for floc breakup), see Chapter 15 – Parameter Specific Treatment. Pressure filtration is commonly used in small-scale applications for particle removal (as defined in Chapter 21 – Small Systems) and as a pre-treatment for nanofiltration and/or reverse osmosis filtration systems.

Pressure filtration units cannot receive pathogen log reduction credits in British Columbia and several other jurisdictions in Canada. They are generally unsuitable for filtration of surface waters, GARP, or other polluted waters. Noted issues with pressure filters include the potential for floc breakup after coagulation, the inability to observe backwash or media levels, and the loss of media during backwash.

8.8.1 Rate of Filtration

The filtration rate should not exceed 10 m/h except where pilot or full-scale testing has demonstrated satisfactory results at higher rates. Loading rates are specific to media and target contaminants.

8.8.2 Details of Design

Minimum criteria relative to the rate of filtration, structural details and hydraulics, filter media, etc., provided for rapid rate gravity filters (Section 8.2 – Rapid Rate Gravity Filtration) also apply to pressure filters where appropriate. However, detailed design criteria is often specific to media and target contaminants.

The following provides additional design considerations for pressure filtration systems:

.1 Loss of head gauges on the inlet and outlet pipes of each filter;

.2 An easily readable meter or flow indicator on each set of filters. A flow indicator is recommended for each filtering unit;

.3 Filtration and backwashing of each filter individually with an arrangement of piping as simple as possible to accomplish these purposes;

.4 Minimum side wall shell height of 1.5 m. Reduction of the inside wall height is acceptable where proprietary bottoms permit reduction of the gravel depth;

.5 The top of the backwash water collectors should be at least 450 mm above the surface of the media;

.6 The underdrain system should efficiently collect the filtered water and uniformly distribute the backwash water at a rate of not less than 37 m/h;
.7 Backwash flow indicators and controls that are easily readable while operating control valves;
.8 An air release valve on the highest point of each filter;
.9 An accessible manhole of adequate size to facilitate inspection and repairs for filters 900 mm or more in diameter. Sufficient handholds should be provided for filters less than 900 mm in diameter. Manholes should be at least 600 mm in diameter where feasible;
.10 Means to observe the wastewater during backwashing; and
.11 Construction to prevent cross connection.

9 Aeration

9.1 General

This chapter describes design considerations for aeration treatment processes which remove contaminants in water by transferring gas to the water or by vaporizing the contaminants. The selection of a particular aeration treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

Aeration is typically used in water treatment for two purposes. The first is for the transfer of a gas to water, such as in the pre-oxidation of raw water for iron and/or manganese removal. This process is known as gas absorption or aeration. The second is for vaporization of contaminants in water into an airstream, such as in the removal of hydrogen sulphide, carbon dioxide, as well as volatile organic compounds causing taste and odour in water. This process is typically known as gas desorption or air stripping.

Because aeration and air stripping are gas-liquid contact processes, the Designer should consider contaminant transfer efficiency, off-gas disposal issues, available hydraulic head, ease of operation, and capital and operating/maintenance costs during treatment evaluation.

This chapter provides guidance for the following aeration methods that are typically used in water treatment:

.1 Natural draft aeration;
.2 Forced or induced draft aeration;
.3 Spray aeration;
.4 Pressure aeration; and
.5 Packed tower aeration.

Other methods of aeration may be used if applicable to the treatment needs. Such methods include, but are not restricted to: diffused air, cascades, and mechanical aeration. The treatment processes should be designed to meet the particular needs of the water to be treated. These methods may require pilot testing to validate treatment.

Where practical, aeration should be applied ahead of treatment. When aeration is required at the end of treatment (such as in air stripping of trihalomethanes), filtration of the source air will be required to prevent contamination of treated water. The materials used in the construction of the aerator(s) should meet *NSF/ANSI Standard 61: Drinking Water System Components – Health Effects*.

In air stripping for methane, due to the relatively low solubility of methane in water, even a splash plate type aerator may provide sufficiently effective treatment. Appropriate ventilation should be provided to ensure that methane concentrations do not reach the Lower Explosive Limit (LEL).

Air stripping for hydrogen sulphide removal has specific limitations, as carbon dioxide is also stripped, leading to pH increases and the potential for scaling. Pilot testing should be conducted to ensure sulphide levels can be sufficiently reduced without causing scaling issues. If air stripping cannot be used, alternative chemical processes to reduce sulphide concentrations to inoffensive levels should be considered. The feasibility of aerators or air strippers should be evaluated through piloting.

9.2 Piloting Requirements

All aeration systems should be piloted to evaluate a variety of loading rates and air-to-water ratios at the peak contaminant concentration. Consideration needs to be given to removal efficiencies, oxidation rates or scaling due to incidental carbon dioxide stripping when multiple contaminants are present. Note that aeration effectiveness will depend on dissolved gases (mainly DO and CO_2), pH and temperature. Also, note that care should be applied with respect to the gas saturation levels in water that will be further treated by downstream processes. Super-saturation of gases can result in "air-binding" in downstream filters.

Piloting may not be required where sufficient past performance data demonstrates the feasibility of the process for a specific contaminant and at a similar concentration level.

9.3 Natural Draft Aeration

The design should provide:

.1 Perforations in the distribution pan 5 mm to 12 mm in diameter, spaced 25 mm to 75 mm on centers to maintain a 150 mm water depth;
.2 Distribution of water uniformly over the top tray; in some cases, these trays may be designed with a pebble type media to help distribute flow and/or promote precipitation of metals in raw water;
.3 Discharge through a series of three or more trays with separation of trays not less than 305 mm;
.4 Loading at a rate of 2.5 - 12.5 m/h depending on the application and as demonstrated by pilot testing;
.5 Trays with slotted heavy wire (12 mm openings) mesh or perforated bottoms;
.6 Construction of durable material resistant to the aggressiveness of the water and dissolved gases;
.7 Protection from loss of spray water by wind carriage by enclosure with louvres sloped to the inside at an angle of approximately 45°;
.8 Air intake protection with 24-mesh screen and cover, i.e. louvre or shroud, accessible for maintenance and inspection. Frost protection should be considered for cold climate applications; and
.9 Provisions for continuous disinfection feed should be provided after aeration.

9.4 Forced or Induced Draft Aeration

Devices should be designed to:

.1 Include a blower with a weatherproof motor in a tight housing and screened enclosure;
.2 Ensure adequate counter current flow of air through the enclosed aerator column;
.3 Exhaust air directly to the outside atmosphere;
.4 Ensure air intake and outlet are protected with 24-mesh screen and cover, i.e. louvre or shroud, and are accessible for maintenance and inspection and should be down turned;
.5 Introduce air free from noxious fumes, dust, and dirt;

.6 Allow easy access to the aerator for maintenance and inspection of the interior;
.7 Provide loading at a rate of 2.5 - 12.5 m/h depending on the application and as demonstrated by pilot testing;
.8 Ensure that the water outlet is adequately sealed to prevent unwarranted loss of air;
.9 Discharge through a series of five or more trays with separation of trays not less than 150 mm. Alternatively, air-water surface contact may be achieved with plastic media (packing), or spraying system (see Section 9.5 – Spray Aeration);
.10 Provide distribution of water uniformly over the top tray;
.11 Be of durable material resistant to the aggressiveness of the water and dissolved gases; and
.12 Provide for continuous disinfection feed after aeration.

9.5 Spray Aeration

The design should provide:

.1 A hydraulic head between 1.5 to 8 m;
.2 Nozzles, with the size, number, and spacing of the nozzles being dependent on the flow rate, space, and the amount of head available;
.3 Nozzle diameters in the range of 25 to 40 mm to minimize clogging and provide good air-water surface contact;
.4 An enclosed basin to contain the spray. Any openings for ventilation should be protected with 24-mesh screen and cover, i.e. louvre or shroud and be accessible for maintenance and inspection; and
.5 Continuous disinfection feed after aeration.

9.6 Pressure Aeration

Pressure aeration may be used for oxidation purposes only if a pilot plant study indicates the method is applicable. This process is not acceptable for removal of dissolved gases. Filters following pressure aeration should have adequate exhaust devices for release of air. Pressure aeration devices should be designed to:

.1 Give thorough mixing of compressed air with the water being treated; and
.2 Provide screened and filtered air, free of noxious fumes, dust, dirt and other contaminants.

9.7 Packed Tower Aeration

Packed tower aeration (PTA), also known as air stripping, involves passing water through a column of packing material while pumping air counter-currently up through the packing. PTA is used for the removal of volatile organic compounds, trihalomethanes, carbon dioxide, radon, as well as the control of methane and/or hydrogen sulphide in groundwater.

Generally, PTA is feasible for compounds with a Henry's Constant greater than 100 atm mol/mol at 12 °C, and not normally viable for removing compounds with a Henry’s Constant less than 10. For values between 10 and 100, PTA may be feasible but should be evaluated using pilot studies. Values for Henry's Constant should be identified early in the design.

9.7.1 General Packed Tower Aeration Considerations

The following items should be considered when designing a PTA system:

.1 A sufficient number of access ports with a minimum diameter of 600 mm to facilitate inspection, media replacement, media cleaning, and maintenance of the interior;
.2 A method of cleaning the packing material when fouling occurs;
.3 Tower effluent collection and pumping wells constructed according to the recommendations for clearwells discussed in Chapter 17 – Water Storage;
.4 Provisions for extending the tower height without major reconstruction;
.5 An acceptable alternative supply of water during periods of maintenance and operation interruptions;
.6 Disinfection application points both ahead of and after the tower to control biological growth;
.7 Adequate contact time for disinfection after the water has passed through the tower and prior to the distribution system. Refer to Chapter 11 – Disinfection;
.8 Adequate packing support to allow free flow of water and to prevent deformation with deep packing heights;
.9 Standby power to allow operation of the blower and disinfectant feeder equipment during power failures;
.10 Adequate foundation to support the tower and lateral support to prevent overturning due to wind loading;
.11 Fencing and a locking gate to prevent vandalism;
.12 An access ladder with safety cage for inspection of the aerator including the exhaust port and de-mister;
.13 Electrical interconnection between blower, disinfectant feeder and well pump;
.14 The following environmental items should be considered:
  a. The applicant should contact local regulatory authorities to determine if permits are required for the air discharge; and
  b. Noise control facilities should be provided on PTA systems located in residential areas.

9.7.2 Process Design

.1 Process design for PTA involves the determination of Henry's Constant for the contaminant, the mass transfer coefficient, air pressure drop and stripping factor. Pilot plant testing may be required. The Designer should provide justification for the design parameters selected, including:
  a. height and diameter of unit;
  b. air to water ratio;
  c. packing depth; and
  d. surface loading rate.
.2 Water loading rates should be in the range from 37 to 73 m/h, however the pilot test should evaluate a variety of loading rates and air to water ratios at the peak contaminant concentration. Special consideration should be given to removal efficiencies when there are multiple contaminants.
.3 The tower should be designed to reduce contaminants below the maximum acceptable concentration (MAC) and to the lowest practical level;
.4 The ratio of the packing height to column diameter should be at least 7:1 for the pilot unit and at least 10:1 for the full-scale tower. The type and size of packing used in the full-scale unit should be the same as that used in the pilot test;
.5 The minimum volumetric air to water ratio at peak water flow should be 25:1 and the maximum should be 80:1;

.6 The design should consider potential fouling problems from calcium carbonate, iron precipitation and bacterial growth. Where fouling is expected or demonstrated by the pilot, it may be necessary to provide pre-treatment. Disinfection capability should be provided prior to and after PTA; and

.7 The effects of temperature should be considered since a drop-in water temperature can result in a drop in contaminant removal efficiency.

9.7.3 Materials of Construction

.1 The tower can be constructed of stainless steel, concrete, aluminum, fiberglass or plastic. Uncoated carbon steel is not recommended due to corrosion. Towers constructed of light-weight materials should be provided with adequate support to prevent damage from wind; and

.2 Packing materials should be resistant to the aggressiveness of the water, dissolved gases and cleaning materials, and should be suitable for contact with potable water.

9.7.4 Water Flow System

.1 Water should be distributed uniformly at the top of the tower using spray nozzles or orifice-type distributor trays that prevent short circuiting. For multi-point injection, one injection point for every 190 cm^2 of tower cross-sectional area is recommended;

.2 A mist eliminator should be provided above the water distributor system;

.3 A side wiper redistribution ring should be provided at least every 3 m in order to prevent water channeling along the tower wall and short circuiting;

.4 Sample taps should be provided in the influent and effluent piping;

.5 The effluent sump, if provided, should have easy access for cleaning purposes and be equipped with a drain valve. The drain should not be connected directly to any storm or sanitary sewer;

.6 A blow-off line should be provided in the effluent piping to allow for the discharge of water/chemicals used to clean the tower;

.7 The design should prevent freezing of the influent riser and effluent piping when the unit is not operating. If piping is buried, it should be maintained under positive pressure;

.8 The water flow to each tower should be metered;

.9 An overflow line should be provided which discharges 300 to 350 mm above a splash pad or drainage inlet. Proper drainage should be provided to prevent flooding of the area;

.10 Butterfly valves may be used in the water effluent line for better flow control, as well as to minimize air entrainment;

.11 Means should be provided to prevent flooding of the air blower; and

.12 The water influent pipe should be supported separately from the tower's main structural support.

9.7.5 Air Flow System

.1 The air intake and outlet vent should be protected with 24-mesh screen and cover, i.e. louvre or shroud, and be accessible for maintenance and inspection;

.2 The air inlet should be in a location protected from airborne contaminants;

.3 An air flow meter should be provided on the influent airline or an alternative method to determine the air flow should be provided;

.4 A positive air flow sensing device and a pressure gauge should be installed on the air influent line;

.5 The positive air flow sensing device should be a part of an automatic control system which will turn off the influent water if positive air flow is not detected. The pressure gauge will serve as an indicator of fouling build-up; and

.6 A backup motor for the blower or standby blower should be readily available.

9.8 Protection of Aerators

All aerators, except those discharging to the influent lines of surface water treatment plants, should be protected from contamination by birds, insects, wind borne debris, rainfall and water draining off the exterior of the aerator.

9.9 Groundwater Disinfection

Groundwater supplies exposed to the atmosphere by aeration should be disinfected. Disinfection should meet the guidelines set out in Chapter 11 – Disinfection and provincial treatment objectives.

9.10 Bypass

A bypass should be provided for all aeration units except those installed to comply with maximum contaminant levels. The use of a bypass should also be reviewed against the ability to operate the process train without the aeration unit.

9.11 Corrosion Control

The aggressiveness of the water after aeration should be determined and corrected by additional treatment, if necessary (see Chapter 12 – Internal Corrosion Control).

9.12 Monitoring

Equipment should be provided to test for DO, pH, and temperature to determine proper functioning of the aeration device. Equipment to test for iron, manganese, and carbon dioxide should also be considered where aeration is used for removal of these parameters.

9.13 Redundancy

Redundant equipment should be provided for units installed as per best practices.

10 Taste and Odour Control

10.1 General

This chapter describes design considerations for taste and odour control treatment processes. The selection of a particular taste and odour control treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

As taste and odour cannot be measured objectively, a maximum acceptable limit for drinking water has not been specified. However, taste and odour can often be a large source of customer complaints (Health Canada, 2005).

Taste and odour in surface water is often caused by the breakdown of organic material and/or the production of volatile organic compounds (specifically geosmin and 2-methylisoborneol, 2-MIB) by cyanobacteria (blue-green algae) and other microorganisms. Taste and odour in groundwater can often be attributed to hydrogen sulphide (H_2S, which is frequently characterized as a rotten-egg odour), reduced iron and manganese, and high total dissolved solids (TDS).

Taste and odour reduction and control can be accomplished at the source, in the treatment plant, and to a certain extent in the distribution system. Provisions should be made for the control of taste and odour at all treatment plants where needed. Chemicals should be added to ensure adequate contact time for effective and economical use of the chemicals. Where taste and odour problems are encountered, full scale and/or pilot plant studies should be considered to determine the best treatment process(es).

For taste and odour attributed to cyanobacteria, refer to Chapter 15 – Parameter Specific Treatment. Additionally, reference should be made to the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Documents – Odour* (1979), and *Taste* (2005) by Health Canada.

For taste and odour attributed to high TDS, reverse osmosis is the recommended treatment approach. Refer to Chapter 8 – Filtration.

10.2 Common Treatment Options

The following section describes common treatment options that may be considered for treatment of the taste and odour problems.

10.2.1 Powdered Activated Carbon

Use of powdered activated carbon (PAC, activated carbon with mean particle size of 20-50 µm) can be considered for taste and odour control, particularly for organics including geosmin and MIB. PAC is used as a continuously fed additive that must be removed following the required contact time, but before primary disinfection, by processes such as filtration. Reference to *AWWA B600 – Powdered Activated Carbon* should be made for design of PAC systems.

The following should be considered when designing PAC systems:

.1 PAC should be added as early as possible in the treatment process to provide maximum contact time. Flexibility to allow the addition of carbon at several points is preferred;
.2 PAC should not be applied near the point of chlorine or another oxidant application;
.3 PAC can be added as a pre-mixed slurry or by means of a dry-feed machine as long as the carbon is thoroughly wetted before its introduction to the water to be treated;
.4 Continuous agitation or resuspension equipment should be provided to keep the PAC from depositing in the slurry storage tank;
.5 The required rate of feed of carbon in a water treatment plant depends upon the tastes and/or odours involved and the contact time available, but provision should be made for adding from 0.1 mg/L to 40 mg/L;
.6 Pilot scale testing is recommended to determine contact time and the range of dosages required;
.7 PAC should be considered potentially combustible material and should be stored in a separate fire-retardant building or room, equipped with explosion proof outlets, lights and motors; and
.8 Provision should be made for adequate dust control.

10.2.2 Granular Activated Carbon

Granular activated carbon (GAC or activated carbon with mean particle size of 0.5 - 3.0 mm), like PAC, is also a common taste and odour control measure for organics (including geosmin and MIB). However, its application differs from PAC:

.1 GAC can be used in place of anthracite in granular filters (see Chapter 8 – Filtration) or in separate contactors;
.2 When GAC is used as a layer in filters, the GAC cannot be removed from service or by-passed during periods when tastes and odours are not a problem. This potentially shortens the life of the GAC for taste and odour control as other compounds are adsorbed onto the active sites on the carbon. GAC contactors, however, can be bypassed in winter months to extend the effective bed life;
.3 The empty bed contact time (EBCT) required for taste and odour control depends on the nature of the taste and odour compounds and typically varies from 10 to 30 minutes. Pilot testing is recommended to determine EBCT and expected bed operation life. Where the contaminant to be controlled is present only in short term seasonal excursions, pilot work may be useful to indicate effective bed life and the potential need for off-line contactors;
.4 After filter breakthrough of the taste and odour compounds, GAC media must be removed for regeneration and replaced in order to maintain taste and odour treatment; and
.5 GAC filters should meet the requirements of Chapter 8 – Filtration.

10.2.3 Copper Compounds

Copper compounds (including copper sulphate and chelated copper algaecides) have been used for the treatment of water to kill algae or other growth, and therefore minimizing taste and odour in the source water. The use of copper algaecides is not recommended for blue-green algae (cyanobacteria) control due to the risk of cell lysis (breakage and subsequent release of cyanotoxins). However, it could be incorporated into a multi-treatment approach for algae reduction with other appropriate means of removing dissolved cyanotoxins during subsequent water treatment.

Application of algaecides needs to occur when potentially toxic species are at relatively low densities so that large releases of toxin into the water source do not occur. All the aforementioned mitigation methods are most effective in small water bodies.

The following should be considered if using copper compounds:

.1 Continuous or periodic treatment of water with copper compounds should be controlled to prevent copper in excess of 1.0 milligram per litre as copper in the plant effluent or distribution system;
.2 Care should be taken to ensure that there is an even distribution of the chemical within the treatment area;
.3 Necessary approval and/or permits should be obtained prior to application, if required. Consult the responsible regulatory agencies (BC Ministry of Water, Land and Resource Stewardship) before making applications to public waters;
.4 Algaecidal power of copper sulphate depends on pH, alkalinity, and dissolved organic carbon in water; for example, copper sulphate has low effectiveness in hard, alkaline water;
.5 The BC Ministry of Water, Land and Resource Stewardship specifies chronic and acute WQG values (freshwater aquatic life) for copper based on pH, hardness, and dissolved organic carbon; and
.6 Overfeeding of copper compounds can also cause water discolouration (blue).

10.2.4 Microscreens

Microscreens or microstrainers are mechanical screens with very small openings capable of removing suspended matter from the water by straining. Microscreens generally follow immediately after coarse screens. Microscreens are used during periods when raw water contains nuisance organisms such as algae, and when heavy loadings may negatively impact downstream processes (e.g. granular and membrane filtration).

Designers should consider:

.1 Expected loading and duration of algae blooms;
.2 Corrosiveness of the water;
.3 Effect of chlorination when required as pre-treatment and possibility of DBP formation;
.4 Duplication of units for continuous operation during equipment maintenance;
.5 Automated backflushing; and
.6 Alternative technologies such as dissolved air flotation.

The design should provide:

.1 Bypass arrangements;
.2 Protection against backsiphonage when treated water is used for washing; and
.3 Proper disposal of backwash water.

10.2.5 Dissolved Air Flotation (DAF)

Dissolved air flotation (DAF) can be used to reduce taste and odour resulting from presence of algae in the water. Refer to Section 7.5.7 – Dissolved Air Flotation for details on DAF design.

10.2.6 Chemical Oxidation

Various chemical oxidants can be applied to reduce taste and odour issues. Chemical oxidants for taste and odour control should be added sufficiently upstream of other treatment processes to ensure adequate contact time for an effective and economical use of chemicals. Additionally, potential disinfection by-product formation should be investigated by bench-scale testing prior to design. Chemical options are summarized in Table 10-1.

Table 10-1 Chemical Oxidation Methods for Taste and Odour Control

Chemical	Reference for Design Details	Additional Considerations
Chlorine	Chapter 13 – Chemical Application	• Overdosing or high residual can cause taste and odour issues.
Chlorine dioxide	Chapter 13 – Chemical Application	• Generally recognized as a treatment for tastes caused by industrial wastes, such as phenols.
Potassium permanganate	Chapter 13 – Chemical Application	• Frequently used for taste and odour control. • Comparatively expensive and can cause water discolouration when overdosed (pink/purple).
Ozone	Chapter 13 – Chemical Application	• Generally more desirable for treating water with high threshold odours.
Aeration	Chapter 9 – Aeration	• Feasible for volatile compound removal (i.e. hydrogen sulphide). • Not as effective for algal-related taste and odours.

10.2.7 Advanced Oxidation Processes

Advanced oxidation processes (AOPs) are processes that provide powerful oxidizing conditions to mineralize organic water contaminants. AOPs involve the use of any one of several possible combinations of UV, hydrogen peroxide, ozone and titanium dioxide. For detailed design guidance for AOP processes for taste and odour control, refer to AWWA's *Ozone in Drinking Water Treatment: Process Design, Operation and Optimization,* Raknesss 2015.

The following should be considered when applying an advanced oxidation process for taste and odour control:

.1 AOPs depend on extremely unstable radical chemical species that react very rapidly with any organic material present. Any natural organic matter (NOM) which may also be present in the water is mineralized at a similar rate to the target contaminants. As a result, AOPs should only be used on very low to trace amounts of specific contaminants such as N-nitrosodimethylamine (NDMA) or 1-4 dioxane, and only in water with low NOM content;

.2 UV/H_2O_2 (ultraviolet/hydrogen peroxide) has been shown to be effective in the treatment of taste and odour compounds such as 2-methylisoborneol (MIB) and geosmin. Refer to Chapter 13 – Chemical Application for further guidance;

.3 Bench and/or pilot scale evaluation using the specific source water and covering seasonal variations is needed to establish effectiveness and costs; and

.4 AOPs that use hydrogen peroxide may produce water with a peroxide residual that behaves like chlorine in colourimetric tests, reacts with and destroys free chlorine, and can upset downstream biological processes. Thiosulphates, sulphites or GAC can be used to destroy peroxide residuals, however caution should be used as they can also act as chlorine scavengers/adsorbers.

11 Disinfection

11.1 General

This chapter describes design considerations for chemical and ultraviolet (UV) disinfection treatment processes. The selection of a particular disinfection treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

Section 5 (2) of the DWPR states that drinking water from a water supply system must be disinfected by a water supplier if the water originates from a surface water source or groundwater that, in the opinion of a Drinking Water Officer, is at risk of containing pathogens (GARP). Schedule A of the DWPR specifies water quality standards for potable water in relation to fecal coliform bacteria, total coliform and *E. coli*. These standards may be achieved through disinfection. There are two distinct types of disinfection, which have two unique functions: primary disinfection and secondary disinfection. These processes are described in the following sections.

Table 11-1 provides a summary of the disinfection methods described within this chapter and the typical application (either primary or secondary disinfection) for each method.

Table 11-1 Disinfection Methods

Disinfection Method	Typical Application	Design Considerations
Hypochlorite (12 – 15%)	Primary or secondary	• Provides an effective disinfectant residual. • Solution strength degrades over time. Design to account for appropriate environmental controls and dose verification monitoring. • Off-gassing can occur in storage, dosing systems and piping systems. • Chlorates may be formed through solution decay. • Trihalomethanes (THMs) and haloacetic acids (HAAs) may be formed as disinfection by-products (DBPs).
Ultraviolet (UV) disinfection	Primary	• Highly effective at inactivating protozoa. • Does not provide a disinfectant residual. • Does not lead to the formation of THMs and HAAs. • May be accompanied with strong oxidant to achieve advanced oxidation (see Chapter 10 – Taste and Odour Control).
Chlorine gas	Primary or secondary	• Highly effective disinfectant and easy to operate. • Highly acidic and consumes alkalinity (may reduce pH). • Specialty operator training required for storage and handling to meet OHS guidelines. • Requires specific risk management planning for transport, storage and handling of the toxic gas.

Disinfection Method	Typical Application	Design Considerations
		• Use of gaseous chlorine requires spill mitigation measures, such as containment or scrubbers. • Proponents of new installation should coordinate this with the local fire prevention authority. • Trihalomethanes (THM) and haloacetic acids (HAA) may be formed as DBPs.
Chlorine dioxide	Primary	• Generated on-site using chlorine gas and sodium chlorite. • Chlorite and chlorate form as DBPs. The GCDWQ should be referenced for maximum acceptable concentrations.
On-site sodium hypochlorite generation	Primary or secondary	• See notes for hypochlorite above. As on-site generation typically produces lower concentration hypochlorite solutions (~0.8%), off-gassing is reduced. • NSF/ANSI Standard 60 certified sodium chloride (salt) to be used to generate the hypochlorite solution. • The design should address ventilation for hydrogen gas to minimize the risk of explosion.
Tablet chlorinators (calcium hypochlorite)	Primary or secondary	• See notes for hypochlorite above. • Design should consider potential for variations in chlorine dosage.
Chloramines	Secondary	• Weak disinfectant. • Long lasting residual. • Forms lower concentrations of THMs and HAAs. • Presents risks to kidney dialysis patients and fish aquariums. • Can increase lead solubility.
Ozone	Primary	• Bromate can be formed as a DBP. • Does not provide a disinfectant residual. • Strong disinfectant.

11.1.1 Primary Disinfection

Primary disinfection kills or inactivates bacteria, viruses, protozoa, and other potentially harmful microorganisms that may be present in the source water prior to the water reaching the first customer. To meet the requirements of Section 5 (2) of the DWPR and to achieve the recommended minimum pathogen log reduction for the source water type, primary disinfection should be employed.

The Ministry of Health *Guidelines for Pathogen Log Reduction Credit Assignment* provides details on the recommended design and operational criteria for the different types of treatment processes used for primary disinfection including CT calculations for chemical disinfection.

11.1.2 Secondary Disinfection

Secondary disinfection or 'residual disinfection' is the maintenance of a disinfection residual concentration to help protect against pathogen contamination and reduce pathogen regrowth within the distribution system. Drinking water distribution system integrity is one of the three core elements of the multi-barrier approach to safe drinking water and secondary disinfection can assist with maintaining and monitoring water quality in the distribution system. A risk-based analysis from a source-to-tap perspective on the biostability of the water should be considered when developing a plan for the maintenance of safe drinking water in the distribution system.

The *British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems* recommends secondary disinfection as a best management practice to maintain the microbiological quality of water in the distribution system to protect against contamination and degradation. A risk-based approach should be used to guide the implementation of secondary disinfection.

The introduction or growth of pathogens (e.g. bacteria, protozoa and viruses) within the distribution system can pose health risks to consumers and impact aesthetic quality. Several factors can cause introduction or growth of pathogens in the distribution system including:

.1 Extended residence times due to network configuration, low water demands, oversized watermains, poor mixing in storage facilities and low storage turnover rates;
.2 Limited network circulation including dead-end watermains or poor network looping;
.3 Leaks within piping and storage facilities;
.4 Cross connection with non-potable sources; and
.5 Biological instability of the water.

Secondary disinfection may be achieved by either maintaining a residual of the primary disinfectant in the distribution system or by adding additional disinfectant(s) prior to the water reaching the customers. Distribution systems with longer retention times or with higher disinfectant residual demands may apply chemical disinfectants at various points within the distribution system to maintain secondary disinfection. Consideration should be given to the formation of disinfection by-products (DBPs) when selecting the disinfectant and feed rates. DBPs are discussed in the following section.

Factors such as the source water pH, temperature and organics levels may impact the stability and effectiveness of chemical disinfectants. Designers should assess the disinfectant demand of the water under the range of anticipated operating conditions (i.e. using bench-scale testing) to determine the disinfectant dose required to meet the minimum residual disinfectant levels without causing formation of DBPs in excess of the *Guidelines for Canadian Drinking Water Quality.*

Secondary disinfection also serves as a method to monitor for changes in the water quality in the distribution system: fluctuations in residuals (against an established baseline) can indicate potential incidents of water quality degradation or contamination, and allow the Water Supplier to respond quickly. Designers should include considerations for disinfection residual monitoring in the distribution system, so that the water system can demonstrate maintenance of a detectable residual in all active parts of the distribution system. This includes provision of sampling ports and/or disinfectant residual monitoring equipment at pump stations, inlet and outlet piping to reservoirs, and throughout the distribution pipe network.

In B.C., secondary disinfection is most commonly accomplished using one of the following chemicals:

.1 Chlorine (chlorine gas or hypochlorite); or
.2 Chloramination.

Primary disinfectants such as chlorine dioxide, ozone, and ultraviolet light (UV) do not maintain a residual and cannot achieve secondary disinfection.

11.2 Disinfection By-Products

Disinfection by-products (DBPs) are formed when disinfectants react with naturally occurring organic (NOM) or inorganic substances (other DBP precursors) in the water. Other factors that affect DBP formation include water temperature, pH, disinfection conditions (i.e. disinfectant, dose, contact time, residual) and the presence of reactive species such as bromide, iodide, ammonia and sulphur.

To manage DBP formation, Health Canada recommends the treatment targets for organics as described in Table 11-2. These are suggested as guidance only as some water sources can be extremely reactive (e.g. form more DBPs), more stringent water quality targets may be required. The treatment targets are determined by the specific DBP yield, which is defined as the mass (in micrograms) of DBP produced by disinfection divided by the DOC (in milligrams) in the water prior to disinfection (µg DBP/mg DOC).

Table 11-2 Treated Water Targets for Organics

Parameter	Source with high specific DBP yield or extensive distribution system	Source with low specific DBP yield
Organic colour	5 - 10 TCU	< 15 TCU
UV absorbance (at 254 nm)	0.02 - 0.04 cm^{-1}	0.02 - 0.07 cm^{-1}
UV transmittance	90 - 95%	85 - 95%
Chemical oxygen demand (COD)	< 5 mg/L O_2	< 5 mg/L O_2
Dissolved organic carbon (DOC)—for DBP control	<2 mg/L carbon	<4 mg/L carbon
DOC—for biological stability	<1.8 mg/L carbon	<1.8 mg/L carbon

Disinfectants may be capable of producing DBPs in concentrations that can present long-term health risks to drinking water consumers. Health Canada provides maximum acceptable concentrations for six types of DBPs: trihalomethanes (THMs), haloacetic acids (HAAs), N-nitrosodimethylamine (NDMA), bromate, chlorate, and chlorite. To reduce DBP formation, it is important to characterize the source water and ensure that the treatment process is optimized for precursor removal. Designers should also assess the disinfection by-product formation potential (DBP-FP) using laboratory analysis, or alternatively conduct distribution system sampling to verify the propensity to generate DBPs. The sampling should assess the seasonal variation and be representative of the distribution system. Refer to APHA/AWWA/WEF *Standard Methods for the Evaluation of Water and Wastewater* for best practices on laboratory sampling and analytical procedures.

Treatment approaches that can reduce disinfection by-product formation potential include the following:

.1 Evaluate alternatives to pre-chlorination;
.2 Alternative oxidants and disinfectants;
.3 Granular media filtration;
.4 Enhanced coagulation;
.5 Biological filtration;
.6 Membrane filtration;
.7 Granular activated carbon;
.8 Powdered activated carbon; and
.9 Anion exchange.

Adding or changing a chemical disinfectant will change water chemistry and could generate secondary effects beyond DBP formation. These secondary effects may cause significant water quality changes in the distribution system, such as the release of corrosion by-products due to changes in oxidation-reduction potential. Refer to Chapter 12 – Internal Corrosion Control for information regarding corrosion control measures.

Operational changes can be made to reduce DBP formation including:

.1 Decreasing stagnation time; and
.2 Providing in-reservoir aeration.

Health Canada recommends sampling of organic indicators as described in Table 11-3 for continued optimization and protection against DBP formation.

Table 11-3 Disinfection By-Product Sampling Program (sourced from Guidance on Natural Organic Matter in Drinking Water, Health Canada 2020)

Parameter	Location	Frequency		
		Variable Source[d]	Stable Source[d]	Ideal
Organic colour (true colour)	Raw and treated	Daily	Weekly	Online
UV absorbance (at 254 nm, UV254) or UV transmittance	Raw and filtered	Daily	Weekly	Online
Chemical oxygen demand (COD)	Raw, treatment processes[a] and treated	Daily	Weekly	Online
Dissolved or total organic carbon (DOC or TOC)	Raw and treated	Weekly	Monthly	Online
Specific UV absorbance (SUVA)— calculate from UV254 and DOC	Raw and treated[b]	Weekly	Monthly	Daily
Inorganic compounds that can enhance the reactivity of NOM to form DBPs: – **Ammonia** – **Bromide** – **Iodide** – **Sulphur**	Raw and treated	Quarterly	Quarterly	Quarterly
Coagulant demand	Coagulation process [c]	Daily	Daily	Online
Zeta potential or streaming current— when NOM controls or influences coagulant dose	Coagulation process [c]	Online	Online	Online
Disinfection by-products (DBPs)	Distribution system	Quarterly (measure DOC and inorganic compounds on same day to calculate specific DBP yields to assess NOM reactivity)		

[a] COD decreases across each treatment process. Selected monitoring locations will vary depending on the process trains in place (e.g. flocculation, clarification, filtration) and the Water Supplier's monitoring program.

[b] $\text{Treated water SUVA} = \frac{\text{UV254 (measured in filtered water before disinfectant addition}}{\text{DOC after disinfectant addition}} \times 100\%$

[c] Strict pH control is critical for NOM removal during coagulation. As alkalinity affects pH control, pH and alkalinity are other important coagulation process monitoring parameters.

[d] A variable source water is subject to rapidly changing raw water quality conditions such as in a river. A stable source would be one that generally experiences consistent raw water quality that may be subject to seasonal fluctuations in raw water quality due to lake turn-over or similar event.

11.3 Ultraviolet Disinfection

Ultraviolet (UV) disinfection may be used for primary disinfection. UV irradiation is effective at inactivating *Giardia*, *Cryptosporidium* and bacteria. Viruses generally require a significantly higher dose for inactivation, depending on the target virus (e.g. adenovirus versus rotavirus). UV systems do not provide a disinfectant residual and therefore cannot be used for secondary disinfection. Refer to the *Guidelines for Ultraviolet Disinfection of Drinking Water* by the Ministry of Health for dose selection and design considerations, including validation methods.

There are two primary types of UV disinfection system, low pressure (LP) and medium pressure (MP). LP lamps produce monochromatic wavelength (254 nm) whereas the MP lamps produce polychromatic wavelengths (200-300 nm). MP lamps operate under a mercury vapour pressure of approximately 10 kPa, whereas LP lamps operate between 100-1000 Pa; lamps between these pressures tend to be LPHO (low pressure-high output) lamps.

Due to higher operating pressures for MP lamps, they require higher input power (3-7 kW) as compared to LP lamps (0.05-0.5 kW). LP lamps require more lamps and higher surface area than the MP lamps to provide the same amount of effective dose delivery. MP units typically have higher capital and power costs than their LP counterparts.

11.4 Ozone

Ozone is a strong oxidant that is especially effective for disinfection of *Giardia lamblia*, viruses and bacteria at relatively low CTs; *Cryptosporidium* has comparatively higher tolerance to ozone, but can be effectively disinfected at higher CT values. Ozone is also known to be effective at oxidizing organics present in the source water; due to this, it may be used as part of DBP management program and to control taste and odours.

As a minimum, bench scale studies should be conducted to determine minimum and maximum ozone dosages for disinfection compliance and oxidation reactions. Particular attention should be made to confirm and validate measurements of gas flow rate and ozone concentration. Consideration should be given to multiple points of ozone addition.

Use of ozone may result in an increase in biologically available organics in the ozonated water and may be used to facilitate organics removal through biologically active filtration. Designers should include consideration for unintended biological impacts on downstream processes. Ozone use may also lead to increased chlorinated by-product levels if the water is not stabilized and free chlorine is used for secondary disinfection.

When considering ozone, the potential formation of bromate should also be evaluated. Factors which influence bromate formation potential include source water bromide, temperature, pH, alkalinity, organic matter, as well as applied ozone dose. Refer to the GCDWQ *Guideline Technical Document - Bromate* for mitigation strategies.

Ozone is generated on-site using dried ambient air, oxygen-enriched air, or high-purity oxygen. Ozone systems have a higher level of operational complexity than other disinfection approaches, except in the case of small packaged generators that provide only a few grams of ozone per day. The ability to develop operator skills should be evaluated during treatment process selection. Refer to Chapter 13 – Chemical Application for the design of the ozone generation and feed requirements.

11.5 Chlorination

Chlorination is the process of adding chlorine-containing compounds to water for the purpose of disinfection. Chlorination can be performed through the use of chlorine gas, sodium hypochlorite or calcium hypochlorite. The following Table 11-4 describes the considerations of each. Health Canada recommends that the concentration of chlorine be determined on a system by system basis. Refer to Chapter 13 – Chemical Application for the design considerations for chlorination systems.

Systems are available to generate sodium hypochlorite on-site in low (~0.8%) or medium (12% - 15%) strength solutions. These systems use an electrolytic cell and brine solution to generate sodium hypochlorite. Further details of these and the above chlorine disinfectants are discussed in Chapter 13.

Table 11-4 Chlorination Method Comparison

Chlorine Species	Chlorine Gas (Cl_2)	Sodium Hypochlorite (NaOCl)	Calcium Hypochlorite ($Ca(OCl)_2$)
Description	Transported and stored as a liquefied gas under pressure. Water treatment facilities typically use chlorine in 100 and 150-lb cylinders or one-ton containers. Some large systems use railroad tank cars or tanker trucks.	Produced by adding elemental chlorine to sodium hydroxide and sold as a solution. Typically, hypochlorite solutions contain from 5 to 15% chlorine (trade percent) and are shipped by truck in 5,000 to 40,000 L containers.	Used primarily in smaller applications. It is a white, dry solid containing approximately 65% chlorine, and is commercially available in granular and tablet forms. Typical applications include puck style dose delivery systems.
Advantages	Lowest cost of available chlorine disinfectants. Unlimited shelf life. Simple and effective dose control. Highest concentration of elemental chlorine, requiring the smallest footprint.	Less hazardous than chlorine gas.	More stable than sodium hypochlorite. Less onerous to operate.
Disadvantages	Hazardous gas requires special handling and operator training. Risk of chlorine gas exposure to the environment and public during storage, transport, and delivery.	Limited shelf life. Off-gases within storage and dosing systems. Potential to add inorganic by-products (chlorate, chlorite, and bromate) to water, especially after extended storage.	Precipitates may form in chemical feed systems. Fire/explosive hazard (requires specialty fire retardant). Potential to add inorganic by-products (chlorate, chlorite, bromate) to water.

11.5.1 General Chlorination Design Considerations

The following equipment should be used for chlorination systems:

.1 The chlorinator capacity should be such that primary disinfection requirements can be met under the maximum flow conditions at the facility, and the secondary disinfection requirements can be met under all conditions. The equipment should be designed such that it will provide an accurate chlorine feed over the entire dosing range. Where chlorination is provided for the protection of public health, redundant stand-by equipment should be provided such that it can replace the largest unit. Spare parts should be made available to replace parts subject to wear or breakage. Accurate metering of emergency units should also be provided;

.2 Chemical feed systems should meet the recommendations of Chapter 13 – Chemical Application;

.3 Automatic switchover of standby or emergency chlorine, storage and feed systems should be provided to ensure adequately disinfected water enters the distribution system at all times;

.4 Provide automatic proportioning (flow-pacing) in systems where the rate of flow is variable. Discrete, controlled changes in flow may not require flow proportioning, provided the system is designed to automatically adjust the dose in response to changes in flow (i.e. additional pump start-up); and

.5 The chlorine solution injector/diffuser should be compatible with the point of application to provide a rapid and thorough mix with the water being treated. Where chlorine is injected into pipes, injectors should extend to the center of the pipe. CFD modelling or tracer studies may be required to verify the effective mixing of the applied disinfectant.

11.5.2 Secondary Disinfection with Chlorination

Chlorination is the most common type of secondary disinfection. Water suppliers should maintain secondary disinfection at concentrations that will protect against human health risk while minimizing the impact on the aesthetic quality of the drinking water (e.g. taste and odour) and disinfection by-product formation.

Effective secondary disinfection requires an adequate free chlorine residual throughout the distribution system. The free chlorine residual is defined as the chlorine available as hypochlorous acid (HOCl), hypochlorite ion (OCl^-) and dissolved gas (Cl_2, only present at pH < 2) that is not combined with ammonia or other compounds in water.

Generally, 0.2 mg/L of free chlorine is considered the minimum concentration to control the growth of bacteria in the distribution system. Health Canada recommends a range of 0.4 to 2.0 mg/L of free chlorine in treated water leaving the water treatment plant. Chlorination booster stations may be located throughout the distribution system to maintain adequate residual and reduce DBP levels (as compared with a single, higher concentration injection point).

11.6 Chlorine Dioxide

Chlorine dioxide is a powerful disinfectant that does not form chlorinated organic DBPs, however, the formation of chlorite and chlorate by-products should be evaluated against the GCDWQ MAC. As chlorite is added to water to produce chlorine dioxide, incomplete reactions can result in high chlorite concentrations. Furthermore, chlorine dioxide degrades slowly in water to produce chlorite and chlorate.

Chlorine dioxide is not recommended as a secondary disinfectant. WorkSafeBC *Occupational Health and Safety Exposure Limits* should be reviewed to ensure a safe work environment.

Chlorine dioxide gas, even in mixtures of over 10% in air, is highly unstable. As a result, it must be generated on-site through the reaction of sodium chlorite with chlorine gas, hypochlorous acid or hydrochloric acid, or using an electrochemical process. The gas is toxic and can be explosive; therefore, the Designer should make appropriate provisions to protect operations staff from excessive exposure. Furthermore, advanced leak detection, explosion proof measures and special safety precautions should be provided to protect workers. The gas should be handled only in water solution with feed lines arranged to avoid gas pocket formation, be maintainable under moderate pressure and be easily water purged.

Levels of both chlorite and chlorate should be evaluated against the GCDWQ MAC via bench- or pilot-scale testing.

Refer to Chapter 13 – Chemical Application for general design considerations.

11.7 Chloramination

Chlorine combines with ammonia to form chloramine compounds: mono-, di-, and trichloramine. The ammonia may be naturally occurring or may be added to the water (usually after the chlorine injection point). Chloramines are less powerful oxidants than free chlorine: monochloramine is the strongest and most stable disinfectant of the chloramines and is the desired species in chloramination. Chloramination is inadequate in strength for primary disinfection, as the CT required to inactivate key pathogens is unfeasibly high for water treatment applications.

Typically, chloramines are used for secondary disinfection. In the distribution system, chloramines are more persistent and better at controlling biofilms than free chlorine. Monochloramine has fewer taste and odour issues than free chlorine, although complaints may occur at combined chlorine levels above 3 mg/L, especially if di- and tri-chloramine are present.

The required chloramine concentration at each entry point depends on the size of the distribution system and the decay rate. A generally accepted target concentration for chloramines as they enter the distribution system is at least 2 mg/L; however, residuals greater than 1 mg/L may be necessary to control biological regrowth within piping (Health Canada, 2020).

When using chloramination, the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Chloramines* by Health Canada should be referenced.

11.7.1 Health and Safety Considerations

Chloramines in water present risks to kidney dialysis patients and fish aquariums. Provide public notice prior to changing the type of chlorine residual. Blending water supplies that contain both free chlorine and chloramines should be avoided except in an emergency. Chloramines depress oxygen levels in natural water bodies and are therefore considered highly toxic to fish populations. Special provisions are to be made for monitoring and responding to system leaks and pipeline breaks.

While chloramines produce lower concentrations of THMs and HAAs, they can generate higher concentrations of N-nitrosodimethylamine (NDMA) and other DBPs (including organic chloramines). NDMA production should be considered when designing chloramination systems and may be mitigated through dose control and reduction of NDMA precursors (dimethylamine, trimethylamine, and dichloramine). The MAC and reduction strategies for NDMA can be found in Health Canada's *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document: N-Nitrosodimethylamine* (NDMA).

Switching from free chlorine to chloramines may increase lead solubility in water. Additionally, the type of chlorine and ammonia chemicals used can affect the finished water pH. An evaluation of the corrosion control strategy is required prior to changing chemicals or disinfectant strategies.

11.7.2 Chloramine Formation

Chloramine formation is dependent on temperature, pH, mixing, organics, and chlorine to ammonia-nitrogen weight ratio. The chlorine to ammonia-nitrogen weight ratio is based upon chlorine residual, not chlorine dose. The desired chloramine compound is monochloramine. The chlorine to ammonia-nitrogen weight ratio for monochloramine formation is between 4.5:1 - 5:1 when pH > 8. A higher ratio can lead to formation of dichloramine and trichloramine and the production of undesirable taste and odours. The Designer should refer to AWWA's *Nitrification Prevention and Control in Drinking Water, M56* for further information on preventing nitrification.

Too low of a ratio will result in excess free ammonia and possible nitrification in the distribution system. Water quality problems caused by nitrification include the formation of nitrite and nitrate, loss of disinfectant residual, bacterial regrowth and biofilm formation, DBP formation, and decreases in pH (especially in low alkalinity waters) and alkalinity that can lead to corrosion issues, including the release of lead and copper. If water contains ammonia (either naturally or added), and a free chlorine residual is desired, the ammonia can be removed by oxidation with chlorine to produce primarily nitrogen gas and some nitrate by the breakpoint reaction.

Ammonia reacts rapidly with chlorine to form chloramines. The chlorine initially reacts with NH_3 to form monochloramine (NH_2Cl). The additional free chlorine then reacts with monochloramine to form dichloramine ($NHCl_2$), and then trichloramine (NCl_3). Chlorine dosing passed the breakpoint results in free chlorine residual. Breakpoint chlorination is thus the addition of chlorine to water until the chlorine demand has been satisfied to reach the breakpoint. The procedures for calculating the breakpoint reaction can be found in *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association, the American Waterworks Association and the Water Environment Federation (APHA/AWWA/WEF).

11.7.3 Feed System Design

The following should be considered when designing a chloramine feed system:

.1 Chemical feed systems should meet the recommendations of Chapter 13 – Chemical Application with respect to specific chemical requirements for chlorine gas, sodium hypochlorite, ammonium sulphate, aqua ammonia, and anhydrous ammonia;

.2 Ammonia and ammonia compounds should be stored in a separate room from chlorine because of the potential explosive or violent reactions that could occur;
.3 Both chlorine and ammonia must be mixed thoroughly and rapidly in the main plant stream to prevent formation of dichloramine and trichloramine; and
.4 A method to maintain the desired chlorine to ammonia-nitrogen weight ratio should be provided. An automated, continuous instrument control method is recommended.

11.7.4 Chloramine Booster System

Booster chlorination of chloraminated water in the distribution system can be used to reform monochloramine from the ammonia released during the decay process. Booster chloramination (adding chlorine and ammonia) may be necessary in certain situations.

11.7.5 Monitoring

A distribution sampling program should be established to verify proper chloramine formation and to monitor for nitrification (see Section 11.7.6 – Nitrification). Sampling should be implemented at the following key points in the water system:

.1 Entry point to distribution system (baseline);
.2 Storage facilities;
.3 Upstream and downstream of booster stations;
.4 In areas of low flow or high-water age;
.5 Pressure zone boundaries;
.6 In mixed zones (blended water); and
.7 In areas with various sizes and types of pipe material.

The *British Columbia Guidelines (Microbiological) On Maintaining Water Quality in Distribution Systems* and Health Canada's *Guideline Technical Document on Chloramines* recommends the following parameters be monitored for systems using chloramination:

- Free and total ammonia;
- Monochloramine;
- Dichloramine;
- Nitrite;
- Nitrate;
- Adenosine triphosphate (ATP);
- Heterotrophic plate count (HPC);
- pH;
- Total organic carbon (TOC);
- Temperature; and
- Alkalinity.

Table 11-5 provides an example sampling program; however, selected parameters and sampling frequency should be adjusted based on the Water Supplier's needs and unique trends in water quality.

Table 11-5 Chloramination Sampling Frequency (example)

Frequency	Parameter
Daily	Free and total chlorine, pH, temperature
Weekly	Nitrite, nitrate, free and total ammonia, alkalinity, monochloramine, dichloramine, TOC
Monthly	Heterotrophic plate count (HPC) or adenosine triphosphate (ATP)

11.7.6 Nitrification

Nitrification is a microbially-mediated process through which ammonia is oxidized to form nitrite and nitrate. Free ammonia concentration should be kept below 0.1 mg/L. Nitrification at the WTP can be prevented by maintaining a chlorine to ammonia ratio that is optimal for monochloramine formation. Nitrification has the potential to occur in the distribution system under various conditions and is most commonly associated with elevated temperatures (above 15 ^{o}C), high water age, lower pH, high free ammonia concentrations, high chlorine demand (i.e. high total organic carbon), and low monochloramine residuals.

The following factors may indicate nitrification in a distribution system:

.1 Decrease in total chlorine residual;
.2 Increase in HPC, ATP and potentially an increase in total coliforms;
.3 Decrease in free ammonia;
.4 Increase in nitrite (≥ 0.05 mg/L as N);
.5 Decrease in dissolved oxygen (DO) (associated with moldy and earthy-tasting water); and
.6 Decrease in alkalinity and pH.

Steps can be taken to reduce water age in the distribution system, such as adding loops to the system. The addition of mixing can prevent tank stratification. Once established, nitrification may require steps such as flushing to restore water quality. A nitrification control plan should include flushing and the temporary use of free chlorine. The following strategies can minimize nitrification:

.1 Decreasing the detention time;
.2 Increasing pH;
.3 Decreasing total organic carbon (TOC);
.4 Increasing the Cl_2/NH_3-N ratio and chloramine residual;
.5 Decreasing excess ammonia; and
.6 Performing occasional breakpoint chlorination.

12 Internal Corrosion Control

12.1 General

This chapter describes design considerations for internal corrosion control treatment processes. The selection of a particular internal corrosion control treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

Corrosion is the oxidation process by which a native metal (i.e. in pipe or fittings) is converted to an oxidized species, either in the form of metal oxide precipitates or released to the solution as metal ions. Internal corrosion in a drinking water distribution system (i.e. occurring on the insides of pipes) can cause contaminants to leach from the metal components in contact with the water. Internal corrosion in drinking water distribution systems is primarily driven by two factors:

.1 The corrosive properties of the water in contact with the pipes; and
.2 The presence of corrodible metal pipes or piping components.
  - Due to its health effects, lead is normally the target metal for corrosion control strategies; however, copper and iron may also leach due to corrosion.

Mitigating at least one of these two main factors prevents metal leaching, and is therefore the goal of a corrosion control strategy. While pipes and plumbing components (especially those containing lead) can be replaced as part of a corrosion control strategy, most lead-containing pipes and fixtures are located in households (not in distribution systems). Therefore, the primary approaches to managing internal corrosion control in drinking water systems include modifying water chemistry to make water less corrosive, and encouraging the formation of passivating films on the contacting surface (insides of pipes and fixtures).

Water corrosivity can be reduced by pH and/or alkalinity adjustment. Increasing the carbonate buffer level is a consistent method for reducing the corrosion rate and is particularly recommended for systems treating soft water. Where adjustments to water quality parameters prove insufficient to control corrosion rates, the use of corrosion inhibitors should be considered. Corrosion inhibitors generate a protective (passivating) oxide film on the surfaces in contact with potable water, which reduces the rate of corrosion. The application of corrosion inhibitors should be carefully monitored to ensure sufficient concentrations are applied to prevent corrosion while not overdosing and causing deposits or scale buildup on the internals of the distribution system.

The application of water treatment chemicals, such as coagulants, can change the characteristics of the water (e.g. pH, alkalinity, the chloride-to-sulphate mass ratio (CSMR), etc.) and potentially create corrosive water. Designers should carefully assess the corrosivity of the water when selecting new or modifying existing treatment processes. Where material changes in water chemistry are anticipated, if new source water is being considered, or if multiple water sources are to be blended, Designers should consider the impacts on corrosion. A corrosion study serves as a first step in a comprehensive corrosion control strategy that may be employed before or in conjunction with making changes to an existing water system. Water may also become corrosive after prolonged contact with water system components such as distribution or storage facilities. Water that is corrosive due to natural and/or subsequent treatment processes should be stabilized to minimize corrosion in the distribution system and prevent the leaching of contaminants into the water.

Other factors that affect corrosion rates are elevated water temperatures, fluctuations in free chlorine residual, chloramines, chloride, sulphate, natural organic matter (NOM), oxidation-reduction potential (ORP), and the chloride-to-sulphate mass ratio (CSMR). Longer stagnation times in pipes can also lead to increased corrosion.

The following processes can be used for corrosion control, and should be considered based on the specific characteristics of the water system:

.1 Alkalinity and/or pH adjustment using chemical addition including:
   a. Sodium bicarbonate, $NaHCO_3$;
   b. Carbon dioxide, CO_2;
   c. Caustic potash, KOH (potassium hydroxide);
   d. Caustic soda, NaOH (sodium hydroxide);
   e. Hydrated lime, $Ca(OH)_2$ (calcium hydroxide);
   f. Potash, K_2CO_3 (potassium carbonate);
   g. Soda ash, Na_2CO_3 (sodium carbonate);
   h. Sodium silicates, e.g. Na_2SiO_3;
   i. Acid addition;
   j. Alkali addition;
.2 Corrosion Inhibitors:
   a. Phosphate based;
   b. Silica based; and
.3 Split treatment.

Reference should be made to the Health Canada *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* (2009) for additional details and recommendations.

For guidance on external corrosion control, refer to Chapter 16 – Transmission and Distribution.

12.2 Corrosion Control Study

12.2.1 General

A corrosion control study is recommended for source and treatment changes that could alter finished water chemistry (refer to Section 12.2.2 – Scenarios Where Corrosion Control Studies Are Recommended for more details). The *Guidelines on Evaluating and Mitigating Lead in Drinking Water Supplies, Schools, Daycares and Other Buildings* by the Ministry of Health should be referenced when developing the study.

The corrosion control study should include the following key steps:

.1 A sample site location plan for water quality parameter monitoring.
   - When developing a sampling program, refer to Health Canada *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* (2009) and the USEPA's *Lead and Copper Rule* and *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems* (2016).

- Entry point and distribution system samples should be collected; however, the most effective sampling locations are the customers' taps.
- Water quality data and other system information pertinent to achieving optimum corrosion control should be collected from all sample sites.
- The frequency of sampling and number of sites should be determined in consultation with the Issuing Official.
- Water quality parameters which can be considered for a corrosion sampling program include:
  - Lead and copper
  - Aluminum
  - Iron
  - Calcium
  - Manganese
  - Sulphate
  - pH
  - Conductivity
  - Temperature
  - Hardness
  - Alkalinity
  - Ammonia
  - Dissolved oxygen
  - Oxidation reduction potential (ORP)
  - Total dissolved solids (TDS)
  - Total phosphorus
  - Natural organic matter (for example, through total and/or dissolved organic carbon measurements)
  - Chloride
  - Total and free chlorine
  - Corrosion control inhibitors (orthophosphate, silica), if applied prior to distribution

.2 Health Canada recommends against using corrosion indices (like the Langelier index) to assess corrosion control programs. Corrosion indices should only be used in conjunction with a rigorous sampling program which includes the water quality parameters listed in .1 above.
- For example, modelling a corrosion index across a distribution system may help identify areas with higher water corrosivity for further sampling. This can be spatially overlaid with information on house age, known or potential lead service line presence, and historical test results for the above parameters to help water suppliers design a meaningful sampling program that includes higher risk areas in the distribution system.

.3 A summary and evaluation of all water quality parameter monitoring results collected;
.4 A desktop evaluation using corrosion control computer modeling and/or regulatory guidance; and
.5 Identification of possible limitations and secondary impacts for treatment options.

12.2.2 Scenarios Where Corrosion Control Studies Are Recommended

Changes to the water supply system which affect the finished water chemistry may have impacts on internal corrosion. Scenarios that may warrant a corrosion control study include the following:

.1 Change in source water;
.2 Blending of source waters (e.g. combining surface and groundwater);
.3 Blending of finished waters from two distinct treatment systems;
.4 Change in disinfection type (including additional oxidants) or disinfection strategy;
.5 Addition of any process which changes water pH or alkalinity (may include coagulation and GAC);

.6 Change in coagulation type (for example, from iron to aluminum-based, or chloride to sulphate-based);
.7 Addition of ion exchange; and
.8 Change in a treatment process that increases the final amount of natural organic matter (NOM) in the water.

12.3 Corrosion Control Methods

12.3.1 Alkalinity/pH Adjustment

12.3.1.1 General Considerations

The main water quality parameters that can be adjusted to control corrosion are pH and alkalinity. The pH of water is a measure of its acidity, otherwise known as its hydrogen ion concentration (H^+ or H_3O^+). Alkalinity is the capacity of water to neutralize acid. Both a pH that is too low (acidic) or too high (basic) can cause increased corrosion rates.

The Health Canada *Guidance on Controlling Corrosion in Drinking Water Distribution Systems* (2009) provides guidance on adjusting pH and alkalinity for lead and copper corrosion control. The following are the recommended optimal ranges:

- pH: 7.5 – 9.5
- Alkalinity: 30 – 75 mg/L as $CaCO_3$ (> 60 mg/L $CaCO_3$ is preferable for iron corrosion control)

Treated water may need to be chemically adjusted to within the recommended pH and alkalinity ranges to limit corrosion in the distribution system, depending on other water quality parameters and water system pipe materials.

Alkalinity/pH adjustment systems:

.1 Should be capable of providing a stable pH;
.2 Should be injected after all disinfection log inactivation requirements are achieved;
.3 Should produce water with an alkalinity of at least 30 mg/L as calcium carbonate ($CaCO_3$);
.4 Should have chemical feed facilities conform to Chapter 13 – Chemical Application;
.5 Operator safety precautions should be followed as outlined in Chapter 13 – Chemical Application; and
.6 Piping materials should be of a type suitable for the chemical being fed.

12.3.1.2 Secondary Impacts of Alkalinity/pH Adjustment

The following secondary impacts should be evaluated:

.1 Optimal pH for all other processes;
.2 Calcium carbonate precipitation;
.3 Oxidation of iron and manganese;
.4 Disinfection by-product (DBP) formation (trihalomethanes, haloacetic acids); and
.5 Final sodium content in water.

12.3.1.3 Alkalinity/pH Adjustment Options

Table 12-1 provides a summary of commonly used chemicals for pH or alkalinity adjustment.

When choosing a chemical for pH adjustment, the dissolved inorganic carbon (DIC) content of the water should be reviewed to ensure the applicability of the chosen chemical. DIC is an estimate of the amount of total carbonates in the form of carbon dioxide gas (CO_2 or H_2CO_3), bicarbonate ion (HCO^{3-}), and carbonate ion (CO_3^{2-}). Appendix B of the *Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems* can be referenced to calculate DIC.

Table 12-1 pH/Alkalinity Adjustment Chemical Summary (sourced from the Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems)

Chemical	Composition	pH Change	Alkalinity Change	DIC Change [a]	Notes
Sodium bicarbonate, $NaHCO_3$	98% purity. Dry storage with solution feed [b]	Tends to pH 8.3	Increases 0.60 mg/L as $CaCO_3$ alkalinity per mg/L as $NaHCO_3$ [b, c, e]	0.14 mg/L as C per mg/L as $NaHCO_3$	• Good alkalinity adjustment chemical but expensive. [b] • Recommended for systems with limited technical resources. • Recommended for waters with a DIC < 5 mg/L.
Sulfuric acid, H_2SO_4	Available in 62, 78, or 93% strengths	Decreases	Decreases	None	• Must be stored in corrosion-resistant tanks.
Carbon dioxide, CO_2	Pressurized gas storage. Fed either through eduction or direct gas feed [b]	Decreases	None [b]	0.27 mg/L as C per mg/L as CO_2	• Can be used to enhance NaOH or lime feed systems. [b] • Converts hydroxide to bicarbonate and carbonate species. • Adequate mixing needs to be provided for CO_2.
Caustic potash, KOH (potassium hydroxide)	KOH is available as a 45% solution. Has a low freezing point and can be stored at higher concentrations.	Increases	0.89 mg/L as $CaCO_3$ alkalinity per mg/L as KOH. Converts excess carbon dioxide to carbonate alkalinity species.	None	• pH control is difficult when applied to poorly buffered water. • Is a hazardous chemical, requires safe handling and containment areas.

Chemical	Composition	pH Change	Alkalinity Change	DIC Change [a]	Notes
Caustic soda, NaOH (sodium hydroxide)	93% purity liquid bulk, but generally shipped/stored at < 50% purity to prevent freezing.	Increases	1.25 mg/L as $CaCO_3$ alkalinity per mg/L as NaOH[c, d] Converts excess carbon dioxide to carbonate alkalinity species.	None	• pH control is difficult when applied to poorly buffered water. [b] • For low alkalinity waters, caustic soda should be used in conjunction with carbon dioxide. • Is a hazardous chemical, requires safe handling and containment areas. • Caustic soda can cause severe burns and damage the eyes, WorkSafeBC recommendations should be followed when handling caustic soda. • Recommended for water with DIC > 5 mg/L.
Hydrated lime, $Ca(OH)_2$ (calcium hydroxide)	95 to 98% purity as Ca(OH)[b]. 74% active ingredient as CaO. Dry storage with slurry feed. [b]	Increases	Increases 1.35 mg/L as $CaCO_3$ alkalinity per mg/L as $Ca(OH)_2$	None	• pH control is difficult when applied to poorly buffered water. Slurry feed can cause excess turbidity. O&M is intensive. • Can be applied in form of limestone contactors, which are well suited for small systems. • Increases calcium content (hardness).
Potash, K_2CO_3 (potassium carbonate)	Dry storage with solution feed. [e]	Moderate Increase	Increases 0.72 mg/L as $CaCO_3$ alkalinity per mg/L K_2CO_3 [c, d]	0.09 mg/L as C per mg/L as K_2CO_3	• More expensive than soda ash but more soluble and easier to handle.
Soda ash, Na_2CO_3 (sodium carbonate)	95% purity. Dry storage with solution feed. [b]	Moderate Increase	Increases 0.94 mg/L as $CaCO_3$ alkalinity	0.11 mg/L as C per mg/L as Na_2CO_3	• More pH increase compared with $NaHCO_3$, but less costly .[b] • Has increased buffer capacity over hydroxides.

Chemical	Composition	pH Change	Alkalinity Change	DIC Change [a]	Notes
			per mg/L as $Na2CO_3$ [c, d]		• Recommended for waters with a DIC concentration between 2 to 25 mg/L.
Sodium silicates, e.g. Na_2SiO_3	Available in liquid form mainly in 1:3.2 or 1:2 ratios of $Na_2O:SiO_2$. [h]	Moderate increases in pH.	Depends on formulation Moderate increases in alkalinity.	None	• More expensive than other options but easier to handle than lime and other solid feed options. Has additional benefits in sequestering or passivating metals. [h]

[a] Calculated by the formula DIC Change = 12 x (moles carbon/mole compound) / molecular weight of compound.
[b] USEPA, 1992a
[c] Wachinski, 2016
[d] Simon, 1991
[e] USEPA, 2003
[f] Caustic potash (KOH), or potassium hydroxide, is an alternative that does not add sodium to water.
[g] Lime is available as hydrated or slaked lime ($Ca(OH)_2$) and quicklime (CaO).
[h] Schock, 1996

Acids such as hydrogen chloride (HCl), sulphuric acid (H_2SO_4) and citric acid ($C_6H_8O_7$) addition can be used to decrease the pH of the water to within the range stipulated by the regulatory requirements. Adequate precautions should be taken for operator safety: for example, never adding water to concentrated acid. Reference should be made to Chapter 13 – Chemical Application for design and safety considerations when using acids.

12.3.2 Corrosion Inhibitors

Corrosion inhibiting chemicals are used to minimize corrosion in the distribution system. Corrosion inhibiting chemicals include phosphate- and silicate-based compounds.

12.3.2.1 Phosphate-Based Inhibitors

Phosphate-based compounds for use in water distribution systems include orthophosphate, polyphosphates, and blended phosphates (a combination of the two). Orthophosphate-based compounds act as a corrosion inhibitor by forming a protective coating on pipe walls. This film protects the pipe by reducing or eliminating the potential for lead and copper to leach into the water. Orthophosphates need to be fed indefinitely, or there is a risk that the passivation film that has built up will break down and release trapped metals into the water system. Orthophosphates are the most effective phosphate-based compounds for controlling lead release in the distribution system and can also control copper release. Orthophosphates can be added in the form of phosphoric acid, alkali metal orthophosphates (e.g. sodium orthophosphate), or zinc orthophosphate. Phosphates containing zinc help to protect cement lined pipes at low alkalinity/hardness/pH conditions.

Polyphosphates sequester hardness, iron, and/or manganese but do not form a protective barrier on pipe interiors, nor do they react with lead; therefore, they should not be considered as corrosion inhibiting chemicals. Blended phosphates contain some proportion of orthophosphate and polyphosphate. The orthophosphate portion is beneficial for corrosion control while polyphosphate sequesters hardness, iron, or manganese. The orthophosphate to polyphosphate ratio is very important to ensure sufficient orthophosphate residual to control the lead or copper release. Blended phosphates may be used in situations where sequestration and corrosion control are simultaneously sought, but the protective films formed on the pipes will be less uniform (i.e. more amorphous). Caution should be taken to ensure minimal hydraulic or mechanical upset in the pipes, which may disturb the amorphous films and cause release of metals into the water.

Phosphates can have secondary impacts that limit their use. Factors that should be evaluated prior to the installation of these corrosion control systems include:

.1 Reactions with aluminum causing amorphous precipitate rather than a smooth passivation layer;
.2 Impacts on wastewater treatment plants;
.3 Increased biological activity in distribution systems (biofilm formation); and
.4 Possibility of reacting and precipitating with other metals, including iron and manganese. Finding an optimum phosphate dose may be challenging with multiple pipe metal types.

The feeding of polyphosphates may be used for sequestering calcium in lime-softened water and in conjunction with pH adjustment following ion exchange softening. Phosphate addition should meet the following criteria:

.1 Feed equipment should conform to Chapter 13 – Chemical Application;
.2 Stock phosphate solution should be kept covered and disinfected by maintaining approximately 10 mg/L chlorine residual (phosphate solutions having a pH of 2 or less may be exempt from this requirement);
.3 Should include provision to monitor the phosphate residual;
.4 Should be designed to operate within the optimum pH range and alkalinity concentration.
.5 Adequate chlorine residuals should be maintained in the distribution system;
.6 Should have a chemical feed system capable of maintaining an orthophosphate residual of at least 1.0 mg/L as P (3.0 mg/L as phosphate, PO_4) throughout the distribution system;
.7 Should consider a six-month higher dose period to establish the desired residual; and
.8 Should not begin operation until the distribution system has been cleaned by flushing, with hydraulic pigs, or swabbing.

12.3.2.2 Silicate-Based Inhibitors

Silicate-based corrosion inhibitors are a mixture of soda ash and silicon dioxide. The mechanisms by which silicate inhibitors control lead and copper release have been debated. Silicates may form an adherent film on the surface of the pipe. Silicates will also increase the pH of the water, which may reduce lead and copper release.

Many systems have not considered silicate inhibitors for lead and copper control due to the lack of research and field information proving its effectiveness, the estimated operating costs and high dosage rates required, and the time it takes to reduce lead concentrations. There has been demonstrated effectiveness against intermittent red water issues due to silicates' ability to sequester iron and manganese, and they can also reduce loss of calcium from asbestos cement or cement-lined pipes.

The effectiveness of silicate inhibitors depends on silicate level, pH, and the DIC of the water. A start-up dose of 24 mg/L is recommended, followed by a gradual reduction after 60 days to a maintenance dose of 8 to 12 mg/L.

12.3.3 Split Treatment

Under some circumstances, a softening water treatment plant can be designed using "split treatment" in which raw water is blended with softened water to partially stabilize the water prior to secondary clarification and filtration. Treatment plants that use "split treatment" should also contain facilities for further stabilization by other means.

12.4 On-Going Testing

Corrosion cannot be measured using one single parameter or method. Instead, corrosion should be measured by establishing a baseline measure of the existing rate of corrosion by documenting water quality complaint location and frequency, or preferably by adopting widespread sampling.

The most common method for measuring corrosion is to monitor lead concentrations at the consumer's tap. Monitoring lead levels at the consumer's tap can help identify sources of lead (i.e. service lines, solder, or fixtures), and can provide information about water corrosivity throughout the distribution system.

Water Suppliers may assess the corrosion control methods by first making limited water quality changes, such as pH shift of +0.5 units or soda ash addition of up to 10 mg/L and then confirming the effectiveness of the change after allowing 6 to 9 months for the corrosion process to adjust. Effective pH adjustment requires proper process control through monitoring, instrumentation, and alarms. Continuous monitoring of pH should be provided upstream of the chemical injection point and downstream after the chemical is completely mixed.

Monitoring/testing equipment should be provided for determining the effectiveness of stabilization treatment and the chemical residuals at the entry point and in the distribution system, including an acceptable pH probe that uses three standards for calibration.

Laboratory testing equipment should be provided for determining the effectiveness of stabilization treatments where specific water quality parameter targets have been established (e.g. pH, alkalinity, etc.). A coupon corrosion testing station should be considered for in-situ measurement of corrosion in distribution systems to establish the current rate of corrosion and evaluate changes over time with the implementation or adjustment of corrosion control treatment strategies (e.g. addition of corrosion inhibitors). Pipe-loops or other pilot scale work can also be used to evaluate actual corrosion or corrosion rates of proposed treatment.

13 Chemical Application

13.1 General

This chapter provides an overview of the general requirements for the storage, handling, dosing, and safety of chemicals used in drinking water treatment applications. The Designer should refer to WorkSafeBC for safe work practices, which should lead the design of chemical handling systems.

All chemicals and water contact materials should meet the current versions of NSF/ANSI/CAN 60: *Drinking Water Treatment Chemicals – Health Effects* and NSF/ANSI/CAN 61: *Drinking Water System Components – Health Effects*, where these materials are available for the application.

When designing chemical storage rooms, Chapter 5 – Facility Recommendations should be referenced.

13.1.1 Plans and Specifications

Plans and specifications should include:

.1 Descriptions of feed equipment, including maximum and minimum feed ranges;
.2 Procedures for handling overfeed;
.3 Location of feeders, piping layout and points of application;
.4 Storage and handling facility details include duration of storage;
.5 Operating and control procedures including proposed application rates;
.6 Descriptions of testing equipment; and
.7 System description including all tanks with capacities (with drains, overflows, and vents), feeders, transfer pumps, connecting piping, valves, points of application, backflow prevention devices, air gaps, secondary containment, and safety eyewash and showers.

For each chemical, the following documentation should also be available:

.1 Documentation that the chemical is NSF/ANSI Standard 60 approved;
   - In addition to confirming the correct certification for the chemical is met (NSF and/or AWWA), suppliers may also elect to conduct quality assurance testing on the product to confirm suitability and compliance with relevant specifications.

.2 Specifications for the chemical to be used;
.3 Purpose of the chemical;
.4 Proposed minimum non-zero, average and maximum dosages; solution strength or purity (as applicable); and specific gravity or bulk density;
.5 Method for independent calculation of the amount fed daily; and
.6 Chemical hazards class, if any, and regulatory workplace health/safety and chemical exposure standards listed in safety data sheets (SDS).

13.2 Safety

Designers should carefully consider chemical delivery and storage when designing water treatment plants. Improper delivery, storage, or use may result in a toxic or explosive environment. The Designer should discuss the safe use and storage of treatment chemicals with the local fire marshal, building code officials, and other authorities responsible for implementing regulations as part of the design process. The Emergency Response Plan (ERP) for the facility should include relevant emergency information for each chemical.

General safety design considerations for chemical systems should include:

.1 Chemical safety considerations and labelling should be in accordance with the Workplace Hazardous Materials Information System (WHMIS).
.2 Eyewash and shower stations with tempered water accessible to operators and delivery personnel with alarm and strobe to indicate shower is in use as per WorkSafeBC;
.3 Separate containment around unloading, storage and feed facilities for each chemical;
.4 Double walled piping or shrouding directing any leakage back to containment or a control sump for overhead piping systems;
.5 Seismic bracing, supports, and pipe design to prevent damage to chemical storage and handling facilities during an earthquake;
.6 Separate delivery, storage, and feed facilities for strong oxidants, such as gaseous chlorine or calcium hypochlorite. Where separate delivery and storage facilities are not feasible, means must be provided to prevent storage and mixing of incompatible chemicals;
.7 Clearly labeled chemical fill ports, piping, and storage tanks with the chemical used;
.8 Locks on every chemical fill port to prevent access when the operator is not present;
.9 Covered spill containment around chemical fill ports;
.10 Equipment to contain and scrub chlorine gas, and/or appropriate containment and treatment for other gases used or created on-site (e.g. hydrogen gas formed during on-site generation of sodium hypochlorite);
.11 Egress and ingress requirements for rooms or areas with chemical storage and feed facilities;
.12 Compliance with all applicable WorkSafeBC standards, such as signage, safety gear, training, atmospheric monitoring devices, ventilation, and eyewash and safety shower locations;
.13 The Designer should review the *Safe Work Practices for Chlorine* by WorkSafeBC when designing chlorination systems;
.14 Chemical buildings or storage areas must be provided with adequate warning signs, conspicuously displayed where identifiable hazards exist;
.15 A storage area for filing safety data sheets (SDS) as set out under the *Federal Hazardous Products Act* and associated Controlled Products Regulations should be provided; and
.16 A safety data sheet (SDS) should be available for each chemical.

13.2.1 Ventilation

Special provisions should be made for ventilation and heating of chemical feed and storage rooms, see Chapter 5 – Facility Recommendations for further information.

13.2.2 Chemical Overfeed Prevention

Injecting chemicals into the water supply always poses some potential of overfeed if equipment is not designed, installed, operated, or maintained properly.

Design elements and appropriate standard operating procedures (SOPs) can minimize the potential for overfeed. The following design considerations should be made to reduce the likelihood of overfeeding:

.1 Include day tanks when the system needs to use large bulk volumes of treatment chemicals. Size the day tanks to store no more than 30 hours of supply and have an operator fill the tanks in a controlled manner *(Ten State Standards, 2018).* These tanks promote daily inspection of the feed systems and reduce the magnitude of an overfeed;

.2 Evaluate the failure modes of the equipment and add redundant safeguards if needed.
.3 Designers should consider the feasibility of installing flow-based chemical feed control or physical limitations to chemical feed flow (e.g. maximum pump rates);
.4 Chemical feeders should be interlocked with plant system controls to shutdown automatically when raw water flows stop;
.5 Select chemical injection points to minimize the potential for siphoning or hydraulically draining chemical storage tanks, even if their design includes antisiphon features;
.6 Include continuous monitoring equipment with integrated alarms (pH, chlorine, fluoride). In some cases, redundant monitoring equipment should be provided. It is appropriate for these alarms to shut down the equipment;
.7 Provide appropriate cross connection control;
.8 Where chemical feed equipment is automatically controlled, the design must allow for override by manual controls;
.9 Where SCADA allows remote access, conduct a cybersecurity risk assessment (for example, using AWWA's Cybersecurity Risk Management Tool) and address any vulnerabilities; and
.10 Refer to design criteria in Section 13.3.6.1 – Control of Feed Systems for more information.

13.2.3 Other Protective Equipment

The following protective equipment should also be considered:

.1 At least one pair of rubber gloves, a dust respirator of a type certified by NIOSH for toxic dust, an apron or other protective clothing, and goggles or face mask should be provided for each operator;
.2 An appropriate deluge shower and eye washing device should be installed where strong acids and alkalis are used or stored as per *American National Standards Institute (ANSI) Standard Z358.1-2014 Emergency Eyewash and Shower Equipment*; and
.3 Other protective equipment should be provided as necessary.

13.3 Chemical System Design

The following should be considered when designing any chemical system:

.1 Any material in contact with a treatment chemical should be resistant to the aggressiveness of the chemical solution;
.2 Corrosive chemicals should be introduced in such a manner as to minimize the potential for corrosion, i.e. the application should not be near sample taps, screens or pumping equipment; and
.3 Incompatible chemicals should not be stored or handled together (i.e. sodium hypochlorite is incompatible with acids or aluminum sulphate). Such incompatible chemicals should not be allowed to mix, including in a common drain.

13.3.1 Chemical Storage

The following should be considered for the storage of all chemicals:

.1 Sufficient chemical supply should be provided for a 30-day period at the maximum monthly consumption rate, but storage should also consider:
   a. A suitable safety factor based on reserve volume requirements and typical chemical delivery lag times;

b. The rate of decay of the chemical;
c. Emergency scenarios, where a delay in delivery may affect the availability of the chemical;

.2 A minimum storage volume of 1.5 times the delivery volume where the purchase is by truckload or railcar;
.3 Space for convenient and efficient handling of chemicals;
.4 Storage tanks and pipelines should not be used for different chemicals;
.5 Chemicals should be delivered in unopened or covered containers until transferred into an approved storage unit;
.6 Safety data sheets (SDS) for all chemicals used should be kept on-site;
.7 Storage location and associated controls should be selected with considerations for chemical and climate conditions to maintain stable product and should consider chemical decay rate and product reliability;
.8 Dry storage conditions;
.9 Floor surfaces should be smooth, impervious, non-slip, and well-drained; and
.10 Floor drains should be directed to separate containment areas, such that incompatible chemicals cannot mix. Containment areas should include provisions for discharge to an appropriate waste receiving/disposal system.

13.3.2 Application Points

The following should be considered when designing chemical application points:

.1 Ensure maximum efficiency of treatment;
.2 Ensure maximum safety to consumer;
.3 Provide maximum safety to operators;
.4 Minimize the potential for siphoning or hydraulically draining chemical storage tanks, even if their design includes antisiphon features;
.5 Ensure satisfactory mixing of the chemicals with the water (i.e. through a suitably designed diffuser which should be designed for removal and cleaning);
.6 Should not be located where the flow splits;
.7 Provide maximum flexibility of operation through various points of application, when appropriate;
.8 Prevent backflow or backsiphonage between multiple points of feed; and
.9 The sequence of addition of chemicals should be evaluated for potential interactions (reactions) that may decrease or eliminate the intended process effect.

13.3.3 Makeup Water Supply

Makeup water supply should be:

.1 Ample in quantity and adequate in pressure;
.2 Provided with a means for measurement when preparing specific solution concentrations by dilution;
.3 Properly treated for hardness, when necessary;
.4 Properly protected against backflow; and
.5 Obtained from the finished water supply, or from a location sufficiently downstream of any chemical feed point to ensure adequate mixing.

13.3.4 Cross Connection Control

Designers should refer to Chapter 5 – Facility Requirements for general cross connection considerations. Cross connection control should be provided to ensure that:

.1 The service water lines discharging to liquid storage tanks are properly protected from backflow as required;
.2 Chemical solutions or slurries cannot be siphoned through liquid chemical feeders into the water supply;
.3 No direct connection exists between any sewer and a drain or overflow from the liquid chemical feeder, liquid storage chamber or tank by providing that all drains terminate at least 150 mm or two pipe diameters, whichever is greater, above the overflow rim of a receiving sump, a conduit or waste receptacle; and
.4 In the absence of other cross connection control measures, separate day tanks and feeders should be provided for chemical feed systems that have feed points at both unfiltered and filtered water locations such that all unfiltered water feed points are fed from one day tank and feeder, and that all filtered water feed points are fed from another day tank and feeder.

13.3.5 Chemical Handling

When designing the handling methods of chemicals, safe work practices should be followed, including the following:

.1 The offloading area is to be designed to adequately contain spills and account for failure of delivery equipment;
.2 Carts, elevators, dollies and other appropriate means should be provided for lifting chemical containers to minimize any excessive lifting by operators;
.3 Provisions should be made for disposing of empty bags, drums, carboys, or barrels by an approved procedure which will minimize exposure to dust and prevent environmental damage; and
.4 Provision should be made for measuring quantities of chemicals used to prepare feed solutions.

13.3.6 Chemical Feed Equipment

When feeding chemicals into the system, the following should be considered:

.1 Each chemical should be conducted from the feeder to the point of application in separate conduits;
.2 A separate feeder should be used for each chemical applied;
.3 Where a chemical feed pump is necessary for the protection of the supply, such as chlorination, coagulation or other essential processes, a standby unit or a combination of units of sufficient size to meet capacity should be provided to replace the largest unit when out of service;
.4 Spare parts should be available on-site for all feeders and chemical booster pumps to replace parts which are subject to wear and damage;
.5 Feeders should be able to supply, at all times, the necessary amounts of chemicals at an accurate rate, throughout the range of feed;
.6 Chemical feeders and pumps should operate at no lower than 20% of the maximum feed rate (unless the pump is equipped with two independent adjustment mechanisms such as

pump pulse rate and stroke length, in which case the pump should operate at no lower than 10% of the rated maximum unless approved); and

.7 Gravity feed may be used where practical; design must include adequate control (refer to Section 13.3.6.1 – Control of Feed Systems) and safety considerations.

13.3.6.1 Control of Feed Systems

The following should be considered for the control of the feed system:

.1 Feeders may be manually or automatically controlled. Automatic controls must be designed to allow override by manual controls;
.2 Systems should have automatic valve closure to isolate dosing lines in the event of a high-level chemical alarm, where the dosing chemical can have an adverse effect on the process or human health;
.3 Chemical feed rates should be proportional to the flow streams being dosed;
.4 A means to measure the water flow should be provided in order to determine chemical feed rates;
.5 Coagulant and coagulant aid addition may be controlled, where water quality conditions warrant, by turbidity, streaming current detectors, pH, or some other sensed parameter, in addition to plant flow;
.6 Chemical disinfectants should be automatically controlled by monitoring residual disinfectant concentrations in addition to plant flow with appropriate alarms and other procedures to prevent inadequately disinfected water from entering the distribution system; and
.7 Provisions should be made for measuring the quantities of chemicals used.

13.3.6.2 Locations of Feed Systems

The following should be considered for the location of the feed system:

.1 Should be readily accessible for servicing, repair, and observation of operation;
.2 Should be located in a separate room wherever hazards and dust problems may exist;
.3 Chemical feeders should be as near as practical to the feed point, to minimize feed line lengths; and
.4 Chemical feed pumps should be located within secondary spill containment.

13.3.7 Feed Lines

Feed lines should be:

.1 As short as possible;
.2 Avoid overhead installations and provide double wall or shielding where required (refer to Section 13.2 – Safety);
.3 Of durable, corrosion-resistant material;
.4 Easily accessible throughout the entire length;
.5 Readily cleanable;
.6 Neatly installed to avoid excessive changes in elevations and looping, and properly secured;
.7 Provide flushing ports at suitable locations to allow draining and cleaning of pipelines;
.8 Protected from freezing;
.9 Underground chemical lines should have double containment and leak detection;

.10 Slope upward from the chemical source to the feeder when conveying gases;
.11 Designed consistent with the scale-forming or solids depositing properties of the water, chemical, solution or mixtures being conveyed;
.12 Have an isolating valve when chemicals are dosed into a pressurized line; and
.13 Colour-coded and labelled as per Chapter 5 – Facility Recommendations.

13.4 Liquid Chemicals

13.4.1 Liquid Chemical Storage

The following should be considered when storing liquid chemicals:

.1 All tanks should have a liquid level indicator;
.2 All tanks should have an overflow and a receiving basin capable of receiving accidental spills or overflows without uncontrolled discharge. A common receiving basin may be provided for each group of compatible chemicals, which provides sufficient containment volume to prevent accidental discharge in the event of failure of the largest tank;
.3 The minimum containment should be equal to or greater than 110% of the volume of the largest storage unit, or combination of units if interconnected, less the volume remaining in the container(s) where storage vessels are located within the containment area;
.4 Storage tanks and pipelines for liquid chemicals should be specified for use with individual chemicals and not used for different chemicals;
.5 The minimum containment for chemical unloading and delivery areas should be equal to or greater than 110% of the volume of the largest vessel within the vehicle;
.6 Offloading areas should be clearly labelled to prevent accidental cross-contamination; and
.7 Chemicals should be stored in covered or unopened shipping containers, unless the chemical is transferred into an approved storage unit.

13.4.1.1 Bulk Tanks

Bulk liquid storage tanks should:

.1 Have a means, which is consistent with the nature of the chemical stored, to maintain a uniform chemical strength;
.2 Have continuous agitation to maintain slurries in suspension;
.3 Have a means to ensure continuity of chemical supply while servicing a tank;
.4 Have a method to measure the liquid level in the liquid storage tank, and where an external level gauge is provided, a shut-off valve at the tank connection is recommended;
.5 Have fill lines, which should be:
  a. A minimum of 50 mm in diameter;
  b. Properly identified at the end remote from the tank, and have provisions to drain the fill line;
  c. Sloped to drain into the tank;
.6 Low level and high-level alarms, enunciated where an operator is present, should be provided where applicable, and should be alarmed in the SCADA system where appropriate;
.7 Be kept covered. Large tanks with access openings should have such openings curbed and fitted with overhanging covers;
.8 Subsurface locations should:
  a. Be free from sources of possible contamination;

   b. Have positive drainage away from the area for groundwaters, accumulated water, chemical spills, and overflows;

.9 Have overflow pipes, which should be:
   a. Sized appropriately for the rate of fill;
   b. Turned downward, with the end screened;
   c. Not connected directly to the sewer;
   d. Have proper cross connection control;
   e. Sloped down from the tank;
   f. Have a free fall discharge into the containment area;
   g. Located where noticeable;

.10 Have vents, which should be:
   a. Not in common with other chemicals or day tanks;
   b. Minimum size 50 mm;
   c. With a down-turned end;
   d. Provided with an insect screen, where venting outside is required;
   e. Secured, if externally accessible;
   f. The potential for moisture build-up resulting in vent freezing should also be considered;

.11 Acid storage tanks should be vented to the outside atmosphere;

.12 Be provided with a valved drain, which should not discharge directly to a sewer;

.13 Be protected against cross connections;

.14 If lined, weep holes in the outer shell should be provided to give an indication of liner leakage;

.15 Have secondary containment, which should be located so that the chemicals from equipment failure, spillage or accidental drainage do not enter the water system or environment;

.16 Piping should be designed to minimize or contain chemical spills in the event of pipe ruptures.

13.4.1.2 Day Tanks

Chemicals that are delivered to the facility in liquid form and are not likely to precipitate, or chemical solutions that have been mechanically mixed in batch tanks, may be transferred to a day tank which is the supply for liquid metering pumps. Chemicals may be fed directly from the shipping containers if they are less than 200 L in volume, but protection against overfeeding should be considered. Day tanks help to reduce the impact of chemical overfeeding. The following should be considered when designing day tanks:

.1 Day tanks should meet all the requirements of the bulk liquid storage tanks in Section 13.3.1 – Chemical Storage, except that day tanks do not require overflow lines and drains;

.2 Day tanks should hold no more than a 30-hour supply based on average day demand;

.3 Day tank sizing should consider the following:
   a. The rate of use of the chemical;
   b. The decay of the chemical;
   c. The dilution ratio of the chemical;
   d. The frequency of operator attendance to the WTP;

.4 Day tanks should be covered;

.5 Acid storage tanks should be vented to an exterior building vent through separate vent pipes that are located far enough from the air intakes (air condition, ventilation, etc.) to prevent contamination of indoor air;

.6 Subsurface day tanks should not be used; if necessary, they should meet the requirements in Section 13.3.1 – Chemical Storage;

.7 Day tanks should be scale-mounted, or have a calibrated gauge painted or mounted on the side if liquid level can be observed in a gauge tube or through translucent sidewalls of the tank. In opaque tanks, a gauge rod may be used;

.8 Piping arrangement for refilling the day tanks should be such that it will prevent over-filling of the tanks;

.9 Except for fluosilicic acid, hand pumps should be provided for transfer from a shipping container. A tip rack may be used to permit withdrawal into a bucket from a spigot. Where motor-driven transfer pumps are provided, a liquid level limit switch should be provided;

.10 A means which is consistent with the nature of the chemical solution should be provided to maintain uniform chemical strength in a day tank;

.11 Low level and high-level alarms, enunciated where an operator is present, should be provided where applicable, and should be alarmed in the SCADA system where appropriate;

.12 Continuous agitation should be provided to maintain chemical slurries in suspension;

.13 Tanks and tank refilling line entry points should be clearly labelled with the name of the chemical contained; and

.14 Filling of day tanks should not be automated, unless otherwise authorized.

13.4.2 Liquid Chemical Feed Systems

Positive displacement solution feed pumps should be:

.1 Capable of operating at the required maximum rate against the maximum head conditions found at the point of injection;

.2 Provided with calibration tubes or mass flow monitors which allow for direct physical measurement of actual feed rates and to calibrate pumps;

.3 Provided with a pressure relief valve (PRV) on the pump discharge line:

a. The PRV should be adequately sized for the pump and set to be not greater than 20% of the pump discharge pressure in normal operation;
b. If the pumped fluid is relieved through the PRV, it should pass to a safe location, preferably back to the storage tank;
c. Where liquid-filled diaphragm pumps are in use, the over-pressure should be relieved by discharge of the motive fluid to a safe location; and
d. Where oil-filled diaphragm pumps are used, the oil must be of a grade suitable for use in drinking water supplies (food grade).

Special considerations should be made for slurry feed applications based on solids content, homogeneousness, operating pressure, and discharge feed piping configuration.

Eductors can be used to feed liquid chemicals. They should be selected for the point of application with consideration given to the quantity of chemical to be added, the maximum injector flow rate, the injector location pressure, the injector operating pressure, and the size of chlorine solution piping. Gauges for measuring water pressure and vacuum at the inlet and outlet of each eductor should be provided.

Liquid chemical feeders should be designed such that chemical solutions cannot be siphoned or overfed into the water supply, by:

.1 Ensuring discharge at a point of positive pressure;
.2 Providing vacuum relief;
.3 Providing emergency shutoff valves;
.4 Providing a suitable air gap or anti-siphon device; or
.5 Providing other suitable means or combinations as necessary.

13.5 Dry Chemicals

13.5.1 Dust Control

The following dust control measures should be designed to control dust from dry chemicals:

.1 Granular materials are preferred to powders;
.2 Particular care should be taken to protect mechanical and electrical equipment from fine dust;
.3 Provisions should be made for disposing of empty bags, drums or barrels by an approved procedure which minimizes exposure to dust;
.4 The transfer should be in such a way as to minimize the quantity of dust which may enter the room in which the equipment is installed;
.5 Dust control should be provided by use of vacuum pneumatic equipment or closed conveyor systems, facilities for emptying shipping containers in special enclosures and/or exhaust fans and dust filters that put the hoppers or bins under negative pressure;
.6 Where exhaust fans, filters, and conveying systems are used, grounding should be provided to prevent the build-up of static electricity;
.7 Floor drains should be provided for the wash down of floors in the transfer/storage area; and
.8 Silo vent and exhaust systems should be provided with dust filters and/or cyclone type separators to prevent the release of dust into the atmosphere.

13.5.2 Bulk Storage Silos & Feeders

For the design of bulk storage silos and feeders, the following should be considered:

.1 Bulk storage silos should be provided with adequately sized fill openings;
.2 Fill lines, where necessary, should be smooth internally with long radius elbows;
.3 Silos should be provided with suitable level indicating devices, such as load cells;
.4 A pressure relief valve should be provided when pneumatic fill systems are used;
.5 Air exhausted from the handling areas should be directed away from air intakes;
.6 The Designer should take into account material characteristics such as flowability, tendency to pack tightly, the angle of repose in the design of the silo bottom, and method of removal of material to a feeder; and
.7 Provision should be made to relieve bridging or rat-holing of the stored material, either by manual, mechanical or other means of rapping or agitating the hopper bottom or improving the flowability of the material, for example, by air fluidization.

13.5.3 Dry Chemical Feed Systems

When feeding dry chemicals, the following should be considered:

.1 Provide a means of measuring chemicals volumetrically or gravimetrically;
.2 Provide adequate solution water and agitation of the chemical at the point of placing in solution/slurry;
.3 Provide gravity feed from solution containers; and
.4 Completely enclose chemicals to prevent the emission of dust.

13.6 Gaseous Chemicals

13.6.1 Measuring Contents

Means of measuring the contents of gas containers should be provided, and where necessary for the proper operation of the feed system, means of adjusting and indicating gas pressure/vacuum and flow rates should be provided.

13.6.2 Moving Cylinders

The Designer should allow sufficient space in the storage area for convenient moving of cylinders from full storage to on-line to empty storage. For chlorine, sulphur dioxide, ammonia and carbon dioxide gas systems, the Designer should refer to documentation from the Chlorine Institute and gas equipment suppliers.

13.6.3 Storage Areas

Storage areas should:

.1 Be separated from other areas;
.2 Have separate outside access; and
.3 Be arranged to prevent the uncontrolled release of spilled gas to other areas of the plant and surrounding environment.

13.6.4 Feed Rates

Where high feed rates are required by evaporation from liquefied gas, it may not be possible to withdraw the required gas quantity from a single-cylinder due to evaporative cooling and the consequent reduction in gas vapour pressure.

The Designer should consider either using multiple cylinders online or the use of an evaporator to meet higher withdrawal rates. Where multiple cylinders are being used, provision for automatic switching between duty and standby cylinders should be provided for gaseous chemicals that are being relied upon for pathogen log reduction credit (e.g. disinfectants).

13.7 Chemical Specific Design

This section details design considerations that are unique to some of the commonly used water treatment chemicals.

13.7.1 Acids and Caustics

The following should be considered when designing chemical systems for acids and caustics:

.1 Acids and caustics should be kept in closed corrosion-resistant shipping containers or bulk liquid storage tanks;
.2 Acids and caustics should not be handled in open vessels but should be pumped in undiluted form to and from bulk liquid storage tanks and covered day tanks or from shipping containers through suitable hoses, to the point of treatment;
.3 Adequate precautions should be taken for operator safety, such as not adding water to concentrated acid; and
.4 Strong acids and bases require careful selection, storage, and handling to protect worker safety. For example, a 50% caustic solution starts to solidify at approximately 12 °C, which can plug piping and even cause injury if valves or piping fail as a result. For this reason, the use of a more dilute solution (25% or less) is recommended. When feeding concentrated acids and bases, include design features to lower the risk of chemical overfeed. Refer to Section 13.2 – Safety for more information.

13.7.2 Chlorine Gas

The Designer should refer to the *Safe Work Practices for Chlorine* by WorkSafeBC when designing a chlorine gas system. General design considerations for chlorine gas are below.

13.7.2.1 Chlorine Gas Storage

The following should be considered when designing chlorine gas storage:

.1 Chlorinators should be housed in a room separate from, but adjacent to, the chlorine storage room;
.2 Only equipment essential to the chlorine gas system should be stored in the chlorine gas room, including no other chemicals stored in the room;
.3 Regulator should be located as close as possible to the cylinder or tonner head. Regulator pressure relief valve vent should be directed outdoors, alarmed and remote from air intakes and occupied areas;
.4 All piping carrying chlorine gas or liquid should be identified according to WHMIS requirements;
.5 Both the chlorine gas feed and storage rooms should be located in the corner of the building, on the prevailing downwind side of the building and be away from entrances, windows, louvres, walkways, etc.;
.6 Premanufactured chlorine cabinets maybe used for retrofitting cylinder installations only. These cabinets should have an observation window, fan, air intake, ventilation, and light. These cabinets should not be placed on the sunny side of the building;
.7 A valve stem wrench should be kept in place on each cylinder or tonner in use, to allow quick closure during an emergency;
.8 Cylinders or tonners should be equipped with auto shutoff valves to limit release of chlorine gas in the event a chlorine gas leak;
.9 Cylinders should be stored in an upright position, tagged if empty and securely chained to the wall or weigh scale post

.10 Tonners should be stored on trunnions and tagged if empty. Online tonners should be loaded on weigh scales to monitor chemical storage levels;

.11 Ability to shut off chlorine gas at cylinder remotely, either manually or automatically due to alarm, with notice to operator;

.12 Protective hood in place when cylinder is not connected to chlorinator;

.13 Suitable weigh scale in use for active connected cylinder;

.14 Chlorinator rooms should be heated to 15.5 °C and protected from excessive heat. Cylinders and gas lines should be protected from temperatures above that of the feed equipment, with consideration for providing a heat detector alarm;

.15 Both the feed and storage rooms should be constructed to meet the following requirements:

a. A shatter-resistant inspection window should be installed in an interior wall to allow for visual inspection of the room and gas monitor to assess whether the room is safe to enter;
b. Include chlorine gas detection equipment located at floor level to continuously monitor for the presence of chlorine gas. Locate gas monitor display unit in a location that is visible from the monitoring window.
c. Signs should be posted identifying hazards and precautions for safe entry and designated as a restricted work area and limited to entry by authorized staff. The signs also need to be worded to ensure that the interior of the chlorine room is viewed for signs of a gas leak before the exhaust fan is turned on, and that the fan is turned on before routine entry. The specific alarm levels must be noted on the warning signs;
d. Room should be located above ground and enclosed from other rooms with a fire resistant floor and wall and be designed to prevent chlorine gas leaks from entering areas occupied by the public or by staff;
e. All openings between the rooms and the remainder of the plant should be sealed; The chlorine room needs to be smoke or pressure tested to confirm a complete seal upon completion of construction;
f. Doors should be equipped with panic hardware, ensuring ready means of exit, and opening outward only to the building exterior. Doors should also have a locking mechanism but not be self locking;
g. All room exits are external;
h. A signal light showing ventilating fan operation should be provided at each entrance when the fan can be controlled from more than one point;
i. Floor drains are discouraged. Where provided, the floor drains must discharge to the outside of the building and not be connected to other internal or external drainage systems; and
j. Provisions must be made to chemically neutralize or contain chlorine gas (or other acceptable measures) where feed and/or storage is located near residential or developed areas in the event of any measured chlorine release. The chemical neutralizing equipment must be sized to treat the entire contents of the largest storage container on site.

.16 Heating and ventilation in the feed and storage rooms should include the following considerations:

a. The ventilating exhaust fan should take suction near the floor and as great a distance as is practical from the door and air inlet. The point of discharge should be located outside of the building away from air inlets to any rooms or structures and designated walkway areas. The exhaust duct should not pass through other rooms. It also needs to be equipped with a gas-rated back-draft damper, as a major leak from a full cylinder of chlorine could displace several times the volume of air in a normal chlorine room;

b. A ventilating exhaust fan with a capacity to complete one air change per minute when the room is occupied; where this is not appropriate due to the size of the room, a lesser rate could be considered. The fan should be able to be operated in emergency situations and well as routinely;
c. Air inlets with corrosion-resistant louvres should be installed near the ceiling on the exterior wall;
d. Air intake and exhaust louvres should provide airtight closure;
e. Discharge ducts should be separate from other ducts and should be vapour proof and corrosion resistant. Discharge duct should extend vertically up to at least 2.5 m above the roof (if near the edge) or 6 m (if in the middle of the roof); and
f. Separate switches for the ventilating exhaust fan and for the lights should be located outside and at the inspection window and easily identified. Outside switches must be protected from vandalism.

13.7.2.2 Chlorine Gas Feeders

The following should be considered when designing chlorine gas feeders:

.1 Chlorine gas feed systems should be of the vacuum type and include a vacuum regulator on all individual cylinders in service;
.2 Service water to injectors/eductors should be of adequate supply and pressure to operate feed equipment within the needed chlorine dosage range for the proposed system;
.3 Pressurized chlorine feed lines should not carry chlorine gas beyond the chlorinator room. The chlorine gas ejector should be located within the chlorine room, and the ejector water supply line brought to it, so that all chlorine gas facilities are contained within the chlorine room;
.4 Full and empty cylinders of chlorine gas should meet the following requirements:
   a. Housed only in the chlorine storage room;
   b. Isolated from operating areas; and
   c. Restrained in position.

13.7.2.3 Chlorine Gas Leak Detection

Chlorine gas leaks are a public health and safety issue when using chlorine gas as a disinfectant. Leak prevention is the primary objective. The following should be considered when designing a chlorine gas leak detection system:

.1 A bottle of concentrated ammonium hydroxide (56% ammonia solution) should be available for chlorine leak detection;
.2 Where ton containers are used, a leak repair kit approved by the Chlorine Institute should be provided;
.3 Where pressurized chlorine gas is present, continuous chlorine leak detection equipment is required and should be equipped with both an audible alarm and a warning light;
.4 The alarm equipment, except the sensor, should be located inside the building and outside the chlorine room near the viewing window, to protect the equipment from corrosion and to ensure that a major leak does not destroy it before it alarms; and

.5 The gas sensor should be located near floor level within the chlorine room and remote from the door, ventilation inlet, and vacuum regulator vent outlet. The alarm unit should preferably not be hard wired to allow for maintenance, but the connection needs to be protected to prevent accidental unplugging.

13.7.2.4 Respiratory Protection Equipment

Respiratory protection equipment, meeting the requirements of the *CAN/CSA-Z94.4-18 Selection, Use and Care of Respirators* should be available where chlorine gas is handled and should be stored at a convenient heated location, but not inside any room where chlorine is used or stored. The units should use compressed air, have at least a 30-minute capacity, and be compatible with or be the same as the units used by the fire department responsible for the plant.

13.7.3 Chlorine Dioxide

Refer to Chapter 11 – Disinfection for guidance on the use of chlorine dioxide for disinfection.

13.7.3.1 Chlorine Dioxide Generators

Chlorine dioxide generation equipment should be factory assembled pre-engineered units with a minimum efficiency of 95%. Health Canada recommends a maximum feed dose of 1.2 mg/L of chlorine dioxide should not be exceeded to control the formation of chlorite and chlorate.

Common continuous generators require a stream of sodium chlorite solution and a carefully proportioned stream of chlorine. Where chlorine is not available, hypochlorite solution and an acid may be used in a three-feed reactor. When feed streams are correctly proportioned, these generators can show an efficiency in generating chlorine dioxide of over 95%. A variant generator that uses only hydrochloric acid and chlorite solution is simpler to feed but operates at a lower conversion efficiency. It produces chlorine dioxide that does not contain any elemental chlorine contamination; as a result, it does not form any THMs or HAAs when used as a disinfectant.

13.7.3.2 Feed and Storage Facilities

Chlorine gas and sodium chlorite feed and storage facilities should comply with Section 13.7.2 – Chlorine Gas and Section 13.7.4 – Sodium Chlorite, respectively. Sodium hypochlorite feed and storage facilities should comply with Section 13.7.5 – Sodium Hypochlorite.

13.7.3.3 Public Notification

Notification of a change in disinfection practices and the schedule for the change should be made known to the public; particularly to hospitals, kidney dialysis facilities, and fish breeders, as chlorine dioxide in water and its by-products may have health and safety considerations similar to those for chloramines.

13.7.4 Sodium Chlorite

Provisions should be made for the proper storage and handling of sodium chlorite to eliminate any danger of fire or explosion associated with its strong oxidizing nature.

13.7.4.1 Storage

The following should be considered when designing the storage of sodium chlorite:

.1 Sodium chlorite should be stored by itself in a separate room and preferably should be stored in an outside building detached from the water treatment facility. It should be stored away from organic materials because many materials will catch fire and burn violently when in contact with sodium chlorite;
.2 Storage structures should be constructed of non-combustible materials; and
.3 If a storage structure must be located in an area where a fire may occur, water must be available to keep the sodium chlorite area cool enough to prevent heat-induced explosive decomposition.

13.7.4.2 Handling

The following should be considered when designing the handling of sodium chlorite:

.1 Care should be taken to prevent spillage;
.2 An emergency plan of operation should be available for the cleanup of any spillage; and
.3 Storage drums must be thoroughly flushed to an acceptable drain prior to recycling or disposal.

13.7.4.3 Feeders

The following should be considered when designing the feeders for sodium chlorite:

.1 Positive displacement feeders should be provided;
.2 Tubing for conveying sodium chlorite or chlorine dioxide solutions should be Type 1 PVC, polyethylene or materials recommended by the manufacturer;
.3 Chemical feeders could be installed in chlorine rooms if sufficient space is provided, or in separate rooms;
.4 Feed lines should be installed in a manner to prevent formation of gas pockets and should terminate at a point of positive pressure; and
.5 Check valves should be provided to prevent the backflow of chlorine into the sodium chlorite line.

13.7.5 Sodium Hypochlorite

Sodium hypochlorite storage and handling procedures should be arranged to minimize the slow natural decomposition process of sodium hypochlorite either by contamination or by exposure to more extreme storage conditions. Additionally, feed rates should be regularly adjusted to compensate for this progressive loss in chlorine content.

Sodium hypochlorite is highly corrosive; the design should incorporate appropriate precautions such as avoiding contact with metals, including stainless steel.

13.7.5.1 Storage

When designing the storage of sodium hypochlorite systems, the following should be considered:

.1 Sodium hypochlorite should be stored in the original shipping containers or in sodium hypochlorite compatible bulk liquid storage tanks;

.2 Storage containers or tanks should be located out of the sunlight in a cool area and should be vented to the outside of the building;

.3 Wherever reasonably feasible, stored sodium hypochlorite should be pumped undiluted to the point of application. Where dilution is unavoidable, deionized or softened water should be used;

.4 Storage areas, tanks, and pipe work should be designed to avoid the possibility of uncontrolled discharges and a sufficient amount of appropriately selected spill absorbent should be stored on-site; and

.5 Reusable sodium hypochlorite storage containers should be reserved for use with sodium hypochlorite only and should not be rinsed out or otherwise exposed to internal contamination.

13.7.5.2 Feeders

When designing the feeders for sodium hypochlorite systems, the following should be considered:

.1 Avoid the use of threaded connections as much as possible with PVC systems. Flanged or solvent welded joints are preferable;

.2 Positive displacement pumps with sodium hypochlorite compatible materials for wetted surfaces should be used;

.3 To avoid air locking in smaller installations, small diameter suction lines should be used with foot valves and degassing pump heads;

.4 In larger installations, flooded suction should be used with pipework arranged to ease the escape of gas bubbles;

.5 Calibration tubes or mass flow monitors which allow for direct physical checking of actual feed rates should be provided; and

.6 Injectors should be made removable for regular cleaning, where hard water is to be treated.

13.7.6 Calcium Hypochlorite

Calcium hypochlorite, which is sold as a white powder and as tablets, is typically used to boost chlorine concentration in service reservoirs or for chlorination of small systems. Granular calcium hypochlorite comes in the form of chlorinated lime (a mixture of $Ca(OH)_2$, $CaCl_2$ and $Ca(OCl)_2$) or high test hypochlorite (HTH). All forms of calcium hypochlorite are made with added inert materials (i.e. 30-35% w/w in the case of HTH tablets and 65-80% w/w in the case of chlorinated lime in powder form).

Calcium hypochlorite feeders are manufactured for a range of flow rates. For larger flows, volumetric or gravimetric feeders drop a measured amount of HTH powder (in volume or weight) into a dissolution tank (always accompanied by mixing). After dissolution, the solution is dosed similarly to sodium hypochlorite. Solutions should be prepared on a batch basis for use. The use of feeder devices for calcium hypochlorite is uncommon for larger flows which are usually treated by liquid sodium hypochlorite or chlorine gas.

For smaller flows, HTH in solid tablet form is used (65% w/w Cl_2). These tablets lose less than 1 to 2% w/w Cl_2 per year if stored properly under appropriate conditions. Application in tablet form tends to be limited to small chlorine usage (water flow rates < 0.5 ML/d) due to cost and the practical difficulties of making up aqueous solutions of hypochlorite from the solid product. Tablets are typically used in conjunction with tablet erosion feeders.

Both granular calcium hypochlorite and tablets include additives to prevent powdering of the active material and to stop the adsorption of moisture. This inert material must be separated from the dissolved active hypochlorite to prevent clogging and blockages of pumps and equipment. Separation of diluted calcium hypochlorite from inert materials can be achieved as follows:

.1 From granular product, by the provision of a separate mixing tank upstream of the dosing tank and mechanically mixing. Following proper mixing the inert insoluble material can settle prior to decantation of the dissolved liquid only to the dosing tank;
.2 From granular product, by allowing mixed batched solution to stand for a period of 24 hours prior to dosing so that inert residues settle out prior to use; and
.3 By the use of tablet erosion feeders.

A typical calcium hypochlorite tablet chlorinator consists of a cylindrical PVC tank with a diameter ranging from 230 to 610 mm and a height ranging from 0.6 to 1.2 m. A sieve plate with holes supports the 80 mm diameter calcium hypochlorite tablets.

Tablet chlorinator systems can typically provide between 1 and 295 kg of chlorine per day. A side stream from the main flow is piped into the chlorinator at the bottom of the tank. The flow rises through the holes in the sieve plate, contacting and eroding the bottom layer of tablets. The tablets erode at a predictable rate based on the amount of water that enters the chlorinator. A correct chlorine dosage can be achieved by controlling the water flow rate through the chlorinator. The chlorinator effluent is mixed with the main water flow, providing the desired level of available chlorine to meet operational requirements. Due to the simplicity of the dosing method, tablet chlorinators can be useful for applications in small water systems with reduced maintenance requirements; however, for the same reason, it can be difficult to maintain chlorine doses if the influent water flow rate or quality is variable.

13.7.7 On-Site Hypochlorite Generation Systems

For the design of on-site hypochlorite generation systems, the Designer should consult equipment manufacturers and *AWWA M65 Onsite Generation of Hypochlorite*. Proprietary equipment is available to produce dilute hypochlorite solution by electrolysis of sodium chloride brine. The low concentration sodium hypochlorite solution produced (typically around 0.8%) has a number of advantages compared to bulk sodium hypochlorite (typically around 12%): greatly reduced off-gassing, minimal scaling at feed points, lowered impact on finished water pH and reduced health hazards (i.e. skin irritation).

It should be noted that these systems are typically only cost effective for larger WTPs. Additionally, this process may be more advantageous in remote locations where chemical transportation/delivery is an issue.

The following variables determine the overall efficiency of a given system:

.1 The feed rates of brine and dilution water;
.2 The temperature of the dilute brine entering the cell; and
.3 Electrode (particularly anode) condition.

Water is used in the electrolysis process, both to prepare saturated brine and to dilute the brine prior to the electrolytic cell(s). The high pH within the cell during electrolysis will rapidly precipitate the dissolved calcium and magnesium salts naturally present in some waters, forming scale on the electrode surfaces and reducing electrolysis efficiency. To avoid this, an ion exchange (cationic) softener should be used to treat the water supply to reduce the total hardness of the feed water to typically less than 15 mg $CaCO_3$/L to reduce the need for frequent cell cleaning. Even where the natural hardness of the feed water is low, softening may be installed because of the additional purification provided in terms of the removal of manganese and iron, which could otherwise precipitate in the electrolysis cells and on electrodes. Refer to Section 15.2.3 – Ion Exchange for design considerations.

Cell designs vary from one manufacturer to another. Within the electrolysis cell is a matrix of plate type electrodes manufactured from metals which are resistant to the chemically aggressive environment present during electrolysis. The anode typically comprises a titanium base with a precious metal oxide coating; the cathode is made of either Hastelloy C (a nickel-based alloy) or titanium.

A greater electrolysis voltage is required at low temperatures (lower electrical conductivity) and this can lead to stripping of the metal oxide coating on the anode. This may require that the dilute brine entering the cell is heated indirectly via heat exchange with the warmer cell product. Additional thermostatically-controlled electrical heating should be provided in situations where feedstock temperature can fall below 6 °C. A benefit of heating is the enhanced electrolysis efficiency at higher temperatures, although too great an electrolyte temperature leads to accelerated formation of chlorate by-product, and deterioration in overall efficiency.

The electrolyser system is designed to produce hypochlorite with a chlorine concentration usually in the range of 7 to 9 g Cl_2/L (or 0.7 to 0.9% w/v). Salt consumption rates of proprietary systems are typically 3 kg of salt per kg of equivalent chlorine.

The product from the electrolytic cell, a mixture of aqueous sodium hypochlorite and hydrogen gas, passes to a storage tank. A blower is used to force air into the tank headspace during hypochlorite generation, which reduces the hydrogen concentration to < 1% v/v (25% of lower explosive limit of 4% v/v) and assists ventilation. The diluted hydrogen gas is vented to the atmosphere via a vent above the storage tank. An atmospheric gas monitor should be installed to monitor hydrogen concentration in the electrolyser room.

The following should be considered during the design of on-site hypochlorite generating (OSHG) systems:

.1 The design should provide for a supply of brine makeup water of adequate temperature and quality. Water softening should be considered for brine makeup water to remove excess calcium and magnesium in order to protect electrode life and efficiency by preventing scaling;

.2 Hydrogen gas is a by-product: the design should include a means to safely discharge an off-gas stream of hydrogen. The explosion hazard should be addressed by forced venting of storage tanks to maintain low hydrogen concentrations (<1% v/v).
   - Vents must terminate at a safe exterior location (away from walkways/entrances/air intake and adequately above building high points to allow proper discharge into the atmosphere;

.3 A gas monitor should be installed at the highest point within the generation room and provide an alarm and/or shutdown of the equipment if hydrogen concentration exceeds 1% v/v; and

.4 A day tank for storage of the hypochlorite solution should be provided.

13.7.8 Potassium Permanganate

When designing potassium permanganate systems, the following should be considered:

.1 Potassium permanganate solution decomposes slowly and can be purchased as a granular solid;
.2 Potassium permanganate may be supplied in dry form in buckets, drums and bulk;
.3 A concentrated potassium permanganate solution (1 to 4%) can be generated on-site for water treatment applications;
.4 A source of heated water should be available for dissolving potassium permanganate and mechanical mixers should be provided;
.5 Depending on the amount of permanganate required, solutions should be made up in batch modes, using storage tanks with mixers and a metering pump for small feed systems;
.6 Larger systems should include a dry chemical feeder, storage hopper and dust collector configured to automatically supply permanganate to the solution storage tank;
.7 In conventional treatment plants, potassium permanganate solution is added to the raw water intake, or as far upstream of coagulant addition as possible;
.8 Adequate mixing should be provided;
.9 In all cases, potassium permanganate should be added prior to filtration;
.10 Potassium permanganate solution should be pumped from the solution tank to the injection point. If the injection point is a pipe, a standard injection nozzle protruding midway into the pipe section should be used;
.11 Injection nozzles can also be used to supply the solution to mixing chambers and clarifiers; and
.12 Powered activated carbon (PAC) and potassium permanganate should not be added concurrently.

13.7.9 Activated Carbon

When designing an activated carbon system, the following should be considered:

.1 Activated carbon is a potentially combustible material requiring isolated storage;
.2 Storage facilities should be fireproof and equipped with explosion-proof electrical outlets, lights and motors in areas of dry handling;
.3 Bags of powdered carbon should be stacked in rows with aisles between in such a manner that each bag is accessible for removal and stored in locked and secure rooms separate from ammonia storage;
.4 Protection should be provided from direct sunlight or exposure to excessive heat; and
.5 The Designer should avoid feeding chlorinated water to any form of carbon.

13.7.9.1 Powdered Activated Carbon (PAC)

The following should be considered for PAC design:

.1 The Designer should consider the possibility of powered activated carbon (PAC) addition at several points within the treatment process;
.2 PAC addition should take place as far upstream of coagulant addition as possible, preferably with mechanically aided mixing;

.3 PAC can be added as a premixed slurry or by means of dry feed;
.4 Continuous agitation should be provided to ensure that the PAC does not deposit in the slurry storage tank;
.5 PAC should be considered as a potentially combustible material and should be stored in a separate fire-retardant building or room equipped with explosion proof lighting and electrical systems. Spark-free lighting and electrical systems should be provided;
.6 Wet activated carbon may create an oxygen-deficient environment in enclosed spaces; therefore, appropriate safety precautions should be provided;
.7 Manufacturer recommendations regarding storage and handling should be followed;
.8 Provision should be made for adequate dust control;
.9 Provision should be made to scrub or filter carrier air, when dry PAC is off-loaded into silos; and
.10 PAC should be added downstream of potassium permanganate because it may adsorb permanganate, rendering it unavailable for the oxidation of target organics.

13.7.10 Ammonia

Ammonia for chloramine formation may be added to water either as an aqueous solution of ammonium sulphate, as aqua ammonia, or as anhydrous ammonia (purified 100% ammonia in liquid or gaseous form). The special provisions required for each form of ammonia are listed below.

13.7.10.1 Ammonium Sulphate

An aqueous solution is made by the addition of ammonium sulphate solid to water, with agitation. The tank and dosing equipment contact surfaces should be made of corrosion-resistant non-metallic materials. Provision should be made for removal of the agitator after dissolving the solid. The tank should be fitted with an air-tight lid and vented outdoors. The application point should be at the center of treated water flow, at a location where there is high-velocity movement.

13.7.10.2 Aqua Ammonia (Ammonium Hydroxide)

Aqua ammonia feed pumps and storage should be enclosed and separated from other operating areas. The aqua ammonia room should be equipped as in Section 13.6.3 – Storage Areas with the following changes:

.1 Corrosion-resistant, closed, and unpressurized tanks should be used for bulk liquid storage and day tanks, vented through inert liquid traps to a high point outside;
.2 An incompatible connector or lockout provisions should be provided to prevent accidental addition of other chemicals to bulk liquid storage tank(s);
.3 Bulk liquid storage tank(s) should be designed to avoid conditions where temperature increases cause the ammonia vapour pressure over the aqua ammonia to exceed atmospheric pressure. Such provisions should include either:
   a. Refrigeration or other means of external cooling, and/or;
   b. Dilution and mixing of the contents with water without opening the bulk liquid storage tank;
.4 An exhaust fan should be installed to withdraw air from high points in the room and makeup air should be allowed to enter at a low point;

.5 The aqua ammonia feed pump, regulators and lines should be fitted with pressure relief vents discharging outside the building away from any air intake and with water purge lines leading back to the headspace of the bulk storage tank;
.6 Aqua ammonia should be conveyed directly from a day tank to the treated water stream injector without the use of a carrier water stream, unless the carrier stream is softened;
.7 The application point should be placed in a region of rapid, preferably turbulent, water flow;
.8 Provisions should be made for easy access for the removal of calcium scale deposits from the injector; and
.9 Provision of a modestly sized scrubber capable of handling occasional minor emissions should be considered.

13.7.10.3 Anhydrous Ammonia

Anhydrous ammonia is readily available as a pure liquefied gas under moderate pressure in cylinders or as a cryogenic liquid boiling at -15 °C at atmospheric pressure. The liquid causes severe burns on skin contact.

The following should be considered when designing an anhydrous ammonia system:

.1 Anhydrous ammonia and storage feed systems (including heaters where required) should be enclosed and separated from other work areas and constructed of corrosion resistant materials;
.2 Pressurized ammonia feed lines should be restricted to the ammonia room and any feed lines located outside the room should be installed in airtight conduit pipe;
.3 An emergency air exhaust system, as in Chapter 5 – Facility Recommendations but with an elevated intake, should be provided in the ammonia storage room;
.4 Leak detection systems should be provided in all areas through which ammonia is piped;
.5 Special vacuum breaker/regulator provisions must be made to avoid potentially violent results of the backflow of water into cylinders or storage tanks;
.6 Carrier water systems of soft or pre-softened water may be used to transport ammonia to the application point and to assist in mixing;
.7 The ammonia injector should use a vacuum eductor or should consist of a perforated tube fitted with a closely fitting flexible rubber tubing seal punctured with a number of small slits to delay fouling by lime or other scale deposits;
.8 Provision should be made for the periodic removal of lime or other scale deposits from injectors and carrier piping; and
.9 Consideration should be given to the provision of an emergency gas scrubber capable of absorbing the entire contents of the largest anhydrous ammonia storage unit whenever there is a risk to the public as a result of potential ammonia leaks.

13.7.11 Hydrogen Peroxide

Advanced oxidation processes (AOPs) may use a combination of peroxide and ozone or peroxide and UV. For AOPs using ozone, hydrogen peroxide can be added upstream or downstream of ozone, or simultaneously with ozone dosing. Where UV is used, peroxide is added either upstream or simultaneously with UV irradiation. Peroxide residual should be removed before the application of chlorine. Alternatively the peroxide residual can be quenched with chlorine itself through the application of a higher chlorine dose to accommodate for demand from the peroxide residual. In either case, bench-scale testing of the quenching should be conducted, and chlorine residual should be closely monitored after quenching.

Peroxide is a strong oxidant and contact with personnel should be avoided. Secondary containment should be provided for storage tanks. Dual containment piping should be considered to minimize the risk of exposure to plant personnel.

Peroxide can be stored on-site but decomposes gradually over time, releasing oxygen in the process. Peroxide decomposes rapidly if contaminated and with heat or exposure to certain materials. Excessive heat may cause a tank rupture due to gas generation if the tank is not vented properly. Tanks and storage rooms should be vented according to manufacturer/supplier specifications.

Peroxide can be stored in high density polyethylene, 304L or 316L grade stainless steel drums or tanks. Pipes, gaskets and metering pumps should be constructed of peroxide-resistant materials. The Designer should ensure that all wetted stainless-steel components are passivated using industry accepted passivation procedures. Peroxide has a lower freezing point than water, however, housing or heat tracing should be provided for storage tanks and exterior piping if extended periods with temperatures below freezing are anticipated.

Pumps should be designed to prevent potential air binding of off-gas. Adequate mixing should be provided. It is recommended that all peroxide chemical dosing systems be provided with safety relief valves in areas where hydrogen peroxide can become trapped.

13.7.12 Ozone

Ozonation systems are generally used for the purpose of disinfection, oxidation, micro-flocculation and algal control. Typically, only one of these purposes is the primary goal of ozonation, although the other outcomes are achieved as secondary benefits. Ozone may also be used in an AOP (advanced oxidation) installation. For detailed design guidance refer to *Ozone in Drinking Water Treatment: Process, Design and Optimization* (Rakness 2005).

Ozone is an effective disinfectant for pathogens: ozone CT values for the inactivation of viruses, *Cryptosporidium* and *Giardia* cysts are considerably lower than the CT values for other disinfectants. Refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* for the required ozone CT.

Micro-flocculation and enhanced filterability have been demonstrated in many ozone installations, but depend on source water characteristics. Oxidation of organic compounds that contribute to colour, taste and odour, and inorganic compounds such as iron, manganese, heavy metals and hydrogen sulphide has been documented. The effectiveness of oxidation varies, depending on the pH and alkalinity of the water.

These parameters affect the formation of highly reactive hydroxyl radicals, or, the scavenging of this oxidant. High levels of hydroxyl radicals cause lower levels of residual ozone. Depending on the desired oxidation reaction, it may be necessary to maximize ozone residual or maximize hydroxyl radical formation.

As a minimum, bench scale studies should be conducted to determine minimum and maximum ozone dosages for disinfection CT compliance and oxidation reactions. Pilot-scale studies should be conducted when necessary to document benefits and DBP precursor removal effectiveness. Consideration should be given to multiple points of ozone addition. Pilot studies should be conducted for all surface waters. Extreme care should be taken during bench and pilot scale studies to ensure accurate results. Parameters which require particularly accurate and precise measurement include gas flow rate, water flow rate, and ozone concentration.

Ozone does not provide a stable residual. For secondary disinfection, the application of a disinfectant which maintains a measurable residual (i.e. chlorine or chloramine) is needed after ozonation.

Due to the operational complexity of ozone processes, a higher degree of operator maintenance skills and training is required than for most other chemical treatment processes. The ability to obtain qualified operators should be considered in the selection of the treatment process. The necessary operator training for the equipment should be provided prior to plant start-up.

The production of ozone is an energy intensive process: substantial efficiencies in electrical usage, reduction in equipment size, and waste heat removal requirements can be obtained by using oxygen enriched air or 100% oxygen as feed, and by operating at increased electrical frequency.

The use of ozone may increase the biologically available organics content of the treated water. Biologically active filtration may be required to stabilize some treated waters. Ozone use may also lead to increased chlorinated by-product levels if the water is not stabilized and free chlorine is used for distribution system protection.

13.7.12.1 Feed Gas Preparation

Feed gas can be air, oxygen-enriched air, or high purity oxygen. Sources of high purity oxygen include purchased liquid oxygen; on-site generation using cryogenic air separation; or temperature, pressure or vacuum swing (adsorptive separation) technology. For high purity oxygen feed systems, dryers typically are not required.

Air handling equipment on conventional low-pressure air feed systems should consist of an air compressor, water/air separator, refrigerant dryer, heat reactivated desiccant dryer, and particulate filters. Some "package" ozonation systems for small plants may work effectively operating at high pressure without the refrigerant dryer and with a "heatless" desiccant dryer. In all cases the Designer must ensure that the maximum dew point of -60 °C will not be exceeded at any time.

The following should be considered in the design of air compression systems:

- .1 Air compressors should be of the liquid-ring or rotary lobe, oil-less, positive displacement type for smaller systems or dry rotary screw compressors for larger systems;
- .2 The air compressors should have the capacity to simultaneously provide for maximum ozone demand, provide the air flow required for purging the desiccant dryers (where required) and allow for standby capacity;
- .3 Air feed for the compressor should be drawn from a point protected from rain, condensation, mist, fog and contaminated air sources to minimize moisture and hydrocarbon content of the air supply;
- .4 A compressed air after-cooler and/or entrainment separator with automatic drain should be provided prior to the dryers to reduce water vapor; and

.5 A back-up air compressor must be provided so that ozone generation is not interrupted in the event of a break-down.

The following should be considered in the design of air drying systems:

.1 Dry, dust-free and oil-free feed gas must be provided to the ozone generator. Dry gas is essential to prevent formation of nitric acid, to increase the efficiency of ozone generation and to prevent damage to the generator dielectrics. Sufficient drying to a maximum dew point of -60 °C must be provided at the end of the drying cycle;
.2 Drying for high pressure systems may be accomplished using heatless desiccant dryers only. For low pressure systems, a refrigeration air dryer in series with heat-reactivated desiccant dryers should be used;
.3 A refrigeration dryer capable of reducing inlet air temperature to 4 °C should be provided for low pressure air preparation systems. The dryer can be of the compressed refrigerant type or chilled water type;
.4 For heat-reactivated desiccant dryers, the unit should contain two desiccant filled towers complete with pressure relief valves, two four-way valves and a heater. In addition, external type dryers should have a cooler unit and blowers. The size of the unit should be such that the specified dew point will be achieved during a minimum adsorption cycle time of 16 hours while operating at the maximum expected moisture loading conditions;
.5 Multiple air dryers should be provided so that ozone generation is not interrupted in the event of a dryer breakdown; and
.6 Each dryer should be capable of venting dry gas to the atmosphere, prior to the ozone generator, to allow start-up when other dryers are online.

The following should be considered for air filters:

.1 Air filters should be provided on the suction side of the air compressors, between the air compressors and the dryers and between the dryers and the ozone generators; and
.2 The filter before the desiccant dryers should be of the coalescing type and be capable of removing aerosol and particulates larger than 0.3 microns in diameter. The filter after the desiccant dryer should be of the particulate type and be capable of removing all particulates greater than 0.1 microns in diameter, or smaller if specified by the generator manufacturer.

Preparation piping design should consider:

.1 Piping in the air preparation system can be common grade steel, seamless copper, stainless steel or galvanized steel; and
.2 Piping must be designed to withstand the maximum pressures in the air preparation system.

13.7.12.2 Ozone Generator

The following should be considered for capacity design:

.1 The production rating of the ozone generators should be stated in pounds per day and kWh per pound at a maximum cooling water temperature and maximum ozone concentration;
.2 The design should ensure that the minimum concentration of ozone in the generator exit gas will not be less than 1% (by weight);

.3 Generators should be sized to have sufficient reserve capacity so that the system does not operate at peak capacity for extended periods of time. This can result in premature breakdown of the dielectrics;
.4 The production rate of ozone generators will decrease as the temperature of the coolant increases. If the supply temperature of the coolant will vary throughout the year, then relevant data should be used to determine associated production changes. The design should ensure that the generators can produce the required ozone at maximum coolant temperature; and
.5 Appropriate ozone generator backup equipment must be provided.

The generators can be low, medium or high frequency type. Specifications should require that the transformers, electronic circuitry and other electrical hardware be proven, high quality components designed for ozone service.

Adequate cooling should be provided. The required water flow to an ozone generator varies with the ozone production. Normally unit design provides a maximum cooling water temperature rise of 8 °C. The cooling water must be properly treated to minimize corrosion, scaling and microbiological fouling of the water side of the tubes. A closed loop cooling water system is often used to ensure proper water conditions are maintained. Where cooling water is treated, cross connection control should be provided to prevent contamination of the potable water supply.

To prevent corrosion, the ozone generator shell and tubes should be constructed of Type 316L stainless steel.

13.7.12.3 Ozone Contactors

The selection or design of the contactor and method of ozone application depends on the purpose for which the ozone is being used.

For bubble diffusers:

.1 Where disinfection is the primary treatment goal, a minimum of two contact chambers each equipped with baffles to prevent short circuiting. Ozone should be applied using porous-tube or dome diffusers;
.2 The minimum contact time should be 10 minutes. A shorter contact time may be considered if justified by appropriate design and CT calculations;
.3 For ozone applications in which precipitates are formed, such as with iron and manganese removal, porous diffusers should be used with caution;
.4 Where taste and odour control are of concern, multiple application points and contactors should be considered;
.5 Contactors should be separate closed vessels that have no common walls with adjacent rooms. The contactor must be kept under negative pressure and sufficient ozone monitors should be provided to protect worker safety. Placement of the contactor where the entire roof is exposed to the open atmosphere is recommended;
.6 Large contact vessels should be made of reinforced concrete. All reinforcement bars should be covered with a minimum of 38 mm of concrete. Smaller contact vessels can be made of stainless steel, fiberglass or other material which will be stable in the presence of residual ozone and ozone in the gas phase above the water level;

.7 Where necessary a system should be provided between the contactor and the off-gas destruct unit to remove froth from the air and return the froth to the contactor or another location. If foaming is expected to be excessive, then a potable water spray system (with appropriate cross connection controls) should be placed in the contactor head space;
.8 All openings into the contactor for pipe connections, hatchways, etc. should be properly sealed using welds or ozone-resistant gaskets such as Teflon or Hypalon;
.9 Multiple sampling ports should be provided to enable sampling of the effluent from each compartment and to confirm CT calculations;
.10 A pressure/vacuum relief valve should be provided in the contactor and piped to a location where there will be no damage to the destruction unit;
.11 The diffusion system should work on a countercurrent basis such that the ozone is fed at the bottom of the vessel and water is fed at the top of the vessel;
.12 The depth of water in bubble diffuser contactors should be a minimum of 5.5 m. The contactor should also have a minimum of 1 m of freeboard to allow for foaming; and
.13 All contactors should have provisions for cleaning, maintenance and drainage of the contactor. Each contactor compartment should also be equipped with an access hatchway.

Other contactor styles, such as the venturi or aspirating turbine mixer contactor types, may be considered provided adequate ozone transfer is achieved and the required contact times and residuals can be met and verified.

13.7.12.4 Ozone Destruction Unit

.1 A system for treating the final off-gas from each contactor must be provided in order to meet safety and air quality standards. Acceptable systems include thermal destruction and thermal/catalytic destruction units;
.2 In order to reduce the risk of fires, the use of units that operate at lower temperatures is encouraged, especially where high purity oxygen is the feed gas;
.3 The maximum allowable ozone concentration in the discharge is 0.1 ppm (by volume);
.4 At least two units should be provided which are each capable of handling the entire gas flow;
.5 Exhaust blowers should be provided in order to draw off-gas from the contactor into the destruct unit;
.6 Catalysts must be protected from froth, moisture and other impurities which may harm the catalyst; and
.7 The catalyst and heating elements should be located where they can easily be reached for maintenance.

13.7.12.5 Piping Materials

Only low carbon 304L and 316L stainless steels should be used for ozone service; 316L is preferred due to its superior corrosion resistance.

13.7.12.6 Joints and Connections

.1 Connections on piping used for ozone service are to be welded where possible;
.2 Connections with meters, valves or other equipment are to be made with flanged joints with ozone resistant gaskets, such as Teflon of Hypalon. Screwed fittings should not be used because of their tendency to leak; and

.3 A positive closing plug or butterfly valve plus a leak-proof check valve should be provided in the piping between the generator and the contactor to prevent moisture from reaching the generator.

13.7.12.7 Instrumentation

.1 Pressure gauges should be provided at the discharge from the air compressor, at the inlet to the refrigeration dryers, at the inlet and outlet of the desiccant dryers, at the inlet to the ozone generators and contactors and at the inlet to the ozone destruction unit;
.2 Electric power meters should be provided for measuring the electric power supplied to the ozone generators. Each generator should have a trip which shuts down the generator when the wattage exceeds a certain pre-set level;
.3 Dew point monitors should be provided for measuring the moisture of the feed gas from the desiccant dryers. Because it is critical to maintain the specified dew point, it is recommended that continuous recording charts be used for dew point monitoring which will allow for proper adjustment of the dryer cycle. Where there is potential for moisture to enter the ozone generator from downstream of the unit or where moisture accumulation can occur in the generator during shutdown, post-generator dew point monitors should be used;
.4 Air flow meters should be provided for measuring air flow from the desiccant dryers to each of the other ozone generators, air flow to each contactor and purge air flow to the desiccant dryers;
.5 Temperature gauges should be provided for the inlet and outlet of the ozone cooling water and the inlet and outlet of the ozone generator feed gas, and, if necessary, for the inlet and outlet of the ozone power supply cooling water;
.6 Water flow meters should be installed to monitor the flow of cooling water to the ozone generators and, if necessary, to the ozone power supply;
.7 Ozone monitors should be installed to measure ozone concentration in both the feed-gas and off-gas from the contactor and in the off-gas from the destruct unit. For disinfection systems, monitors should also be provided to measure ozone residuals in the water. The number and location of ozone residual monitors should be such that the amount of time that the water is in contact with the ozone residual can be determined; and
.8 A minimum of one ambient ozone monitor should be installed in the vicinity of the contactor and a minimum of one ambient ozone monitor should be installed in the vicinity of the generator. Ozone monitors should also be installed in any areas where ozone gas may accumulate.

13.7.12.8 Alarms

The following alarm/shutdown systems should be considered at each installation:

.1 Dew point shutdown/alarm - This system should shut down the generator in the event the system dew point exceeds -60 °C;
.2 Ozone generator cooling water flow shutdown/alarm - This system should shut down the generator in the event that cooling water flows decrease to the point that generator damage could occur;
.3 Ozone power supply cooling water flow shutdown/alarm - This system should shut down the power supply in the event that cooling water flow decreases to the point that damage could occur to the power supply;

.4 Ozone generator cooling water temperature shutdown/alarm - This system should shut down the generator if either the inlet or outlet cooling water exceeds a certain preset temperature;

.5 Ozone power supply cooling water temperature shutdown/alarm - This system should shut down the power supply if either the inlet or outlet cooling water exceeds a certain preset temperature;

.6 Ozone generator inlet feed-gas temperature shutdown/alarm - This system should shut down the generator if the feed-gas temperature is above a preset value;

.7 Ambient ozone concentration shutdown/alarm - The alarm should sound when the ozone level in the ambient air exceeds 0.1 ppm or a lower value chosen by the Water Supplier.

.8 Ozone generator shutdown should occur when ambient ozone levels exceed 0.3 ppm (or a lower value) in either the vicinity of the ozone generator or the contactor; and

.9 Ozone destruct temperature alarm - The alarm should sound when temperature exceeds a pre-set value.

13.7.12.9 Safety

The following should be considered in ozone safety design:

.1 The maximum allowable ozone concentration in the air to which workers may be exposed must not exceed 0.1 ppm (by volume);

.2 Noise levels resulting from the operating equipment of the ozonation system should be controlled to within acceptable limits by special room construction and equipment isolation;

.3 High voltage and high frequency electrical equipment must meet current electrical and fire codes;

.4 Emergency exhaust fans must be provided in the rooms containing the ozone generators to remove ozone gas if leakage occurs;

.5 A portable purge air blower should be provided to remove residual ozone in the contactor prior to entry for repair or maintenance; and

.6 A sign should be posted indicating “No smoking, oxygen in use” at all entrances to the treatment plant. In addition, no flammable or combustible materials should be stored within the oxygen generator areas.

.7 Refer to the WorkSafeBC *Ozone Safe Work Practices* manual for additional considerations.

13.7.12.10 Construction Considerations

.1 Prior to connecting the piping from the desiccant dryers to the ozone generators, the air compressors should be used to blow the dust out of the desiccant;

.2 The contactor should be tested for leakage after sealing the exterior. This can be done by pressurizing the contactor and checking for pressure losses; and

.3 Connections on the ozone service line should be tested for leakage using the soap-test method.

13.7.13 Carbon Dioxide

.1 Re-carbonation basins should provide:

a. A total minimum detention time of 20 minutes;

b. Two (2) compartments, with a depth that will provide a diffuser submergence greater than 2.3 m but not greater that the submergence recommended by the manufacturer. The two compartments should serve the following purposes:

i. A mixing compartment, having a minimum detention time of 3 minutes; and
ii. A reaction compartment;

.2 To ensure worker safety, re-carbonation tanks should be housed outside, or tanks should be sealed and vented to the outside with adequate seals and adequate purge flow of air;
.3 Where liquid carbon dioxide is used, adequate precautions should be taken to prevent carbon dioxide from entering the plant during the re-carbonation process;
.4 Provisions should be made for draining the re-carbonation basin and sludge removal; and
.5 On-site generation of carbon dioxide is discouraged.

13.7.14 Limestone Contactors

Limestone contactors may be required prior to treatment of the raw water (primary limestone contactor) to provide sufficient alkalinity for coagulation, or after the chlorine contact tank (secondary limestone contactor) for corrosion control. The following general design guidelines are provided for both limestone contactor types, followed by special provisions for the primary limestone contactors.

13.7.14.1 General Limestone Contactor Design Guidelines

.1 Contact time - the required contact time is dependent on the quality of limestone used, and the pH and alkalinity of the raw water or filtered water. In most cases, a minimum 60-minute contact time is recommended;
   - Bench- or pilot-scale testing should be used to confirm the contact time required to increase raw water alkalinity to the amount needed for downstream process optimization, e.g. for adequate coagulation to occur or to meet corrosion control needs;
   - To provide a safety factor, the contact time determined by the test should be increased by 10%. An actual contact time of less than 60 minutes may be considered based on test results. The testing should use the same limestone as proposed for the full-scale limestone contactor;

.2 Tank design - the tank geometry should minimize the wall area to tank volume ratio and minimize short circuiting. The inlet, outlet, and flow through the contactor should be designed to provide uniform flow through all of the limestone and to prevent short-circuiting;
.3 Access - the limestone contactor should be open at the top, or provided with sufficient access points to allow observation of the top of the limestone, and easy installation and removal of limestone and internal components such as piping and valves;
.4 Bypass - provisions for bypassing the limestone contactor should be included; and
.5 Drainage - contactor tanks should be provided with a means for dewatering. The contactor's floor should slope toward the drain at not less than 50 mm in 5 meters (1% slope).

13.7.14.2 Special Considerations for Primary Limestone Contactor

.1 Pre-screening - a basket strainer should be provided capable of preventing an accumulation of debris that cannot be removed by backwashing. The ability to modify the size of screen openings after plant start-up should be provided if required;
.2 Limestone backwash - a water flushing system should be provided to dislodge sediment that may accumulate in the limestone and to remove and dispose of it;
.3 The limestone contactor bypass should include a throttling valve and required piping and fittings to allow the operator to blend limestone treated water with raw water; and

.4 The limestone should be thoroughly washed at the treatment plant site prior to being placed into the contactor tanks.

13.7.14.3 Limestone

The following specifies requirements for the supply, installation and testing of limestone for the limestone contactor(s):

.1 The limestone should yield results similar to the test results used to determine the contact time. The consultant's specifications should require certification of dissolution performance;
.2 The limestone should comply with the latest issue of *NSF/ANSI Standard 60: Drinking Water Treatment Chemicals - Health Effects*;
.3 The material provided and installed should be high calcium content limestone with greater than 95% calcium carbonate ($CaCO_3$) and have a high rate of dissolution. Impurities such as aluminum (Al) and iron (Fe) should be kept to a minimum. Testing should demonstrate that the limestone will not increase aluminum, iron, and heavy metal concentrations in the treated water to concentrations above the GCDWQ MACs/AOs; and
.4 The limestone should have an effective size, D10, between 6 mm and 8 mm. The uniformity coefficient should be 2 to 3. The maximum diameter of the limestone should be 32 mm. The limestone gradation should be determined by using the latest issue of *ASTM C-110, Standard Test*.

14 Waste Residuals Handling and Treatment

14.1 General

This chapter provides design guidance for waste residuals management. Waste residuals represent the liquid, semi-solid and solid waste streams generated by the various water treatment processes used to remove contaminants from the source water in drinking water systems. The process of handling and treating the residuals is referred to as waste residuals management.

When determining the waste residuals management approach for a water treatment facility, the following should be considered, as a minimum:

.1 Cost of handling and treatment of the solid and liquid waste residuals streams;
.2 Characteristics of the waste residuals;
.3 Impacts to the primary treatment process(es)[6];
.4 Impacts to the environment pertaining to the discharge, application or disposal of the waste residuals; and
.5 Environmental regulations and guidelines pertaining to the discharge, application or disposal of the waste residuals.

Water treatment waste residual discharges are not specifically regulated by ENV, however, the Designer and Water Supplier should follow industry best practice and apply professional judgement to adequately treat, manage, and monitor waste residuals streams to limit impacts to the environment.

The Designer should make provisions for the proper handling and disposal of all water treatment plant wastes such as sanitary and laboratory wastes, clarification sludge, softening sludge, filter backwash water, backwash sludge, and brines (including softener/ion exchange regeneration wastes and membrane and reverse osmosis concentrate), spent filtration media or cartridges, hazardous wastes (including radioactive and arsenic waste), and all other potential process waste streams that may impact the environment and drinking water supply.

Where waste residual streams are discharged to ground, the Designer should adequately assess the potential impact on the receiving soils, water supply source and/or aquifer. The Designer should follow the minimum setback distances specified for underground stormwater infiltration facilities with respect to water supply wells, as set out in the *Ground Water Protection Regulation Handbook.*

The Designer should review the B.C. Hazardous Waste Regulation for definitions of “hazardous wastes” and requirements for handling facilities, and the Federal *Transportation of Dangerous Goods Act* for shipping implications. Most WTP residuals will not be considered as hazardous waste, but some (particularly media for removal of specific contaminants) may require further assessment. Refer to Section 14.5 – Hazardous Waste for more details.

Cross connection controls must be provided as needed to protect the public water supply when designing residuals management facilities.

[6] The cost or feasibility of a proposed water treatment approach or technology can be significantly affected by the properties of the residuals produced and should be considered when evaluating treatment alternatives.

14.2 Domestic and Ancillary Waste Streams

14.2.1 Sanitary

The sanitary waste from water treatment plants, pumping stations, and other waterworks installations must be treated or disposed of as required by the authority having jurisdiction. Waste from these facilities should discharge directly to a sanitary sewer system when available and feasible, or to an appropriate onsite sewage treatment system.

For maximum daily flows less than 22.7 m^3/d, the system is regulated under the *Public Health Act* 'Sewerage System Regulation' (SSR). These onsite sewage systems must be constructed and maintained by an authorized person (a *Registered Onsite Wastewater Practitioner* or a professional, as defined in the SSR) and filing documents must be received by the Health Authority. If maximum daily flows are greater than 22.7 m^3/d, the Municipal Wastewater Regulation applies. The MWR stipulates that a person must not discharge non-domestic waste to a municipal wastewater facility unless the person ensures that the pre-discharge quality of the non-domestic waste meets the standards or is within the ranges specified in the Standard for Discharges Directed to Municipal or Industrial Effluent Treatment Works under Column 3 of Schedule 1.2 of the Hazardous Waste Regulation, B.C. Reg. 63/88.

14.2.2 Laboratory Wastes

Laboratory wastes should be appropriately disposed, based on the types of chemicals used in analysis and discarded in laboratory drains. Toxic laboratory wastes should be drained to a separate holding tank and disposed of at a toxic waste facility or the local wastewater treatment plant as appropriate.

14.2.3 Online Analyzer Wastewater

If the waste stream from an online analyzer does not can contain any additional reagents, due to the small volumes and low toxicity, these waste streams may be permitted to be recycled to the head of the water treatment facility, blended with the treated water, or discharged to ground. The Designer should implement appropriate best management practices, and all known, available, and reasonable methods of prevention, control and mitigation to prevent negative impacts to the environment or quality of drinking water supply.

A waste stream containing online analyzer reagents must not be discharged to a surface water without prior treatment and consultation with ENV. The toxicity and content of the waste stream should be reviewed, and the waste stream should be treated and/or discharged appropriately. Typically, these types of waste streams are directed to a sanitary sewer or disposal field.

14.2.4 Coarse Screening and Pre-Sedimentation

Course screening and pre-sedimentation processes are designed to remove larger debris and particulates from the source water, to protect and improve the efficiency of the downstream treatment processes. The waste from these processes consist of larger inorganic solids such as rocks and sediment, as well as organic material such as wood debris, rags, or other stringy materials.

The solids residuals from these processes may be disposed through an appropriate manner depending on the nature of the waste, including landfill or land application.

14.3 Sludges

Sludges produced from the water treatment processes are the semi-solid and solid waste streams captured from the clarification and treated filtration waste processes. Treatments for sludges should be designed to properly condition and reduce the volume for disposal, to limit the impact on downstream sewage treatment processes, reduce disposal costs and reduce environmental impacts. These processes may involve any combination of thickening, pre-conditioning, and/or dewatering processes.

Methods for sludge thickening may include gravity thickeners, dissolved air flotation, lagoons, and drying beds. These processes can increase the solids content of the sludge from less than 1% to as high as 6%, depending on the characteristics of the sludge and the thickening process employed.

Mechanical dewatering methods such as centrifuges, rotary drum thickeners or filter presses may be appropriate to further dewater the sludge for disposal or land application of the dewatered sludge. Where land availability and climatic conditions permit, natural lagoon dewatering, drying beds or freeze-thaw methods may be considered.

The liquid stream from the dewatering process should be discharged to the sewer or further treated to satisfy ground discharge, surface water disposal or reuse alternatives. With the agreement of the Owner, sludge may be directed to a sanitary sewer provided that the sewer and the wastewater treatment plant have enough hydraulic and treatment capacity. Some water treatment sludges contain high concentrations of grit and can increase the wearing of sewer collection and headworks equipment. Use of pre-sedimentation tanks or a settling process is recommended when discharging sludges with high grit contents to a sanitary sewer.

> Residuals can sometimes be reused by other industries in their manufacturing processes (e.g. the manufacture of cement and compost). Designers are encouraged to explore options for alternative uses of residuals.

14.3.1 Metal Hydroxide Sludge

Metal hydroxide sludge can be generated from sedimentation/clarification processes or treated filter waste backwash waters when metal salts (e.g. alum, ferric chloride) are used as coagulants. The sludge can be discharged to a sanitary sewer if the owner of the wastewater system and the authority having jurisdiction give approval before final designs are made.

Thickening lagoons/basins, drying beds, or other mechanical thickening may be used as a method of handling metal hydroxide sludge. The thickening process should be sized based on the solids and hydraulic loading determined by calculating the solids produced by the total chemical, turbidity, and suspended solids concentrations in the primary process while accounting for the total process removal efficiency. Mechanical concentration should be considered to condition and reduce the volume of the waste stream prior to disposal. It is recommended that a pilot plant study be conducted prior to the design of a mechanical dewatering installation.

14.3.1.1 Land Application

Metal hydroxide sludge or dewatered cake may be disposed by land application alone or in combination with other wastes, in cases where an agronomic value has been determined and disposal has been approved by the authority having jurisdiction. Refer to Section 14.3.2.1 – Land Application for more information on land application of sludges.

14.3.2 Precipitative Softening Sludge

Sludge from treatment plants using precipitative softening, often called lime sludge, varies in quantity and in chemical characteristics depending on the softening process and the chemical characteristics of the water being softened. The quantity of sludge produced may be much larger than indicated by stoichiometric calculations, so additional sludge capacity should be considered. The high pH of this material can make it difficult to provide adequate treatment and disposal. Methods of treatment and disposal are as follows: lagoons, land application, mechanical dewatering and landfilling.

14.3.2.1 Land Application

The application of precipitative softening sludge to farmland (for soil pH adjustment) can be considered as a method of disposal. Prior to land application the BC *Environmental Management Act* and the Code of Practice for Soil Amendments (B.C. Reg. 210/2007) should be reviewed; additionally, a chemical analysis of the sludge including calcium and heavy metals content should be conducted. Approval from the authority having jurisdiction should be obtained. When this method is selected, the following provisions should be considered:

- .1 Transport of sludge by vehicle or pipeline should incorporate a plan or design which prevents spillage or leakage during transport;
- .2 Interim storage areas at the application site should be kept to a minimum and facilities should be provided to prevent runoff of sludge or flooding of the facilities;
- .3 Sludge should not be applied at times when runoff from the land could be expected;
- .4 Sludge should not be applied to sloping land where runoff could be expected unless provisions are made. For suitable land, the sludge can immediately be incorporated into the soil;
- .5 Trace metals loading should be limited to prevent significant increases in trace metals in the food chain, phytotoxicity or water pollution; and
- .6 Each area of land to receive lime sludge should be considered individually and a determination made as to the amount of sludge needed to raise soil pH to the optimum for crop growth.

14.3.2.2 Additional Considerations and Alternative Uses

Additional considerations for the disposal of lime sludge include:

- .1 Discharge of lime sludge to sanitary sewers should be avoided since it may cause both liquid and solids volume problems at the sewage treatment plant. This method should be used only when the sewage system has the capability to adequately handle the lime sludge;
- .2 Appropriate and sufficient storage should be allowed for between applications or pickup;
- .3 Mixing of lime sludge with activated sludge waste (from a wastewater treatment plant) may be considered as a means of co-disposal; however, the Organic Matter Recycling Regulation should be reviewed if land application is considered in this scenario;
- .4 Disposal at a landfill can be done as either a solid or liquid if the landfill can accept such waste;

.5 Mechanical dewatering of sludge may be considered. It is recommended that a pilot study on the particular plant waste be conducted. Mechanical dewatering should be preceded by sludge concentration and chemical pre-treatment; and

.6 Calcination, of sludge as a resource recovery process for use in concrete mixtures may be considered. Pilot studies on a particular plant waste are required. Calcination is the process of heating of residuals to a high temperature but below the melting or fusing point, causing loss of moisture, reduction or oxidation, and dissociation into simpler substances.

14.3.3 Treatment of Sludges

14.3.3.1 Gravity and Flotation Thickening of Sludges

Gravity and flotation thickening processes may be used to increase the solids content of the waste residuals by removing a portion of the water. Gravity thickening may be designed similar to a solids contact clarifier, where the sludge is fed into the centre and a rotating circular collector mechanism promotes compaction of the sludge matrix. Flotation thickening is most commonly implemented with a DAF process and relies of saturated air-water mixture to float solids to the surface for removal of the concentrated sludge float. For both processes, the clarified liquid stream may be returned to the headworks of the process, depending on the quality and capabilities of the treatment processes. The thickened sludge can be discharged to sanitary sewer, directed to mechanical dewatering for further solids concentration or disposed through other appropriate manner.

The following Table 14-1 provides a summary of typical design data used to size gravity and flotation process for thickening waste residual sludges.

Table 14-1 Typical Design Data for Mechanical and Flotation Sludge Thickening Processes (MWH, 2015)

Parameter	Unit	Gravity Thickener	DAF	Notes
Solids Content Feed Flow Thickened Sludge	%	0.1 – 1 2 - 3	0.5 – 1 3 - 5	Feed solids concentrations will vary based on the primary treatment process and preceding sludge conditioning.
Hydraulic Loading	m/h	0.2 - 0.5	4.5 - 6.3	DAF hydraulic loading rates may be increased to conventional rates between 10 – 12 m/h when feed flow solids content is less than 0.1%.
Solids Loading	$kg/m^2/day$	20 - 80	48 - 120	

14.3.3.2 Passive Dewatering and Thickening of Sludges

When passively dewatering and thickening sludges, decanting and drainage systems should be provided and required solids concentration, climate, drainage discharge location, and regulatory requirements should be considered. The following provides brief design considerations for air/gravity drying processes:

.1 Sand drying beds: Sludge is placed on a sand medium, and dewatering occurs primarily by gravity drainage.
   a. More effective for lime sludges than for metal hydroxyl sludges;
   b. Loading rates are typically between 1.0 and 2.4 kg/m^2;
   c. Draining time is typically 3 to 4 days;
   d. Applied sludge depth should be 20 - 75 cm for coagulant sludges and 30 - 120 cm for lime sludges;

.2 Freeze-assisted drying beds: Freeze-thaw cycling is used to break the molecular bonds between the water and the sludge, which enhances the dewatering rate;
   a. More suitable for dewatering alum sludges in cold climates;
   a. Should be designed using two drying beds, each sized to accommodate one year of sludge storage;

.3 Solar drying beds: Asphalt is used as a sub-base for dewatering of sludge, where the absorbed heat effects promote faster drying;

.4 Vacuum-assisted drying beds: Vacuum provides a suction to the underside of rigid, porous media plates upon which the residuals are placed, which draws the water from the sludge;
   a. Frequent plate cleaning and chemical sludge conditioning is typically required for this type of process; and
   b. Sludge layers should be kept thin to maximize drying rates.

.5 Dewatering bags: The waste residual stream or sludge is pumped into a manufactured woven geotextile bag or tube that separates the solids from the liquid stream;
   a. Chemical addition may be added to increase the solids separation efficiency;
   b. Bags may be filled multiple times;
   c. Filtrate and sludge should be sampled to confirm suitability for disposal; and
   d. Filtrate should be collected and discharged in an appropriate manner.

14.3.3.3 Lagoon Design

Thickening lagoons/basins should be designed to produce an effluent satisfactory to the authority having jurisdiction and should provide:

.1 Two and half years of sludge storage;
.2 A location free from flooding;
.3 Adjustable decanting device;
.4 Effluent sampling point;
.5 Low permeability liner;
.6 Retention time of between 15 and 30 days;
.7 Adequate safety provisions;
.8 Where necessary, dikes, deflecting gutters, or other means of diverting surface water runoff so that it does not flow into the lagoon;
.9 Outlet at the end opposite the inlet;

.10 A weir overflow device at the outlet end with weir length equal to or greater than the depth;
.11 Velocity dissipation at the inlet end;
.12 A minimum usable depth of 1.5 to 1.75 m;
.13 Adequate freeboard of at least 0.6 to 1.0 m;
.14 A minimum of two cells, each with appropriate inlet/outlet structures to facilitate independent filling/dewatering operations;
.15 Length four times width, and the width at least three times the depth, as measured at the operating water level;
.16 An acceptable means of final sludge disposal; and
.17 Provisions for convenient cleaning of the lagoons.

> The Designer should refer to the Dam Safety Regulation to determine if the lagoon would be required to meet the stipulations set out in regulation. As of 2016, dams with a live storage capacity of more than 10,000 m^3 or greater than 7.5 m in height are regulated under the Dam Safety Regulation.

Subsurface infiltration lagoons may be acceptable, however consideration should be given to the downstream watercourse.

14.3.3.4 Mechanical Dewatering of Sludges

Mechanical dewatering may be implemented to produce a dried cake for improved handling of the residual solids. It is recommended that a pilot study for the mechanical process(es) be conducted on the waste produced at the water treatment plant. Mechanical dewatering should be preceded by sludge concentration and chemical pre-treatment. The following are general design recommendations for filter presses and centrifuges:

.1 Belt and diaphragm filter presses: Dewater residuals by sandwiching sludge between two porous belts;
  a. Suitable for dewatering lime sludges to 50% - 60%, and coagulant sludges to 15% - 20%;
  b. Applied pressure is typically in the 600 to 1,500 kPa (87 to 218 psi) range;
  c. Roller bearings should be designed to have an L10 service life of approximately 300,000 hours;
  d. A polymer conditioning system should be provided for all belt filter presses;
  e. Consideration should also be given to desired cake solids content, conditioning requirements, pressure requirements, belt speed, belt tension, belt type, and belt mesh size;

.2 Centrifuges: Dewater residuals by forcing water from solids under high centrifugal forces;
  a. Both concurrent and counter-current designs are acceptable;
  b. Design criteria will be proprietary in nature and the manufacturer should be consulted in each case a centrifuge is being considered; and
  c. A polymer conditioning system should be provided for all centrifuge systems.

Similar to passive dewatering systems, decanting and drainage systems should be provided for the water produced from the dewatering of the sludge, including leachate, centrate or filtrate. Additionally, the required solids concentration, drainage discharge location and regulatory requirements should be considered for disposal of the liquid waste streams.

14.4 Wastewater

14.4.1 Filter Backwash Water and Filter-to-Waste

14.4.1.1 Rapid Rate Media Filter or Membrane Backwash Water

Filter backwash water (FBWW) produces high volume, short duration wastewater flows with relatively low concentrations of solids (i.e. typically less than 0.1% solids content) and requires handling in a suitably sized surge/equalization tank. These waste streams are generated from rapid rate media filters and membrane backpulse or wash cycles.

Surge tank discharges may be directed to a sanitary sewer where the sewer and the wastewater treatment plant have sufficient hydraulic and treatment capacity, and with the agreement of the wastewater treatment plant owner.

Where limited wastewater treatment capacity exists, the waste flow may be directed to a holding tank and allowed to settle before the supernatant is discharged to a sanitary sewer and the sludge removed for further treatment.

Where sewer discharge is not possible, appropriate effluent quality control measures are provided (i.e. treatment processes) and applicable environmental regulatory requirements are met, discharge to ground, a receiving water body or recycle to the head of the water treatment facility may be acceptable. Refer to Section 14.4.1.3 – Recycling Filter Backwash Water for more information about recycling requirements.

Discharges to ground may be achieved using infiltration basins or other subsurface ground disposal methods, where the soil and ground water conditions are determined to be suitable through hydrogeological investigation. The Designer should refer to principles set out in the *Groundwater Protection Regulation Handbook*, Municipal Sewage Regulation, and industry best practices to prevent detrimental impacts to source waters and the environment.

14.4.1.2 Filter-to-Waste

Filter-to-waste is the water produced by filters immediately after backwashing. This water has higher particulate and turbidity levels, above the criteria required for pathogen log reduction credit assignment.

Filter-to-waste water may be discharged directly to a sanitary sewer system, if the sewers and the wastewater treatment plant can withstand the hydraulic surges.

Filter-to-waste water may also be recycled back into the headworks without further treatment or recycled back immediately upstream of the filters if the recycled flow does not exceed 10% of the total inflow into the filters.

Recycling of the filter-to-waste stream can be used to accelerate the filter ripening process. This process is known as filter maturation, where the filter-to-waste stream is returned to the headworks or immediately upstream of the filters. This process may be particularly effective for direct filtration processes, where the incoming raw water may have very low turbidity (i.e. <1 NTU) to promote filter stabilization and reduce the filter ripening times.

Refer to Section 14.4.1.3 – Recycling Filter Backwash Water for more information about recycling requirements.

14.4.1.3 Recycling Filter Backwash Water

Recycling filter backwash water (FBWW) or filter-to-waste to the head of the water treatment facility may be an effective method to reduce waste volumes and increase the climate change resiliency of the WTP. Recycling of backwash water involves consideration of special hazards due to the potential for increased concentration of pathogens in the water. Reference should be made to the USEPA's Technical Guidance Manual, the *Filter Backwash Recycling Rule* (2002).

Recommendations for recycling filter backwash water or filter-to-waste include:

.1 FBWW or filter-to-waste should not be recycled when:
  a. The raw and/or reclaimed water contains excessive:
    a. pathogen concentrations;
    b. algae; or
    c. turbidity;
  b. The raw and/or reclaimed water contains algal toxins;
  c. Disinfection by-product levels in the distribution system may exceed allowable levels; or
  d. Finished water taste and odour are problematic;

.2 The recycling of filter backwash wastewater, thickener supernatant, and other liquids to the head of the plant may be acceptable under the following conditions:
  a. The recycle stream should be monitored for flow rate, turbidity, and any other relevant parameters;
  b. The recycle stream should be returned at a rate of less than 10% of the instantaneous raw water flow rate entering the plant, as per *Filter Backwash Recycle Rule* (USEPA, 2001);
  c. A recommended operational goal for recycle stream turbidity is less than 2 NTU;
  d. The primary treatment process train is designed (and where possible, demonstrated through a pilot study) to effectively treat the anticipated recycled stream hydraulic and solids loading;
  e. Suspended solids in the backwash water from surface water treatment and lime softening plants should be reduced prior to recycling to the head of the plant through additional settling or chemical treatment (e.g. coagulation);
  f. Reclaimed filter backwash water does not add increased risk to the treated water quality;
  g. Consideration should be given to the presence of protozoa such as *Giardia* and *Cryptosporidium* concentrating in the wastewater stream;
  h. Pre-treatment of filter backwash wastewater prior to recycling may be required; and
  i. The use of a disinfecting agent effective for the inactivation of protozoa, typically UV disinfection, is recommended in the recycling line.

.3 A backwash reclaim tank should be included in the design and contain:
  a. The anticipated volume of wastewater produced by the WTP when operating at design capacity;
  b. A volume that takes into account the number of filters and the anticipated backwash frequency and volume, using the greater of the design backwash duration and rate or 15 minutes of backwashing at a rate of 50 m/h. As a minimum the tank should be sized to

hold the total flow from two consecutive backwash cycles plus a 20% safety factor without concurrent recycling;

.4 Consideration should be made for emergency discharge or backup storage of the FBWW, should the WTP not be able to accept the recycled FBWW due to diminished water quality.

14.4.2 Membrane Filtration Wastewater

Membrane filtration produces many types of wastewater including backwash water, chemical cleaning residuals, and membrane reject water.

14.4.2.1 Membrane Backwash Residuals

Refer to Section 14.4.1.1 – Rapid Rate Media Filter or Membrane Backwash Water.

14.4.2.2 Membrane Clean-in-Place Residuals

All membrane filters require periodic chemical cleaning (recovery clean or clean-in-place), which generates waste residuals with high oxidant concentrations, high pH or low pH, depending on the cleaning type or phase. Chemical cleaning wastes should be reviewed on a case-by-case basis: depending on community infrastructure, there may be alternative uses for such waste residuals (i.e. for pH adjustment or reduction of organic loading at wastewater treatment plants). Such alternative uses must be assessed to ensure all applicable regulations are adhered to and that safety and transportation/handling are considered in design.

For disposal, chemical cleaning residuals should be treated on-site where possible and discharged to either a sanitary sewer or holding tank for further disposal. Oxidants such as chlorine used in the chemical cleaning process should be quenched prior to discharge, and acids and bases should be neutralized. The use of other chemicals, such as surfactants or proprietary cleaning agents, may require additional treatment. The rinse water applied to the membranes after the cleaning process may also represent a chemical waste and thus may require treatment prior to discharge.

14.4.2.3 Membrane Reject Water

Reject or concentrate water produced by NF or RO membrane filtration processes typically contain high levels of TDS and inorganic solutes. If appropriate effluent quality control measures are provided (i.e. treatment) and applicable environmental regulatory requirements are met, discharge of chemically unaltered membrane reject water to a ground or a receiving water body may be acceptable. Dilution may be required to reduce the concentration of regulated parameters prior to discharge to the environment or sanitary sewer. Dilution can be a legitimate treatment strategy given that the concentrated inorganic solutes originate from a natural water source.

Where this option is not available, the concentrate or reject should be discharged to a sanitary sewer.

14.4.3 Iron and Manganese Wastewater

Iron and manganese waste or "red water" wastes can be treated using sedimentation basins, thickening processes, lagoons, or discharge to a sanitary sewer. For thickening process design criteria, refer to Section 14.3.3 – Treatment of Sludges. For lagoon design criteria, refer to Section 14.3.3.3 – Lagoon Design.

14.4.3.1 Discharge to Sanitary Sewer

“Red water” can be discharged to a sewer if the owner of the wastewater system and the authority having jurisdiction give approval before final designs are made. An equalization basin or tank is recommended to prevent overloading of the sewers. Consideration should be given to the hydraulic, TSS and organic loading on sewage conveyance and treatment systems. The design should prevent cross connections and there should be no common walls between potable and non-potable water compartments.

14.4.3.2 Recycling Red Water Wastes

Recycling of supernatant or filtrate from "red water" waste treatment facilities to the head of the WTP is not recommended.

14.4.4 Brine Waste

Waste from ion exchange, demineralization, and reverse osmosis or nanofiltration membrane plants, or other plants which produce brine, must be treated or discharged in accordance with all federal, provincial, and local regulations. Dependent on approval by the authority having jurisdiction, brine wastes may be disposed by discharge to a soak-away pit, deep well injection into the ground, or discharge to a wastewater treatment system provided it is approved by the wastewater treatment plant owner.

When discharging to a sanitary sewer, an equalization basin or tank may be required to prevent the overloading of the sewer and/or interference with the waste treatment processes. The quality of the brine waste should be confirmed to ensure that the high salinity will not negatively affect the performance of the wastewater treatment plant prior to design. The effect of brine discharge to sewage lagoons may depend on the rate of evaporation from the lagoons. Brine waste may be toxic to microbial processes in a wastewater treatment plant. If practical, it may be preferable to blend the brine waste stream with the wastewater treatment plant effluent. If brine wastes are deemed to be acceptable to discharge to the sanitary sewer, the Designer should coordinate with the wastewater treatment owner/operator and include provision for controlling the discharge rate to allow for optimizing the wastewater treatment plant unit process operation and avoid slug loading of brine waste to the system.

Other higher cost technologies (e.g. mechanical, thermal, etc.) are available for treatment of brine waste and can be considered if regulatory or environmental constraints warrant.

14.5 Hazardous Waste

14.5.1 Regulatory Information

Under the *Environmental Management Act*, the Hazardous Waste Regulation (HWR) provides a definition of hazardous wastes. Solid residuals from WTPs which treat specific contaminants may be considered as hazardous wastes if they meet the criteria for leachable toxic wastes: “wastes [which] when subject to the extraction procedure described in the US EPA Method 1311 produce an extract with a contaminant concentration greater than those prescribed in Table 1 of Schedule 4 [of the HWR]”. These wastes should be managed through off-site treatment at a hazardous waste facility.

Furthermore, as stated in Schedule 3 of the HWR: "Wastes which when subjected to the Modified Leachate Extraction Procedure referenced in Part 2 of Schedule 4 produce an extract which contains one or more contaminants in Column 1 of Table 1 of Schedule 4 in concentrations equal to or greater than the concentration specified for each contaminant in Column II of the Table" may not be disposed in a secure landfill. Therefore, WTPs may need to conduct both the US EPA Method 1311 (also referred to as the Toxicity Characteristics Leaching Procedure, or TCLP) and the HWR Modified Leachate Extraction Procedure tests on the solid residuals to determine the proper disposal method or facility for the waste.

If the production in a 30-day period or storage amount of residuals exceeds the limits listed in Schedule 6 of the HWR, the hazardous waste must be registered with the Ministry of Environment and Climate Change Strategy. Refer to the Ministry's website (https://www2.gov.bc.ca/gov/content/environment/waste-management/hazardous-waste/registration-of-hazardous-waste-generators-and-facilities) for more details.

14.5.2 Arsenic Waste Residuals

Arsenic-bearing wastes may be found in the following waste streams and may be considered hazardous, including but not limited to:

.1 Filter backwash wastewater and sludge;
.2 Lime softening sludge;
.3 Reverse osmosis reject water, and
.4 Adsorptive filter media.

Under the *Environmental Management Act* and the Hazardous Waste Regulation, residual wastes from an arsenic water treatment facility may be defined as being hazardous waste. Solid residuals should be tested as described in Section 14.5.1 – Regulatory Information to determine if they would be considered as leachable toxic wastes and how they can be properly disposed.

14.5.3 Radioactive Waste

Radioactive materials may be found in the following waste streams, including, but not limited to:

.1 Granulated activated carbon (GAC) used for radon removal;
.2 Radium adsorptive filter media;
.3 Ion-exchange regeneration wastewater;
.4 Manganese greensand backwash solids from manganese removal systems;
.5 Precipitative softening sludge; and
.6 Reverse osmosis concentrates.

The build-up of radioactive decay products should be considered, and adequate shielding, ventilation, and other safeguards should be provided in the plant design to protect water operators and visitors, particularly when raw water radiological parameters are in excess of the GCDWQ MACs.

Radioactive materials and waste facilities are regulated by the Canadian Nuclear Safety Commission (CNSC). Reference should be made to the *Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM)*. Approval should be obtained from the authority having jurisdiction prior to disposal of all wastes.

Additional guidance on the handling of radioactive residuals is in the U.S. EPA's *A Regulators' Guide to the Management of Radioactive Residuals from Drinking Water Treatment Technologies*.

14.6 Filtration Media and Cartridges

Landfill is the most common disposal approach for spent filtration media, cartridge filters and membranes. Depending on source water and treatment targets, spent treatment components may need to be disposed as hazardous waste – refer to Section 14.5 – Hazardous Waste for more information.

Granular activated carbon can be regenerated after exhaustion (i.e. when contaminant breakthrough occurs). For drinking water facilities, off-site regeneration is normally conducted as on-site regeneration is not practical nor cost effective. Provisions for storage and shipment of spent media should be considered during design.

Some manufacturers may offer recycling or disposal of proprietary media, cartridge filters or other spent treatment components. Options for recycling and disposal should be discussed early during the design process.

15 Parameter Specific Treatment

15.1 General

This chapter provides a high-level overview of the treatment processes for specific water contaminants. The selection of a particular treatment technology and/or technology train will depend on an evaluation of the nature and quality of the water to be treated, seasonal variations in raw water quality, and the desired quality of the finished water.

15.2 Iron and Manganese

Iron (either Fe (II) or Fe (III)) and manganese are commonly occurring metals that can impact aesthetic water quality and, for manganese, can have health implications when the GCDWQ is exceeded. Presence of these parameters may lead to visible water colour, increased turbidity, staining on plumbing fixtures, and growth of iron bacteria in watermains.

The GCDWQ identifies a maximum acceptable concentration (MAC) limit for manganese of 0.12 mg/L, based on the neurological health risks to infants and other sensitive populations. Elevated iron and manganese concentrations are more frequently found in groundwater sources from rock and soil weathering than surface waters. Under reducing conditions, which may exist in some groundwaters, lakes or reservoirs, and in the absence of sulphide and carbonate, high concentrations of soluble Fe(II) may be found. At neutral and oxic conditions, iron (Fe(III)) and manganese are generally insoluble and settle out or adsorb onto surfaces.

Testing equipment should be provided for water treatment plants where iron and manganese pose potential issues, with the capacity to measure iron and manganese to minimum concentrations of 0.1 mg/L and 0.05 mg/L, respectively. Some manganese sampling protocols utilize reagents containing cyanide, requiring disposal and handling of hazardous chemistry. For this reason, offsite analysis at commercial laboratories may be advisable when appropriate analytical equipment (such as inductively coupled plasma (ICP) mass spectrometry/atomic emission spectroscopy, or atomic absorption spectroscopy (AAS)) is not available on-site. Where polyphosphate sequestration is practiced, phosphate testing equipment should also be provided.

This section describes treatment processes designed specifically for iron and manganese control. For further guidance, refer to the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Iron*, and *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Manganese* by Health Canada, and *Guidance on Manganese in Drinking Water* by the B.C. Ministry of Health.

15.2.1 Oxidation, Detention and Filtration

Oxidation of soluble iron and manganese results in the formation of solid, oxidized precipitate that can then be filtered. Oxidation can be performed by aeration, and/or through chemical oxidation with chlorine, potassium permanganate ($KMnO_4$), ozone, or chlorine dioxide. The most effective oxidation and filtration of iron and manganese occurs at pH 7.5 and above, and the minimum effective pH level should be above 7. This process is highly pH dependant as iron and manganese solubility varies with pH. Elevated pH levels may be required for adequate removal, particularly for manganese.

Aeration or chemical feed points should be provided prior to filtration. Aeration and chlorine do not effectively oxidize manganese unless it is present at very low levels relative to iron. See Chapter 9 – Aeration for specific aeration design considerations. Water systems that use chlorine should consider and monitor for disinfection by-products.

The minimum detention time following the addition of oxidants differs depending on the oxidant used. For example, aeration typically requires a minimum detention time of 30 minutes for iron and 60 minutes for manganese (depending on the raw water pH) to ensure that the oxidation reactions are as complete as possible. The minimum detention time should be determined based on the oxidant used and may be optimized based on the findings from pilot testing. The Designer should also account for seasonal variations in temperature, pH, and the presence of natural organics as these will impact the detention time required.

The detention basin may be designed as a free surface holding tank (i.e. water surface open to atmosphere) or pressure vessel. The basin should have sufficient baffling and be designed to prevent short circuiting. The basin should be provided with an overflow, vent and access hatch in accordance with Chapter 17 – Water Storage.

Sedimentation basins may be required when treating water with high iron and/or high manganese content, or where chemical coagulation is used to aid in filtration of iron and manganese. Coagulants should be added after oxidation reactions have reached sufficient completion. Sedimentation basin design should meet the design requirements specified in Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification. Provisions for sludge removal should be made where sedimentation basins are required.

Filters should be provided and should conform to design requirements specified in Chapter 8 – Filtration.

15.2.2 Manganese Oxide Media

Manganese oxide filter media (coated or solid) selectively removes iron and manganese through contact adsorption. This process is the option of choice for treating waters with moderate amounts of iron and manganese (< 5 mg/L of iron and < 1 mg/L of manganese), however piloting is recommended to confirm the feasible level of iron and manganese removal. The equipment for this process is typically more compact than ion-exchange or chemically assisted filtration processes. Silica levels in the raw water should be tested as they can impact the feasibility of manganese oxide for removal of iron and manganese.

15.2.2.1 Oxidation

An oxidant is typically added to the raw water to oxidize soluble iron and manganese. The dosage and selection of oxidant should take into consideration the oxidant demands of all contaminants to be removed (DOC, H_2S, ammonia etc.). Designers are encouraged to sample for contaminants affecting oxidant demand to confirm dosing requirements. For example, benchtop testing of chlorine demand can inform dose selection to achieve breakpoint chlorination and maximize oxidation of soluble iron and manganese. Multiple oxidizing agents may be used; for example, aeration may be used prior to the oxidant feed to reduce the amount of chemical needed. Provisions should be made to supply the oxidant as far in advance of the filters as possible to maximize contact time before the oxidized water reaches the filters, and to a point immediately before the filter for media regeneration.

15.2.2.2 Filtration

The filter media that could be used are:

.1 Manganese greensand or other manganese dioxide coated media;
.2 Pyrolusite or other form of solid pure manganese dioxide media; and
.3 Other proprietary media.

Filter media should conform to *NSF/ANSI Standard 61: Drinking Water System Components - Health Effects* and the applicable *AWWA Standard B101: Precoat Filter Media* or *AWWA Standard B102: Manganese Greensand for Filters*.

The key to the success of the contact adsorption process is the re-generation of the manganese dioxide (MnO_2) coating on the media. Regeneration can be done on a continuous basis or on an intermittent basis.

Typically, this media is used in a pressure filtration setup. Per the *Guidelines for Pathogen Log Reduction Credit Assignment*, pressure filters are not assigned pathogen log reduction credits. Refer to Chapter 8 – Filtration for further guidance on filter design.

15.2.2.3 Design Considerations for Manganese Dioxide Media Filtration

Dual media filtration incorporating a layer of anthracite with a layer of MnO_2 is recommended if iron removal is the main objective. Continuous regeneration of the manganese dioxide (MnO_2) is also recommended where iron removal is the main objective, regardless of the presence of manganese. Continuous regeneration operation involves the feeding of a pre-determined amount of oxidant (typically $KMnO_4$ or chlorine) directly to the raw water prior to the filters. If chlorine is used for waters containing ammonia, sufficient chlorine should be added to go beyond the breakpoint to produce free chlorine for media regeneration.

Intermittent regeneration is recommended for waters where only manganese or manganese with small amounts of iron is to be removed. This involves adding a pre-determined amount of oxidant after a specified quantity of water has been treated. Intermittent regeneration is often conducted during the filter backwash cycle.

Filter backwash rates should be determined in accordance with pilot studies, manufacturer information, or sufficient reference materials. Backwash rates should be controlled to prevent complete stripping of the base catalytic surface from the media, as this can result in process failure and may require media replacement. Air scour should also be provided.

A summary of the design considerations for manganese coated media filtration systems is shown in Table 15-1. The Designer should refer to the media manufacturer’s specifications for design details and consider piloting bench-scale testing.

Table 15-1 Design Considerations for Manganese Coated Filtration Systems

Design Parameter	Metal to be Removed	
	Iron	Manganese
Regeneration of media	Continuous	Intermittent
Bed type	Dual media	Single media
Depth of bed	Anthracite - 375 to 450 mm MnO_2 media - 450 to 600 mm	MnO_2 media > 750 mm
pH	6.2 to 8.5	7.0 to 8.5
Typical media loading rate [1]	4 to 12 m/h	4 to 12 m/h
Head loss	1.5 m (maximum)	1.5 m (maximum)
Backwash [2]	Sufficient for 40% bed expansion	Sufficient for 40% bed expansion

.1 Filter loading rates should be established based on media manufacturer requirements. As concentrations of iron and manganese increase, loading rates for equivalent run lengths will decrease. Pilot testing should be undertaken to determine optimum design parameters.

.2 Typical backwash rates for manganese dioxide-coated media and solid manganese dioxide media are 20 - 24 m/h and 37 - 49 m/h respectively.

15.2.3 Ion Exchange

15.2.3.1 General Ion Exchange Design Considerations

Ion exchange (IEX) is a process in which ions of given species are displaced (exchanged) from insoluble exchange material by ions of different species in solution (MWH, 2015). Treatment systems which use ion exchange may also be referred to as 'softeners'. Ion exchange units can be used to treat many raw water quality issues including hardness, and high levels of nitrate, natural organic material, arsenic, iron, manganese, and fluoride, among others.

Pilot studies should be conducted to confirm the suitability of the ion exchange media, assess ion exchange performance, hydraulic considerations (flow rate, head loss, backwashing rate), and regeneration requirements (i.e. salt requirements, backwash cycle time, rinse requirements, and column requirements).

15.2.3.1.1 Types of Resin

Based on the functional groups bonded to the resin backbone, the four general types of exchange resins are strong-acid cation (SAC), weak acid cation (WAC), strong-base anion (SBA), and weak-base anion (WBA). Anion exchange resin should have a generally high selectivity for the contaminant of concern. Table 15-2 below provides recommendations for the resin type and the ion to be removed.

Table 15-2: Ion Exchange Resins (MWH, 2015)

Resin Type	Ions Removed	Regenerant	pH Operating Range
Strong-acid cationic (SAC)	Cations: e.g. Ca^{2+}, Mg^{2+}, Ra^{2+}, Ba^{2+}, Pb^{2+}	HCl or NaCl	1 to 14
Weak-acid cationic (WAC)	Cations: e.g. Ca^{2+}, Mg^{2+}, Ra^{2+}, Ba^{2+}, Pb^{2+}	HCl or NaCl	~ 6 to 11
Strong-base anionic (SBA)	Anions: e.g. NO_3^-, SO_4^{2-}, ClO_4^-, $HAsO_3^{2-}$, SeO_3^{2-}	NaOH or NaCl*	1 to 13
Weak-base anionic (WBA)	Anions: e.g. NO_3^-, SO_4^{2-}, ClO_4^-, $HAsO_3^{2-}$, SeO_3^{2-}	NaOH, NH_4OH, Na_2CO_3 or $Ca(OH)_2$	< 6

*KCl may also be used in place of NaCl; consult with the equipment supplier for compatibility.

Prior to start-up of the equipment, the resin should be regenerated with no less than two bed volumes of water containing an appropriate regenerant followed by an adequate rinse.

15.2.3.1.2 Pre-treatment

Pre-treatment may be required for contaminant-specific resins. Iron, manganese or a combination of the two, should not exceed 0.3 mg/L in the water as applied to the ion exchange resin. Pre-treatment is required when a combination of iron and manganese exceeds 0.5 mg/L. Pre-treatment may also be required for water with high concentrations of natural organic matter (measured as total organic carbon, TOC).

15.2.3.1.3 Design

The following should be considered when designing an ion exchange resin:

.1 Ion exchange units are gravity or pressure type, upflow or downflow design. Automatic regeneration based on volume of water treated should be used unless manual regeneration is justified. A manual override should be provided on all automatic controls;

.2 If a portion of the water is bypassed around the units and blended with treated water, the maximum blend ratio allowable must be determined based on the highest anticipated raw water level of the contaminant of concern. If bypassing is provided, a totalizing meter and a proportioning device or flow regulating valves must be provided on the bypass line;

.3 Design capacity - The design capacity of the regeneration process should be in accordance with the specifications of the resin manufacturer.

.4 Number of units - For water systems treating health-related contaminants, at least two units should be provided. The treatment capacity must be capable of meeting the maximum day water demand at a level below the treatment objective for the contaminant of concern with one exchange unit out of service;

.5 Flow rates - For the contaminant of concern, the treatment flow rate should not exceed the manufacturer's recommendation for the selected resin;

.6 Adequate distance between the resin media surface and backwash collection units must be provided to accommodate the backwash flow rate of the unit. This distance will depend on the size and specific gravity of the resin. Generally, the backwash water collector should be 600 mm above the top of the resin on downflow units;

.7 Sampling taps - Smooth-nose sampling taps should be provided for the collection of representative samples. The taps should be located to provide for sampling of the influent, effluent and blended water. The sampling taps for the blended water should be at least 6 m downstream from the point of blending. Petcocks are not acceptable as sampling taps. Sampling taps should also be provided on the brine tank discharge piping;

.8 Pipes and contact materials must be resistant to the aggressiveness of the regenerant. Steel and concrete must be coated with a non-leaching protective coating which is compatible with salt and brine, or other regenerants;

.9 The treatment equipment should include an adequate underdrain, resin support system and brine distribution system; and

.10 Brine disposal - Suitable disposal must be provided for brine waste. Refer to Chapter 14 – Waste Residuals Handling and Treatment for further details.

15.2.3.1.4 Brine and Salt Storage Tanks

The following should be considered in the design of brine and salt storage tanks:

.1 Brine tank - Salt dissolving or brine tanks and wet salt storage tanks must be covered and corrosion resistant;

.2 Make-up water - The make-up water inlet must be protected from back-siphonage by an approved backflow prevention device or an air gap. Water for filling the tank should be distributed over the entire surface by pipes above the maximum brine level in the tank.

.3 Tanks should be equipped with manholes or hatchways for access and filling. Openings should be provided with raised curbs and watertight covers having overlapping edges similar to those required for finished water reservoirs. Each cover should be hinged on one side and should have a locking device;

.4 Overflows, where provided, must be protected with corrosion resistant screens and terminate with either a turned downed bend having a proper free fall discharge or a self-closing flap valve;

.5 Two wet salt storage tanks or compartments designed to operate independently should be provided;

.6 Salt should be supported on graduated layers of gravel placed over a brine collection system;

.7 Alternative designs which are conducive to frequent cleaning of the wet salt storage tank may be considered;

.8 Total salt storage should have sufficient capacity to store in excess of 150% of the delivery volume of salt and provide for at least 30 days of operation. Brine storage should be adequate to regenerate the softeners for 24 hours of operation without being replenished;

.9 Bagged salt and dry bulk salt storage should be enclosed and separated from other operating areas to prevent damage to equipment;

.10 Eductor - An eductor may be used to transfer brine from the brine tank to the ion exchange unit. If a pump is used, a brine measuring tank or means of metering should be provided to obtain proper dilution; and

.11 Cross connection control - Regeneration, rinse, and air relief discharge pipes should be installed with an air gap between the discharge and the disposal point to prevent back-siphonage.

15.2.3.2 Considerations for Iron and Manganese IEX Design

Dissolved iron and manganese can be removed via cationic exchange systems (i.e. ion exchange resins). The resin regeneration process should be as directed by the manufacturer. Often a salt brine displaces the iron and manganese ions. Alternatively, some resins use either an acid or sodium hydroxide (NaOH), to remove metals off the resin, in a process referred to as high pH regeneration. The salt brine, laden with iron and manganese, should then be safely disposed; refer to Chapter 14 – Waste Residuals Handling and Treatment for further guidance.

The form of iron and manganese (dissolved vs total), the need for pre-treatment, and competing ions that may reduce ion exchange efficacy should be considered. Ion exchange should not be used where:

.1 The water to be treated contains more than 0.3 mg/L of either iron, manganese, or combination thereof;
.2 The raw water or backwash water contains oxidants (such as chlorine) as they can damage the resins; and
.3 Iron and manganese are organically bound or are not in divalent state.
  a. It is frequently observed that as groundwater wells age, bacterial activity and oxidized iron and manganese become more common. The presence of oxidized iron and/or manganese may result in fouling of the ion exchange resin. Divalent iron and manganese can be measured on-site using colourimetric tests, or proportions of divalent iron and manganese can be roughly estimated by determining the dissolved concentrations of the metals and comparing them with the total concentrations. Dissolved concentrations can be determined by filtering water samples (ideally with a 0.45 µm filter) promptly after collection. Prompt filtration is important to prevent metal oxidation in the water sample when exposed to air.

15.2.4 Lime and Lime-Soda Softening Process

Lime and lime-soda softening may be used to soften water or removal metal ions. Lime softening involves adding lime (calcium hydroxide, CaOH) and optimizing the precipitation of $Mg(OH)_2$ and metal carbonates to either reduce the hardness or remove target dissolved ions, such as arsenic. Lime-soda softening involves adding lime (calcium hydroxide, CaOH) and soda ash (Na_2CO_3) to remove iron and manganese ions through precipitation. Addition of lime increases the pH of the raw water and shifts the carbonate species from carbon dioxide (CO_2) to bicarbonate (HCO^{3-}) to carbonate (CO_3^{2-}). The dissolved iron and manganese ions react with carbonate to form the insoluble precipitates of iron (II) carbonate ($FeCO_3$) and manganese (II) carbonate ($MnCO_3$), respectively. The precipitates can then be removed (see Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification and Chapter 8 – Filtration).

Lime-soda softening operates at a high pH (between 10.3 and 10.6), which reduces magnesium (Mg), and with the use of ferrous chloride ($FeCl_2$) can co-precipitate manganese and silicates (SiO_2).

15.2.5 Biological Removal

Aerobic biofiltration can be used to remove iron and manganese from groundwater. This method involves establishing a biomass on the filter media and providing sufficient oxygen to allow the biomass to oxidize the target contaminants. Porous media such as granular activated carbon (GAC) or pumice stone are commonly used; the micropores of the media provide surface area to support biofilm growth.

The dissolved oxygen content is critical to biotreatment, as sufficient oxygen should be supplied to maintain biological activity. Nutrient addition or pH adjustment may also be required to maintain the biomass.

15.2.5.1 Design Considerations

Pilot testing of biological treatment is recommended as there are limited full-scale aerobic biofilters for iron/manganese removal in operation. The following should be considered:

- .1 Type of filtration/contactor (gravity or pressure);
- .2 Depth of filter/contactor media;
- .3 Type, size, and gradation of filter/contactor media;
- .4 Filtration and backwash rates, backwash system design;
- .5 Filter-to-waste;
- .6 Type of backwash water (raw vs. treated, unchlorinated vs. chlorinated, etc.);
- .7 Empty bed contact time (EBCT);
- .8 Dissolved oxygen concentration and method of/need for oxygen addition;
- .9 Number and types of filters piloted;
- .10 Need for chemical addition and dose;
- .11 Maximum acceptable filter/contactor head loss before backwash; and
- .12 Approximate hydraulic trends (run time, "clean-bed" head loss, total head loss).

For additional design considerations for biological iron and manganese removal, refer to AWWA: *Iron and Manganese Removal Handbook Second Edition*.

15.2.6 Sequestration

Sequestration is the process of adding a chemical sequestrant to keep iron and manganese in a colourless suspension and delay the formation of visible yellow/brown colour in the finished water. Sequestration does not remove iron and manganese. The effects of sequestering last a maximum of a few days. Since sequestration is temporary, iron and manganese may precipitate downstream, especially in hot water heaters.

Sequestration is only appropriate for addressing aesthetic concerns (for example, precipitation in distribution systems), and is not acceptable where manganese levels exceed the GCDWQ MAC.

15.2.6.1 Design Considerations

Sequestering may be performed using polyphosphate or sodium silicate. Both sequestrants are generally more effective for iron than for manganese. On-site colourimetric testing should be conducted to confirm that iron is mostly present in divalent form. Regular total metals analytical scans should be performed to confirm that manganese levels are low relative to iron levels. Seasonal variations in iron and manganese speciation and concentration for GARP and surface water sources should be considered. Designers should also note that groundwater sources tend to show increasing iron levels as they age. In this case, Designers should consider providing space for future iron removal equipment if evidence from other local wells indicate that this may eventually become necessary.

A summary of the design considerations for sequestering systems is shown in Table 15-3. Designers should note that presence of calcium and magnesium hardness will reduce the effectiveness of sequestration and raise the required dosage of sequestrant. Additionally, there is no predictable pattern of the impact of pH on sequestration effectiveness, thus pilot or bench testing is needed to optimize pH based on raw water quality. The success of the sequestration process is highly variable and is largely dependent on the ability to maintain a sequestrant residual throughout the distribution system. Water Suppliers should monitor for the sequestrant residual, contaminants of concern (e.g. lead, copper, etc.), pH and alkalinity to assess the effectiveness of the corrosion inhibitor throughout the distribution system.

Table 15-3 Design Considerations for Sequestering Systems

Consideration	Sequestrant	
	Polyphosphate	Sodium Silicate
Applicable water type	Surface or groundwater	Groundwater prior to air contact
Maximum concentration of either iron, manganese, or combination thereof	• 0.5 mg/L (recommended limit) • 1.0 mg/L (firm limit)	• 2 mg/L
Maximum total concentration of parameter in finished water	• 10 mg/L (total applied phosphate as PO_4)	• 20 mg/L (applied SiO_2) • 60 mg/L (combined applied and naturally occurring SiO_2)
Sequestrant point of application	• Polyphosphates should not be applied ahead of iron and manganese removal systems. • Point of application should be prior to any aeration, oxidation or disinfection if no iron or manganese removal is provided. • Should be as far ahead of oxidant feed point as possible.	• Sodium silicates should not be applied ahead of iron and manganese removal. • Rapid oxidation of metal ions (ex. by chlorine) should accompany or closely precede sodium silicate addition. Addition of sodium silicate more than 15 seconds after oxidation may cause noticeable loss of efficiency.
Sequestrant feed solution	• Stock phosphate solutions should be kept covered and disinfected by carrying ~10 mg/L free chlorine residual (unless phosphate cannot support bacterial growth or has a pH less than 2.0).	• Minimum 5% silica as SiO_2 should be maintained in feed solutions. • Silicate should be diluted to no more than 1:2, preferably with softened water. Greater dilution ratios should be avoided as this reduces sequestering effectiveness, particularly in warm seasons.
Distribution system considerations	• Watermain and service line materials.	• Watermain and service line materials.

Consideration	Sequestrant	
	Polyphosphate	Sodium Silicate
	• Chlorine residuals should be maintained in distribution system.	• Chlorine residuals should be maintained throughout distribution system.
Cost	• Considerably more expensive than sodium silicate.	• Less expensive than polyphosphate.

Initially, higher concentrations of sequestrant may be required to form a corrosion inhibiting film on the distribution pipe wall, after which the concentration can be significantly reduced to only what is required to maintain the presence of the film.

15.2.6.2 Sequestration Equipment

Sequestration equipment is similar to hypochlorite dosing equipment. Specific to sodium silicate sequestering, the following should be provided:

.1 A locally-placed day tank with lid for hypochlorite;
.2 A locally-placed day tank with lid for silicate, sized for up to two weeks of water treatment that allows for 1:2 dilution of silicate (for viscosity reduction), preferably with softened water;
.3 Peristaltic feed pumps, or other pumping arrangements adapted to provide continuous, pulse free addition of hypochlorite and silicate to the flowing water stream;
.4 Injectors of the "duck bill" or other scale blockage resistant variety that allow for injection of the silicate and hypochlorite to the center of a rapidly flowing stream to aid in the necessary rapid dispersion of the two chemicals. Several tappings should be made to allow for easy injector relocation and spacing changes; and
.5 A nearby downstream wide bore sample tap that allows for easy collection of 20 L samples for observation and dosage optimization.

15.3 Arsenic

Arsenic (As) often exists in source waters as arsenite (AsO_3^{3-} and other negatively-charged ions containing As(III)), arsenate (AsO_4^{3-}, containing As(V)), or a combination thereof. Speciation should be performed by a laboratory to determine the form of arsenic present as the oxidation state is critical in the selection of treatment technology. Due to the health effects associated with arsenic, every effort should be made to maintain arsenic levels in drinking water as low as reasonably achievable (or ALARA). The maximum acceptable concentration (MAC) for arsenic in drinking water is based on municipal- and residential-scale treatment achievability. Pilot testing is particularly important to confirm treatment effectiveness.

For information on the arsenic MAC, refer to the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Arsenic*. For additional arsenic removal design information, refer to *USEPA: Arsenic Treatment Technology Demonstrations*.

15.3.1 General Design Considerations

The following points should be considered when selecting and designing an arsenic reduction technology:

.1 Oxidation state of arsenic.
  - Most technologies are more effective at treating arsenate (anions containing As(V)) due to its insolubility and increased tendency to sorb;

.2 Raw water parameters including pH;

.3 Presence of competing ions including fluoride, sulphate, ammonia, silica.
  - Ammonia can prevent effective oxidation of As(III) to As(V). Silica can reduce the effectiveness of arsenic removal, particularly when pH is greater than 8.0. Pre-treatment may be needed to remove these ions in addition to reducing total dissolved solids;

.4 Waste stream/solid waste disposal; and

.5 Cost.

15.3.2 Oxidation and Filtration

Oxidation and filtration can be used to effectively co-remove arsenic in the presence of iron. When iron, manganese, and arsenic are oxidized in the raw water through aeration, the As(V) is adsorbed on the $Fe(OH)_2$ precipitate, which can then be removed by filtration. Filtration rates are typically between 5 - 10 m/h. Higher filtration rates may be achievable using manganese dioxide-coated media or other proprietary media.

Oxidation/filtration systems work well for raw water where the Fe:As ratio is 20:1 or greater; the ratio may need to be greater than 100:1 in some cases. Raw water with a lower Fe:As ratio may require the addition of iron in the form of an iron-based coagulant such as ferric chloride ($FeCl_3$) or ferric sulphate ($Fe_2(SO_4)_3$) to increase arsenic removal. It is recommended that this approach be piloted before detailed design; refer to Chapter 3 – General Design Guidance for further guidance on piloting.

15.3.3 Adsorption

Arsenic can be removed from water through adsorption onto an adsorptive media, typically a proprietary media. The media consists of a porous solid coated with a metal oxide, typically iron (ferric oxide), titanium, or aluminum (including activated alumina). Filtration rates can range from 6 - 20 m/h and EBCT from 3 - 10 minutes.

Chemical pre-oxidation is typically required to ensure that arsenic is present in As(V) form. The pH should be maintained around 8; adjustment of pH may be required to enhance removal effectiveness and reduce corrosion. Silica, phosphates, iron and manganese should also be removed prior to arsenic adsorption to prevent fouling of the adsorptive media.

The replacement period for adsorbents can vary widely and can be significantly reduced due to interference by silica, phosphate and other compounds. Designers should evaluate adsorbents for the specific source water quality before selecting an adsorbent or proceeding with detailed design.

15.3.4 Electrodialysis/Electrodialysis Reversal

Electrodialysis/electrodialysis reversal uses an electrical charge across a reverse osmosis (RO) membrane to remove arsenic. Pre- and post-adjustment of pH may be needed to prevent scaling, to enhance filtration, and to reduce corrosivity. Other contaminants that may be removed using this technology include hardness, dissolved solids, nitrates, and sulphates.

If iron and manganese are too high, this may cause interference with the arsenic removal process. Oxidation and filtration of iron and manganese is normally used upstream to prevent fouling of the RO membrane.

15.3.5 Membrane Processes

Reverse osmosis or nanofiltration membranes can be used as stand-alone arsenic treatment under most water quality conditions. If micro or ultra-membranes are used, they usually require a coagulation step to create arsenic-bound floc prior to filtration. Membrane processes are usually not sensitive to pH, but pre-filtration may be needed if the feed water contains NOM, iron and inorganic ions such as chlorides, silica, calcium and magnesium. To increase the arsenic removal efficiency and reduce the volume of reject water, multiple units should be installed in series. See Chapter 8 – Filtration for membrane filtration process design considerations.

15.3.6 Lime Softening

Lime softening involves adding lime (calcium hydroxide, CaOH) and optimizing the precipitation of $Mg(OH)_2$ and metal carbonates. High iron concentrations are desired for optimal arsenic removal through lime softening. Waters with low dissolved iron may require the addition of ferric chloride or ferric sulphate. Hardness may also be removed in this process.

Other considerations include the disposal of lime sludge (refer to Chapter 14 – Waste Residuals Handling and Treatment), the large quantity of chemicals required and the high labour intensity of handling lime.

15.3.7 Coagulation and Filtration

This method typically consists of chemical oxidation and the addition of a coagulant or polymer to remove arsenic by sedimentation and filtration. Other contaminants may be removed in this process, and pre- and post-adjustment of pH may be needed. Sulphate may cause interference or reduce treatment efficiency.

15.3.8 Anion Exchange

Anion exchange uses a resin to remove arsenic by exchanging the anions for As(V) ions in the raw water. Refer to Section 15.2.3 – Ion Exchange for further ion exchange design guidance. Salt brines are periodically used to regenerate the exchange resin. Chloride-form resins are the most common, however sulphate or nitrate selective resins may also be used. The pH should be maintained between 6.5 to 9.0. Anion exchange should only be used for waters with low concentrations of total dissolved solids and other anions (sulphate, nitrates etc.) which can compete with binding sites on the resin. Typical loading rates are 10 - 30 m/h with EBCT from 2 - 5 minutes.

Corrosion control should also be considered as anion exchange initially decreases the pH and alkalinity. This may make the water more corrosive to lead, copper, and other metals. Additionally, resins require regeneration, which results in the production of a waste stream that needs to be safely disposed. Refer to Chapter 14 – Waste Residuals Handling and Treatment for further direction on proper disposal of the waste stream.

15.4 Cyanobacteria

Cyanobacteria, also known as blue-green algae, are photosynthetic bacteria that share some properties with algae. Primarily in the warmer seasons, cyanobacteria can multiply rapidly in surface water and cause harmful algal blooms. Decay of the bloom consumes oxygen, creating hypoxic conditions which can result in plant and animal die-off. Cyanobacteria also contain toxic by-products known as cyanotoxins, which are excreted when the cell splits during death or through mechanical means (lysis), and may be spontaneously released from intact cells. The most widespread cyanotoxins are in the class called microcystins. There are at least 80 known microcystins, the most toxic of which is microcystin-LR (MLR). Other cyanotoxins include anatoxin-a (ANA), cylindrospermopsin (CYN) and saxitoxins. If persistent cyanobacterial blooms are occurring in the source water, the feasibility of an alternate source should be considered. If an alternative source is not available, steps should be attempted to prevent the blooms from occurring.

Harmful algal blooms can also cause taste and odour concerns. For further information addressing these concerns, refer to Chapter 10 – Taste and Odour Control.

For information on the maximum acceptable concentration (MAC) for total microcystins, as well as design and management strategies, refer to the following:

- .1 *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Cyanobacterial Toxins*, by Health Canada;
- .2 *Decision Protocols for Cyanobacterial Toxins in B.C. Drinking Water and Recreational Water*, by the Ministry of Health;
- .3 *Managing Cyanotoxins in Drinking Water: A Technical Guidance Manual for Drinking Water Professionals*, by the AWWA; and
- .4 *Cyanobacteria and Cyanotoxins: Information for Drinking Water Systems*, by the USEPA.

The following sections discuss treatment approaches for removing cyanobacteria. Cyanobacteria should be monitored post treatment to confirm adequate removal, and that the cells have not been lysed.

15.4.1 Dissolved Air Flotation (DAF)

Dissolved air flotation (DAF) is a clarification process that effectively removes light particles such as blue-green algae. The DAF process involves using microbubbles to bind to particles, and floating them to the surface, where they can be removed with a sludge scraper. DAF is particularly effective as it typically does not damage the algae during the removal process and therefore avoids the release of the cyanotoxins. The waste sludge is then disposed. See Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification for further information on DAF. Flotation processes, including DAF, are effective for removal of intracellular cyanotoxins since many of the toxin-forming cyanobacteria are buoyant. However, DAF will not remove extracellular cyanotoxins (i.e. toxins that have already been released to the water).

15.4.2 Ozone

Ozone (O_3) can be effective in oxidizing extracellular dissolved microcystins. However, its efficacy is impacted by the presence of organic matter and the pH at which it is applied. Another concern is the formation of disinfection by-products as a result of ozone application. Refer to Chapter 11 – Disinfection for use of ozone for disinfection purposes.

Note that application of oxidants upstream of cyanobacteria cell removal treatment should be discouraged as they can cause cell lysis, prompting cyanobacteria release. However, ozone can be an exception because it may simultaneously oxidize cyanotoxins.

15.4.3 Advanced Oxidation Process

Advanced oxidation processes (AOP) involve the generation of highly reactive hydroxyl radicals which can oxidize cyanobacteria and their toxins. This can be done in various combinations: the most common combinations are ozone with H_2O_2 ("peroxone"), ozone with UV light, and H_2O_2 with UV light. AOPs have been effective in treating microcystins (MLR), anatoxin (ANA), and cylindrospermopsin (CYN), in addition to some taste and odour compounds such as 2-methylisoborneol (MIB) and geosmin. The efficacy of AOP is strongly impacted by water quality parameters including natural organic matter (NOM), alkalinity, and pH. Formation of disinfection by-products (DBPs) should be considered when applying advanced oxidation processes.

Bench scale studies have indicated the reactivity of cyanotoxins with ozone to be MLR>CYN>ANA, though oxidation of all cyanotoxins increases with increased ozone dosage (Jasim et al., 2020). The required ozone and H_2O_2 dosage will differ depending on the characteristics of the raw water, cyanotoxin(s) present, and target cyanotoxin(s) to be removed (Schneider and Blaha, 2020). Pilot studies should be performed to determine the optimum dosages and operating method, particularly as AOP efficacy has been studied mostly at the bench scale and few studies have been performed at full scale.

For further information, refer to Section 10.2.7 – Advanced Oxidation Processes in the *Design Guidelines*, the *Cyanobacterial Toxins in Drinking Water Document for Public Consultation* by Health Canada, *Ozone in Drinking Water Treatment: Process Design, Operation, and Optimization* by Rakness (AWWA), the *Advanced Oxidation Handbook* by Collins (AWWA), and *Water Treatment for Purification from Cyanobacteria and Cyanotoxins*.

15.4.4 Powder Activated Carbon

Powdered activated carbon (PAC) can be added to the raw water at the inlet of the treatment plant to mitigate taste and odour issues and toxins associated with cyanobacteria. Refer to Section 13.7.9 – Activated Carbon for more details about PAC application and design.

15.5 Ammonia

The *Guidelines for Canadian Drinking Water Quality* do not specify a MAC for ammonia. However, the GCDWQ recommends that ammonia entering the distribution system is below 0.1 mg/L and preferably below 0.05 mg/L. Excess free ammonia in finished water can lead to nitrification, decreased free chlorine levels due to the formation of chloramines, and corrosion or biofilm problems in the water distribution system. If monochloramine is used as the secondary disinfectant, it is recommended that free ammonia in the finished water be less than or equal to 0.05 mg/L to prevent nitrification in the distribution system. As nitrate is an intermediate compound in the oxidation of ammonia to nitrate in biological filters, utilities should ensure that their systems are optimized such that the biological process is complete, and nitrate is not present in the treated water. The *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Ammonia* by Health Canada should be referred to when designing ammonia removal systems.

15.5.1 Biological Removal

Aerobic biotreatment of groundwater can effectively degrade/oxidize ammonia, similar to the biofilter treatment methods for iron and manganese removal described in Section 15.2 – Iron and Manganese. Sufficient oxygen should be provided to maintain biological activity. In order to have complete nitrification, a stoichiometric oxygen (O_2) demand of 4.33 mg O_2/mg NH_4^+-N is required; for higher ammonia concentrations, a constant oxygen feed may be required. Systems with high nitrates in the raw water may not be suitable for biotreatment as ammonia is converted to nitrate in a 1:1 ratio by ammonia oxidizing bacteria. Additional treatment for nitrate removal may be required if high levels of ammonia removal (6 - 8 ppm) are needed.

The treatment objectives and water quality targets of the biotreatment systems should be clearly defined for ammonia, and other constituents including iron and manganese. The secondary disinfectant should also be specified, if chloramines are used for disinfection.

15.5.2 Breakpoint Chlorination

Breakpoint chlorination is an effective technique for the removal of ammonia in raw water. Ammonia, when in contact with chlorine, reacts rapidly to form chloramines. Chlorine reacts with NH_3 to form monochloramine (NH_2Cl). The additional free chlorine then reacts with monochloramine to form dichloramine ($NHCl_2$), and then trichloramine (NCl_3). Chlorine dosing past the breakpoint results in free chlorine residual. Breakpoint chlorination is thus the addition of chlorine to water until the chlorine demand has been satisfied to reach the breakpoint. Chlorination can then be achieved by using chlorine-based disinfectants, such as chlorine gas and sodium hypochlorite. Refer to Section 11.7.2 –Chloramine Formation for details on breakpoint chlorination.

Breakpoint chlorination is cost effective for removal of water with low ammonia levels, however, removal of higher levels of ammonia may become cost prohibitive and increase DBP formation. The presence of 1 mg/L of ammonia nitrogen in raw water may require 8 to 10 mg/L of chlorine dose to achieve breakpoint chlorination.

15.5.3 Ion Exchange

Ion exchange may be used for ammonia removal from water; however, media should be selected with high ammonium exchange capacity. Zeolites are good options for ammonia removal: in particular, clinoptilolite is a natural zeolite which is most commonly used for ion exchange removal of ammonia. Zeolites can be regenerated using brine. Since only the ionized ammonium form can be removed by the ion exchange process, the pH of water needs to be maintained at 7.2 - 7.6.

Water that is high in hardness will have decreased treatment efficiency due to the simultaneous affinity and removal of calcium, magnesium and ammonium ions. There are selective zeolites that will preferentially remove ammonia in high hardness water, however, use of these media may result in high levels of sodium in the treated water. Ion exchange is a viable method especially when low cost minerals can be used as an exchanger and water has low hardness. Section 15.2.3 – Ion Exchange provides further considerations for ion exchange.

15.6 Radionuclides

Natural sources of radionuclides are responsible for greater than 98% of radiation exposure, excluding medical exposure. Radionuclides may occur naturally in groundwater through contact with rocks or soils that have naturally occurring radioactive materials (NORM) but can also be the result of anthropogenic activities in both groundwater and drinking water. While generally rare, the radionuclides most likely to be found in Canadian drinking water supplies are uranium, lead-210, radium-226, tritium, strontium-90, iodine-131, and cesium-137. Refer to the *Canadian Drinking Water Quality Guidelines* for MAC values.

Water systems should conduct predesign studies and pilot tests to determine the treatment and waste disposal options appropriate for their situation. Table 15-4 provides removal efficiencies for treatment processes that are commonly used to treat radionuclides (note removal efficiencies were observed for point-of-entry (POE) or point-of-use (POU) systems).

Constituent concentrations in the waste streams will be a key consideration in disposal and should be estimated through desktop calculations and where possible through testing (bench and/or pilot scale). Refer to Chapter 14 – Waste Residuals Handling and Treatment for more details on residual handling.

Table 15-4 Radionuclide Removal Methods (sourced from MWH, 2015)

Method	Removal Efficiency (%)		
	Radon	Radium	Uranium
Activated alumina			90 %
Aeration, packed tower or diffused bubble	To 99%		
Aeration, spray	70 to 95%		
Coagulation - filtration			80 to 98%
GAC Adsorption - decay	62 to 99%		
Electrodialysis		90%	
Greensand		25 to 50%	
Hydrous manganese oxide filter		90%	
Ion exchange		81 to 99%	90 to 100%
Lime softening		80 to 92%	85 to 99%
Reverse osmosis		90 to 95%	90 to 99%

15.6.1 Granular Activated Carbon Radon Removal

Radon will decay to form radioactive decay products once adsorbed onto GAC beds. The first four decay products have short half-lives (less than 30 minutes) and are associated with beta and gamma emissions. The fifth decay product is Pb-210, which has a half life of 22 years and will accumulate on the GAC bed over time. GAC beds can be used for radon removal for many years assuming no limiting water quality conditions exist.

Designers should consider measures to reduce operator exposure to radon and radon decay products if GAC units are to be used. Possible measures include automating the treatment system to allow the operator to control the system remotely, adding vessel shielding, or installing physical barriers to prevent casual contact. Disposal of the spent GAC can present a challenge, depending on the contaminants present and the extent of contaminant accumulation. The Designer should consult with relevant authorities to determine the appropriate disposal method(s) for spent GAC, and refer to Chapter 14 – Waste Residuals Handling and Treatment.

15.7 Heavy Metals

Heavy metals present drinking water health risks as they tend to bioaccumulate within humans when consumed. The most common heavy metals in drinking water are lead (Pb) and copper (Cu) as they are leached from plumbing and distribution system components, including watermains, fixtures, and faucets. Other heavy metals such as mercury, chromium, and selenium may be present in source water; however, they are less common and require specialized treatment processes for removal. The treatment considerations for these parameters are not discussed within this section; however, Designers should use industry standards and best management practices to achieve the MACs set out in the GCDWQ.

Corrosion control should be performed to produce non-corrosive water and minimize lead (Pb) and copper (Cu) leaching within the distribution system. Corrosion control studies should assess the effectiveness of pH and alkalinity control, hardness, and the addition of phosphate or silica-based corrosion inhibitors. Every effort should be made to reduce the lead level in drinking water to as low as reasonably achievable (ALARA). Refer to Chapter 12 – Internal Corrosion Control, for details on corrosion control methods.

15.7.1 Household Water Treatment Devices

As the primary source of lead and copper is leaching from plumbing and distribution components, household water treatment devices can be effective in removing these metals at the tap. This includes carbon-based filters, RO devices, and distillation treatment devices. Refer to Chapter 21 – Small Systems for further guidance on point-of-entry and point-of-use systems.

15.8 Fluoride

15.8.1 Fluoride Addition

Sodium fluoride, hydrofluosilicic acid (also known as fluosilicic acid or hexafluosilicic acid) and sodium silicofluoride may be used for fluoridation. These compounds are highly corrosive and require specific considerations. In addition to these guidelines, the Designer should refer to a fluoride manual such as

AWWA Manual of Water Supply Practices M4 – Water Fluoridation Principles and Practices and the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Fluoride.*

Where fluoride addition is practiced, a fluoride dosage of 0.8 mg/L is recommended and should not exceed 1.2 mg/L. The dose selection is dependent upon the local climate; higher temperature regions having high water consumption should target a dose of 0.8 mg/L, and colder temperature regions should conversely target a dose of up to 1.2 mg/L. Water systems that fluoridate should maintain fluoride concentrations between 0.5 mg/L and 0.9 mg/L in the distribution system. If there is naturally occurring fluoride in the source water, the total concentration of naturally occurring fluoride plus added fluoride should be within this range. This requirement ensures that fluoridation is tightly controlled, effective, and reliable.

When fluoridation is practised, adequate controls should be maintained at all times to provide a fluoride ion concentration in treated water to meet the optimum concentration in the latest edition of the GCDWQ. The monthly average and daily variation should be within ± 0.1 mg/L and ± 0.2 mg/L of the targeted concentration, respectively.

Any Water Supplier proposing to add fluoride to a potable water supply should apply for and obtain approval from their Health Authority. The following information should be included in the application for approval:

.1 A description of the proposed fluoridation equipment;
.2 A statement identifying the fluoride compound that is proposed to be added;
.3 A description of chemical storage and ventilation;
.4 A description of the water metering used at the water treatment plant;
.5 The generic name of the chemical to be used as the source of fluoride ion, and its fluoride content;
.6 A current chemical analysis of the fluoride content of the raw water;
.7 The name and qualifications of the person directly responsible for the operation of the proposed fluoridation process;
.8 The type of equipment proposed at the water treatment plant to determine the fluoride concentration of the water; and
.9 A description of the testing procedure to be used to determine the fluoride level of the water.

15.8.2 Design Considerations

When designing fluoride systems, Chapter 13 – Chemical Application should be referenced in addition to the following considerations:

.1 At least two diaphragm operated anti-siphon devices should be provided on all fluoride saturator or fluosilicic acid feed systems;
   a. One diaphragm operated anti-siphon device should be located on the discharge side of the feed pump;
   b. A second diaphragm operated anti-siphon device should be located at the point of application unless a suitable air gap is provided;
.2 A physical break box may be required in high hazard situations where the application point is substantially lower than the metering pump. In this situation, either a dual head feed

pump or two separate pumps are required and the anti-siphon device at the discharge side of the pump may be omitted;

.3 Scales, loss-of-weight recorders or liquid level indicators, as appropriate, accurate to within 5% of the average daily change in reading should be provided for chemical feeds;

.4 Feeders should be accurate to within 5% of any desired feed rate;

.5 Fluoride compound should not be added before lime-soda softening or ion exchange softening;

.6 The point of application if into a horizontal pipe, should be in the lower half of the pipe, preferably at a 45^{o} angle from the bottom of the pipe and protrude into the pipe one third of the pipe diameter;

.7 Water used for sodium fluoride dissolution should be softened if hardness exceeds 50 mg/L as calcium carbonate;

.8 Fluoride solutions should be injected at a point of continuous positive pressure unless a suitable air gap is provided;

.9 Saturators should be of the up-flow type and be provided with a meter and backflow protection on the makeup water line;

.10 Consideration should be given to provide a separate room for fluosilicic acid storage and feed;

.11 Dust control:

a. Provision should be made for the transfer of dry fluoride compounds from shipping containers to storage bins or hoppers in such a way as to minimize the quantity of fluoride dust which may enter the room in which the equipment is installed;
b. The enclosure should be provided with an exhaust fan and dust filter, which places the hopper under negative pressure. Air exhausted from fluoride handling equipment should discharge through a dust filter to the outside atmosphere of the building;
c. Provision should be made for disposing of empty bags, drums or barrels in a manner which will minimize exposure to fluoride dust;

.12 Testing equipment:

a. Equipment should be provided for measuring the quantity of fluoride in the water;

.13 Metering: Metering of the total water to be fluoridated should be provided, and the operation of the feeding equipment is to be controlled unless specifically exempted. Control of the feed rate should be:

a. Automatic/proportional controlled, whereby the fluoride feed rate is automatically adjusted in accordance with flow changes to provide a constant pre-established dosage for all rates of flow; or
b. Automatic/residual controlled, whereby a continuous automatic fluoride analyzer determines the residual fluoride level and adjusts the rate of feed accordingly; or
c. Compound loop controlled, whereby the feed rate is controlled by a flow proportional signal and residual analyzer signal to maintain a constant residual;

.14 Record of Performance Monitoring: Accurate daily records should be kept. These records should include:

a. the daily reading of the water meter, which controls the fluoridation equipment or that which determines the amount of water to which the fluoride is added:
   i. the daily volume of water fluoridated;
   ii. the daily weight of fluoride compound in the feeder;
   iii. the daily weight of fluoride compound in stock;
   iv. the daily weight of the fluoride compound fed to the water;

v. the fluoride content of the raw and fluoridated water determined by laboratory analysis, with the frequency of measurement as follows:
   - treated water being analyzed continuously or once daily;
   - raw water being analyzed at least once a week;

.15 Sampling: The following sampling procedures should be undertaken to monitor the fluoride dosing for consistency:

a. A sample of raw water and a sample of treated water should be forwarded to an approved independent laboratory for fluoride analysis once a month; and
b. On new installations or during start-ups of existing installations, weekly samples of raw and treated water for a period of not less than four consecutive weeks should be submitted to a designated laboratory to determine the fluoride concentration.

15.8.3 Removal of Naturally Occurring Fluoride

Control options for excess fluoride levels in drinking water include blending of fluoride-rich waters with waters of low fluoride content, the selection of low-fluoride source water and removal of excess fluoride concentration by treatment processes at the water supply or household level. Where fluoride is naturally occurring and above the GCDWQ or other regulatory requirements, fluoride should be removed by an acceptable means to less than the required limit. Reference should be made to the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Fluoride.*

A wide range of technologies such as activated alumina (AA), reverse osmosis (RO), lime softening, and conventional ion exchange, are capable of reducing excess fluoride levels from drinking water. Coagulation has been shown to reduce fluoride; however, it is less practical than other approaches.

15.8.3.1 Coagulation Techniques

Although not highly effective, inorganic coagulants such as aluminum sulphate (alum) or a ferric salt, may be able to reduce fluoride in drinking water. These processes require very large concentrations of coagulant for fluoride removal.

Fluoride removal by alum coagulation is affected by factors such as a coagulant dose and pH. Experimental data has demonstrated that the optimum pH range for removal of fluoride is between 6.2 and 7.0.

Due to the high quantity of coagulant required, and the cost of the chemicals, this process has limited applications, especially for small treatment systems. The high coagulant use would result in the generation of a large volume of sludge, which would require pre-treatment and disposal.

15.8.3.2 Ion Exchange

15.8.3.2.1 Activated Alumina

The most practical municipal-scale technology for the reduction of excess fluoride concentrations in drinking water is adsorption with activated alumina (AA). Activated alumina shows a high affinity and selectivity towards fluoride ions; the adsorption process is similar to conventional ion exchange. Full-scale and pilot-scale studies have demonstrated that effluent concentrations of fluoride below 1.0 mg/L are achievable using AA adsorption.

In AA adsorption, raw water is continuously passed through packed media beds (in series or parallel), and the fluoride ions are exchanged with the hydroxide ions bound with the alumina. Factors such as pH, influent fluoride concentration, media particle size, and competing ions (arsenic, selenium, silica, hardness ions) have a significant impact on fluoride removal. In addition, the effectiveness of the process is also a function of the flow rate, the empty bed contact time (EBCT), and media regeneration.

When employing AA technology, operational issues that should be considered include:

.1 AA sourced from "cemented alumina beds" which tends to dissolve as a result of the regeneration process should be avoided;
.2 Fouling of the AA bed with particulates may occur depending on influent water quality, resulting in an increase in head loss across the media bed *(USEPA, 1984, 2002)*; and
.3 Metal hydroxides, suspended solids, carbonates and adsorbed silicates can reduce the adsorption capacity of AA.

If present, iron and manganese should be sufficiently oxidized and filtered prior to the AA beds to reduce fouling. Additional considerations include chemical handling requirements, pH adjustments, and regeneration of exhausted AA beds; due to these complexities, AA may not be viable for small water systems. Refer to the U.S. EPA design manual *Removal of Fluoride from Drinking Water Supplies by Activated Alumina* for more details on AA adsorption.

15.8.3.2.2 Anion Exchange

Factors affecting fluoride removal by anion exchange technology include the influent fluoride concentration, the concentration of competing ions, and media regeneration. Refer to Section 15.2.3 – Ion Exchange for further ion exchange design guidance.

15.8.3.2.3 Bone Char

Bone char - a blackish, porous, granular material with a specific affinity for fluoride - can be used for water with high alkalinity and high total dissolved solids (TDS), but imparts an undesirable taste to the water. Full scale installations (2 units in series) have demonstrated reduction of fluoride from 9 - 12 mg/L to 0.6 mg/L.

Bone char is soluble in acid and the recommended pH to prevent loss of the media is approximately 7.0. The presence of arsenic ions could reduce fluoride removal efficiency.

15.8.3.3 Reverse Osmosis and Nanofiltration Processes

Reverse osmosis and nanofiltration (NF) technologies have been shown to be effective methods for the reduction of fluoride concentrations below 1 mg/L in drinking water.

The performance of the membrane systems depends on the quality of the raw water, the type of the membrane, molecular weight cut-off, and recovery of the system. The presence of iron, manganese, silica, scale-producing compounds, and turbidity could negatively affect system performance. A pre-treatment of the feed water is required to prevent scaling and fouling of the RO membranes. The RO product water typically requires post-treatment consisting of pH and alkalinity adjustments.

15.8.3.4 Lime Softening

Lime softening is more applicable for fluoride reduction in source waters with high magnesium concentrations. If the raw water has a low magnesium content, magnesium salt may be added.

Lime softening is an expensive process due to the large quantity of chemicals used and is not recommended unless there is also a need to reduce hardness in the raw water. These systems also create significant quantities of sludge, which require pre-treatment and disposal, and add to the cost of the process.

15.8.3.5 Electrodialysis Reversal

Electrodialysis is an electrochemical separation process in which ions are transported through semi-permeable membranes under the influence of an electric potential. In electrodialysis reversal (EDR) the polarity of the electrodes is changed periodically across the ion exchange membranes. Pilot and full-scale applications of these processes have demonstrated fluoride removal to meet regulatory requirements. For design criteria, refer to *AWWA M38: Electrodialysis and Electrodialysis Reversal*.

15.9 Saltwater Intrusion

Saltwater intrusion occurs when saline water enters a freshwater aquifer due to either natural processes or human activities. Treatment options for saltwater can include freshwater injection (although not typical for B.C.) or reverse osmosis (RO) membrane filtration, and is typically costly. The type of RO depends on raw water quality: sea water RO membranes have the highest removal but also the highest operating pressure, while brackish water RO membranes have a lower salt rejection. Refer to Chapter 8 – Filtration for further information on membrane filtration.

Pursuant to *WSA 58 (2)*, a person must not operate a well in a manner that causes or is likely to cause the intrusion of saline groundwater, sea water or contaminated water into:

(i) the aquifer from which that well diverts water,
(ii) another aquifer, or
(iii) a stream that is hydraulically connected to an aquifer referred to in subparagraph (i) or (ii).

For further recommendations on preventing saltwater intrusion, refer to Section 6.3.1.7.1 – Saltwater Intrusion as well as the *Best Practices for Prevention of Saltwater Intrusion* and current advisories for coastal areas located here: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-wells/information-for-well-drillers-well-pump-installers/well-drilling-advisories.

15.10 Nitrite and Nitrate

The most common sources of nitrite and nitrate are human activities, including agricultural activities, septic systems, and wastewater treatment. Refer to the *Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Nitrate and Nitrite* by Health Canada for MACs.

The following section describes treatment processes that can effectively reduce nitrite and nitrate concentrations when designed properly. However, primary consideration should be given to non-treatment alternatives to resolve nitrite and nitrate contamination. This includes obtaining water from an alternate source, introducing better control of nitrogen fertilizer application, and better containment of septic systems.

15.10.1 Blending

Blending of two or more sources can be used to decrease the nitrite/nitrate concentration in the resultant water. Note that nitrate levels in groundwater may vary over time. As different source waters have different raw water characteristics, blending studies and pilot testing should be conducted to determine the compatibility of the sources and the optimum blending ratio. Corrosion problems can result from mixing two different waters, therefore a corrosion study is recommended when the two water sources are blended in an existing system. Refer to Chapter 12 – Internal Corrosion Control for more information.

15.10.2 Electrodialysis Reversal (EDR)

Electrodialysis is an electrochemical process that involves applying a direct current between a stack of alternating anion-selective membranes and cation-selective membranes. As the feedwater travels through the stack, anions (such as nitrate) are removed by anion-selective membranes. The polarity and hydraulic channels are periodically reversed to keep the membranes clean. For design criteria, refer to *AWWA M38: Electrodialysis and Electrodialysis Reversal*.

15.10.3 Biological Denitrification

Biological denitrification is commonly used in wastewater treatment processes in which nitrate is reduced to nitrogen gas (N_2). Anoxic conditions are required, so DO must be < 0.1 mg/L. Depending on the type of bacteria involved, additional nutrients (carbon, hydrogen, or sulphur) may be required to maintain the required biomass.

Some treatment plants in Europe and the United States have successfully used biological denitrification in drinking water treatment. A fluidized bed bioreactor or fixed bed bioreactor can be used. In either case, water flows through media which supports bacterial biofilm growth.

15.10.4 Ion Exchange

Nitrate is a negatively charged ion which can be removed through ion exchange using an anion resin. A salt brine is used to periodically regenerate the resin. The volume of water that can be treated by the anion resin prior to regeneration is a key design parameter. Designers should use a pilot test to confirm an estimated volume of water that can be treated before exhaustion. Refer to Section 15.2.3 – Ion Exchange for further design guidance.

The concentration of other anions (sulphate, chloride etc.) in the water should also be considered, as these ions will compete with nitrate for exchange sites on the resin. In particular, ion exchange resins have a higher affinity for sulphate than nitrate. If the resin is not regenerated in time, other anions will displace the nitrate. This can cause the concentration of the nitrate in the treated effluent to exceed the untreated water in an effect known as chromatographic peaking. High levels of dissolved solids may also interfere with the ion exchange process.

Anion exchange will initially decrease the pH and alkalinity, which may increase the corrosivity of the water. Corrosion control treatment may be required.

15.10.5 Reverse Osmosis (RO)

Reverse osmosis is used primarily for very low flows due to the high cost and high volume of reject water. RO rejects many dissolved ions, including nitrate. Refer to Chapter 8 – Filtration for details of reverse osmosis design guidance.

15.11 Emerging Contaminants

New water contaminants of concern continue to emerge, and as laboratory analysis methods improve, some chemicals, constituents, and microbial agents can be detected at very low levels in drinking water. The intent of this chapter is to bring attention to emerging contaminants that may be present in drinking water so that Designers and Water Suppliers can assess risk and plan for mitigation as needed.

While different effects (e.g. fate in water systems) of anthropogenic chemicals and microbiological organisms have been discovered, it is not always clear if these emerging contaminants pose concerns to human health at these low concentrations. Regulatory Authorities and health professionals have established health advisory limits for some contaminants which may become regulated in the future, and research continues to clarify maximum acceptable concentrations and associated health effects. Recent emerging contaminants of concern in drinking water sources include:

- .1 Persistent organic pollutants (POPs) such as polybrominated diphenyl ethers (PBDEs used in furniture), pesticides (DDT, Aldrin etc.), and polychlorinated biphenyls (PCBs used in coolants);
- .2 Pharmaceutical and personal care products (PPCPs) including prescription and over-the-counter medications;
- .3 Veterinary medicines such as antimicrobials and antibiotics;
- .4 Endocrine-disrupting chemicals (EDCs) including synthetic hormones such as estrogens and androgens;
- .5 Microplastics composed of polymers such as PET (polyethylene terephthalate), PP (polypropylene), and PE (polyethylene);
- .6 Nanomaterials: particles ranging in size from 1 to 100 nanometers used in drug delivery, aerospace, and cosmetics, including materials such as titanium dioxide (TiO_2) and carbon nanotubes;
- .7 Perfluoroalkyl and polyfluoroalkyl substances (PFAS); and
- .8 Emerging environmental pathogens such as amoebae, fungi, and opportunistic premise plumbing bacterial pathogens.

Designers and Water Suppliers should remain informed of the emerging contaminants that may be present in drinking water and their potential human health effects, risk of occurrence within source waters and future treatment options. As research and applied science expand the evidence based practice related to specific contaminants, Designers and Water Suppliers should continue to assess the risk and mitigation methods to protect the public from such contaminants.

Designers should consider selection of water sources which minimize emerging contaminants and include provisions for advanced treatment options if needed in the future. The selection of the treatment process will differ depending on the target contaminant. Note that many emerging contaminant-related studies have only been conducted at the laboratory scale, and pilot testing should be performed to determine site-specific technology selection and operating conditions. The Designer should also consider the impact of waste streams on the environment and identify proper disposal methods.

The following sections describe the more widely studied technologies for emerging chemical contaminant removal in drinking water; however, they may be expensive and difficult to operate. For further information, refer to *Treatment Technologies for Emerging Contaminants in Water:* A Review (Rodriguez-Narvaez et al., 2017), *Drinking Water Treatment for PFAS Selection Guide* by AWWA, and *Removal of Endocrine Disruptor Chemicals Using Drinking Water Treatment Processes* by the USEPA.

15.11.1 Adsorption

Adsorption by activated carbon - either granular or powder - is the most widely studied emerging contaminants removal method. In general, activated carbon has provided good results for removal of various organic compounds such as POPs and EDCs (Rodriguez-Narvaez et al., 2017). Activated carbon may be paired with other removal technologies, such as coagulation and filtration, for enhanced emerging contaminant removal. The source of the raw material for the activated carbon is an important factor as different sources result in significantly different removal rates.

A similar technology is biochar, which is a charcoal-based material often used for soil amendment. Biochar has different selectivity and may be more efficient at removing certain ECs compared to activated carbon. Other adsorbents including clay and zeolites have also been studied to a more limited capacity.

15.11.2 Membrane Technologies

Membrane technologies that have been shown to remove emerging contaminants include ultrafiltration (UF), nanofiltration (NF), forward osmosis (FO), and reverse osmosis (RO). UF is generally more effective at removing polar, highly water-soluble ECs. NF has also been shown to effectively remove organic contaminants such as DDT *(Pang et al., 2010)*. Membrane material also impacts removal efficiency of different ECs.

RO and FO have both shown effective removal of organic compounds at low concentrations. RO has been reported to be more efficient than FO, as it can remove particles as small as 1 nm and colloidal particles. For both RO and FO, efficiency increases as pore size decreases.

15.11.3 Advanced Oxidation Process

Bench scale testing has found ozone/H_2O_2 based AOPs applied before coagulation to be effective in removing PPCPs EDCs when performed in conjunction with clarification and filtration (Rahman et al., 2010). Ozone/H_2O_2 based pre-coagulation AOP has also shown the potential to remove trace pharmaceuticals. See Section 15.4.3 – Advanced Oxidation Process for more information.

Other AOP methods such as the Fenton reaction, a catalytic process where H_2O_2 reacts with Fe^{2+} (usually provided in the form of $FeSO_4$), to form OH*, have also been shown to remove organic emerging contaminants. However, there are no known full-scale WTPs using Fenton reaction-based AOPs due to the low pH required and sludge production.

16 Transmission and Distribution

16.1 General

This chapter provides design guidance for transmission and distribution systems for water supply systems. Distribution systems should be designed to protect and maintain microbiological water quality. Distribution system design considerations should include main sizing, provision of multidirectional flow, valving for distribution system control, setbacks from potential contaminants, and provisions for flushing and maintenance to maintain water quality and minimize loss of service to customers. Distribution systems should be designed to maximize turnover rates and to minimize residence times while maintaining the required pressure and flows to provide high reliability and to reduce water quality problems.

Other approval authorities such as local governments may have standards that are more stringent than these guidelines. The Designer should, therefore, ensure that they are aware of the requirements of all other approving authorities before commencing design.

16.2 Water Instability Due to Biological Activity

Treated drinking water quality should ideally undergo minimal changes throughout the distribution system. However, biologically unstable water may experience deteriorating quality during distribution; for example, biodegradation of organic matter, development of biofilms and reduction of sulphates to sulphides can pose aesthetic and health risks.

Biological stability can be encouraged by maintaining a free and/or combined chlorine residual throughout the distribution system. Further information about secondary disinfection or 'residual disinfection' can be found in Section 11.1.2 – Secondary Disinfection and in the Ministry of Health's *British Columbia Guidelines (Microbiological) on Maintaining Water Quality in Distribution Systems*.

Reducing the amount of natural organic matter (NOM) and specifically biodegradable dissolved organic carbon (BDOC) prior to treated water entering the distribution system should also be considered to prevent the development of biologically unstable water. Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification, Chapter 8 – Filtration and Chapter 15 – Parameter Specific Treatment should be referenced for methods of removing BDOC and NOM.

Further information on characterizing biological activity can be found in Health Canada's *Guidance on Monitoring the Biological Stability of Drinking Water in Distribution Systems*.

16.3 Design Criteria

16.3.1 Layout Considerations

Distribution system layouts are usually designed in one of three configurations: arterial-loop systems, grid systems and tree systems. Tree systems often have more dead ends and as such are generally not recommended.

Wherever possible, water distribution systems should be designed to eliminate dead ends by making appropriate tie-ins or looping whenever practical. Water quality problems associated with dead ends include taste and odour concerns, decay of disinfectant residual, bacterial growth, increased corrosion, changes in pH and collection of sediment. Where dead-ends mains cannot be avoided, the Designer should take steps to ensure the water quality issues have been addressed.

Isolation valves should be strategically installed to allow for the maintenance of service through alternate routing while repairing a section of watermain.

16.3.2 Interconnections

If interconnections between distribution systems or different water supply sources are planned, consideration should be given to:

- The differences in water quality and characteristics; and
- The implications of mixing different waters; examples include mixing water from a distribution system where chloramination is used with water from a system where free chlorination is used for secondary disinfection, or when differing water qualities could cause corrosion when combined.

16.3.3 System Pressures

All transmission mains, primary distribution mains, distribution mains and service mains, including those not designed to provide fire protection, should be sized based on a hydraulic analysis of flow demands, municipal by-laws, and pressure requirements. For complex systems that include interconnected piping networks, the Designer should use computer modelling to calculate:

.1 Head loss through various bends and fittings in transmission mains and distribution piping;
.2 The elevation of the highest developable location within the serviced properties, with specific consideration to avoiding the potential for negative pressures occurring within service lines.

16.3.3.1 Minimum Pressures

Unless otherwise specified by municipal bylaws or Water Supplier design standards, water systems should be designed to maintain:

.1 A minimum pressure of 140 kPa (20 psi) at ground surface level at all points in the distribution system under maximum day demand plus fire flow conditions.
.2 Normal and peak hourly demand operating pressures in the distribution system between approximately 345 to 480 kPa (50 to 70 psi) and not less than 275 kPa (40 psi).

16.3.3.2 Maximum Pressures

Unless otherwise specified by municipal bylaws or Water Supplier design standards, water systems should be designed so that:

.1 Maximum operating pressures in the distribution system do not exceed 850 kPa (123 psi) to avoid damage to household plumbing and unnecessary water and energy consumption; and
.2 Pressure reducing devices are provided when static pressures exceed 850 kPa (123 psi).

16.3.3.3 Transient Pressures

Transient pressures can develop within transmission mains and distribution networks due to sudden flow velocity changes resulting from pump starts and stops, power failures, or rapid valve operation. The

Designer should consider the following when designing pumping and valve control facilities to prevent damage to water system components:

.1 Control motor/pump speeds during starting and stopping operations by use of variable frequency drives or motor soft starters;
.2 Control pumped system flow velocity changes by use of one or a combination of hydraulic pump control valves, surge anticipating valves or online surge vessels;
.3 Control valve opening and closing speeds to prevent rapid changes in flow by use of gear reduction mechanisms, pneumatic or electric actuation rate of change;
.4 Pumping systems should be designed to minimize pressure surges;
.5 Pipes and joints should be designed to withstand the maximum operating pressure plus the pressure surge that would be created by stopping a water column moving at the maximum operating velocity; and
.6 Transient pressures vary depending upon the hydraulic flow rate, change in flow velocity, pipe diameter, pipe wall thickness and pipe material used in the distribution system.

Transient analysis should be undertaken for long transmission lines, mains near pump stations, mains that service multiple large consumers, mains with regularly operating on/off valves or PRVs and where high pressure or high velocities warrant an analysis.

16.3.4 Friction Factors

For new pipe conditions, the Designer *s*hould refer to the most recent versions of the following AWWA Manuals:

.1 Manual of Water Supply Practices M9 – Concrete Pressure Pipe;
.2 *Manual of Water Supply Practices M11 – Steel Water Pipe: A Guide for Design and Installation*;
.3 *Manual of Water Supply Practices M23 – PVC Pipe: Design and Installation*;
.4 *Manual of Water Supply Practices M41 – Ductile-Iron Pipe Fittings*;
.5 *Manual of Water Supply Practices M45 – Fiberglass Pipe Design*; and
.6 *Manual of Water Supply Practices M55 – PE Pipe - Design and Installation*.

In evaluating existing systems for expansion, the Hazen-Williams coefficients (C-factors) should be determined by actual field tests wherever possible. Where these data are not available, the Designer may choose to use the Hazen-Williams C-factors shown in Table 16-1 for the design of water distribution systems with pipes made of traditional materials, or when estimating pressure losses in existing systems.

Table 16-1 Hazen-Williams C-factors

Diameter – Nominal	C-Factor
150 mm (6 in)	100
200 mm – 250 mm (8 to 10 in)	110
300 mm – 600 mm (12 to 24 in)	120
Over 600 mm (over 24 in)	130

Source: *Design Guidelines for Drinking-Water Systems 2008, Ontario Ministry of Environment*

Alternatively, the *Designer* may choose to use other methods of calculating friction factors such as the Darcy-Weisbach equation or the Manning equation, noting the relevant assumptions for the calculation method used.

16.3.5 Pipe Diameter

All watermains, including those not designed to provide fire protection, should be sized according to a hydraulic analysis based on flow demands and pressure requirements, as well as the depositional nature of the water with respect to long term watermain carrying capacity. Any deviation from the minimum requirements listed in Table 16-2 should be justified by hydraulic analysis. The actual inside pipe diameter should be used in the hydraulic calculations.

Table 16-2 Minimum Pipe Diameters

Condition	Minimum Diameter
Systems with fire protection	Minimum size of watermain should be 150 mm, except beyond last hydrant where 100 mm diameter is acceptable, however the number of services should be limited; or As determined to maintain the required pressure, flows, and water quality under normal operating conditions.
Systems without fire protection	Minimum size of watermain should be 100 mm diameter where a dead-end termination would preclude the possibility of future extension; or As determined to maintain the required pressure flows, and water quality under normal operating conditions.

The minimum size of watermains may also be dictated by the types of available equipment for cleaning watermains (e.g. swabs or pigs). In all cases, pipe diameters should be such that a flushing velocity of 0.8 m/s can be achieved for cleaning and disinfection procedures.

Larger size mains may be necessary to allow the withdrawal of the required fire flow while maintaining the minimum pressure specified in Section 16.3.3 – System Pressures.

16.3.6 Velocity

The maximum design velocity for flow under maximum day conditions for transmission mains, primary distribution mains, distribution mains and service mains should be 1.5 m/s. The maximum fire flow velocity should be 3.0 m/s, unless otherwise specified by municipal bylaw or Water Supplier design criteria. Energy requirements, transient propagation, and system life-cycle cost analysis may warrant consideration of alternate maximum velocity selection.

Flushing devices should be sized to achieve a minimum cleansing velocity of 0.8 m/s in the watermain being flushed.

16.3.7 Flushing and Swabbing

Flushing hydrants or devices are recommended for systems that are not capable of providing fire flow and for dead-ended watermains and areas where the degradation of water quality may be possible due to low consumption/flow conditions. Flushing devices should by sized to provide flows that have a velocity of at least 0.8 m/s in the watermain being flushed. No flushing device should be directly connected to any sewer.

The Designer *s*hould take into account operational procedures such as unidirectional flushing and watermain swabbing when designing looped watermain systems. In watermain loops, unidirectional flushing (strategic valve closing to direct flow to promote flushing velocity) may be required to produce the required flushing velocity. Valve placement to promote unidirectional flushing velocities should be considered in the design stage.

Swabbing should be considered for rural long-distance low-flow pipelines where it is not practical to obtain adequate cleaning with flushing alone. Swabbing is an effective method used to clean the interior surface of watermains. For small diameter mains without hydrants, swab launching and retrieval ports should be included in the design. Valve specifications also need to be considered. Butterfly valves cannot be used as they will trap the swab.

16.3.8 Fire Protection

When fire protection is to be provided, fire flow and system design should consider local bylaw requirements and the latest edition of the Fire Underwriters survey *Water Supply for Public Fire Protection* (also see *AWWA Manual M31 Distribution for Fire Protection*, 1998. ISBN 0-89867-935-4).

16.3.9 Crossing Obstacles

Due to physical constraints along the watermain alignment, there may be a variety of obstacles that will affect the design of the watermain. Considerations include, but are not limited to, the following:

16.3.9.1 Road Crossings

It is recommended for all new watermains crossing existing roads, and all new roads crossing existing watermains, that:

- .1 The minimum cover from the top of the pipe is determined based on regional frost depth, municipal by-laws, internal pressure, deflection, external loading and buoyancy;
- .2 Backfill methods and materials are approved;
- .3 The watermain is properly bedded to ensure structural support of the pipe;
- .4 Drainage is adequate; and
- .5 Ditches crossing watermains should provide minimum cover of 1.0 m or the watermain should be insulated for frost protection and the regional frost depth and municipal by-laws should be reviewed. Refer to Section 16.6.2.2 – Stormwater Ditch Crossings for additional information.

The Ministry of Transportation and Infrastructure (MOTI) should be contacted for design standards and permitting for MOTI-owned roads.

16.3.9.2 Railway Crossing

When a watermain is crossing under a railway, the railway owner should be contacted as design standards and permitting can be owner-dependent. Reference can be made to Transport Canada's *Standards Respecting Pipeline Crossings Under Railways*.

16.3.9.3 Surface Water Crossings

Surface water crossings, whether above or underwater, and areas subject to flooding, require special consideration and approval.

16.3.9.4 Above Water Crossings

For above water crossings, the pipe should be adequately supported and anchored, protected from damage, vandalism and freezing, and accessible for repair or replacement.

16.3.9.5 Underwater Crossings

For underwater crossings, a minimum ground cover of 1500 mm should be provided over the pipe. Consideration should be given to the potential for the stream bottom to change because of scour or dredging. When crossing watercourses which are greater than 5 m in width, the following should be provided:

- .1 The watermain should be of special construction, having flexible, restrained or welded watertight joints; or, the watermain should be placed in a casing/sleeve pipe which is approved for potable water use, and has the same or greater pressure rating as the watermain;
- .2 Valves should be provided at both ends of the water crossing so that the section can be isolated for testing or repair; the valves should be easily accessible, not subject to flooding and should be within a properly constructed chamber; and
- .3 A method for sampling or monitoring of leakage on either side of the isolation valves to allow insertion of a small meter to determine leakage and for sampling purposes.

16.3.10 Location of Pipes in Geologically Vulnerable Areas

Earthquakes and landslides have caused watermains to fail, leading to depressurization of distribution systems, boil water advisories, and significant service. Although transitory seismic waves and strong ground shaking can cause some buried pipelines to fail, buried pipelines are at most risk when they are subjected to permanent ground displacements. The most common causes of permanent ground displacement are:

- .1 Liquefaction and lateral spread;
- .2 Landslide;
- .3 Settlement;
- .4 Fault rupture; and
- .5 Subsidence or uplift.

Designers should prioritize making transmission and distribution systems that serve water for essential services earthquake-resilient, so that these pipelines remain functional after seismic events. Essential services include medical facilities; power plants; fuel refining, storage, and distribution facilities; food production, storage, and distribution facilities; emergency response command and communication centers; firefighting; and emergency shelters.

Designers can reduce or mitigate seismic risk by:

.1 Identifying where pipeline alignments cross through regions of potential permanent ground displacement or strong ground shaking intensity;
.2 Designing to seismic values listed in the NBC;
.3 Using seismic-resistant pipe systems that can accommodate expected permanent ground displacements and strong ground shaking;
.4 Making ground improvements where possible;
.5 Using flexible couplings that permit differential movement when pipelines attached to structures, such as tanks and vaults, move differentially with respect to the ground;
.6 Providing adequate support and bracing to structures that support above-ground pipelines;
.7 Installing redundant facilities and/or looped piping;
.8 Using appropriate valving to isolate vulnerable areas;
.9 Installing pipe within a reinforced pipe tunnel; and
.10 Encasing with polyethylene.

Some pipes, such as butt-fused HDPE (*AWWA 2015a*), molecularly oriented PVC (*AWWA 2009b*), and seismic joint ductile iron pipe, are much less prone to failure in earthquakes and landslides (Water Supply Forum 2015). The Designer can also consider using specialized, flexible expansion joints that can accommodate significant ground motion, especially near where watermains enter structures such as reservoirs and booster pump stations.

In areas with the potential for permanent ground displacement or strong ground shaking, the Designer should seek the services of a qualified Geotechnical Engineer or other Qualified Professional to assist in material selection and addressing other seismic design aspects.

16.3.11 Materials

16.3.11.1 Standards and Materials Selection

All materials used in the construction and operation of drinking water systems including pipe, fittings, valves and fire hydrants, and materials used for the rehabilitation of watermains should conform to the latest standards issued by the CSA, AWWA, ASTM, NSF/ANSI, or NFPA.

Special attention should be given to selecting pipe materials which will protect against both internal and external corrosion.

In selecting pipe material, the Designer should consider the following factors:

.1 Proven performance of the material;
.2 Working pressure rating;
.3 Trench foundation conditions;
.4 Location and other site-specific factors;
.5 Internal and external corrosion resistance;
.6 Soil conditions:
    a. Chemical composition and its effects on pipe material;
    b. Corrosivity (need for cathodic protection);

   c. Ability to provide thrust restraint;
- .7 Drinking water corrosivity;
- .8 Water temperature variations;
- .9 Behavior of the pipe material in case of transient pressures and catastrophic failure;
- .10 Costs (capital, operating, maintenance and other costs);
- .11 Available labour skills; and
- .12 Availability of suitable fittings and appurtenances acceptable to/or recommended by the pipe manufacturer, as well as spare parts and/or repair pieces.

When non-metallic pipes are selected, the Designer should consider the use of pipe tracers (such as tracer wire) for locating purposes.

16.3.11.2 External Corrosion Prevention/Reduction

External corrosion prevention and reduction should be considered for watermain installations. External corrosion prevention can include protecting watermains and fittings by encasement, such as wraps and coatings, and/or cathodic protection. Protection against galvanic corrosion should be considered when pipes and apparatuses of differing materials are connected.

The design and installation of watermain encasement and cathodic protection should be per the manufacturer's recommendations and as determined by a qualified professional in the field of corrosion protection.

Watermains are especially susceptible to corrosion in the following installations:

- .1 If soils are found to be aggressive, and the choice of materials is limited and subject to corrosion;
- .2 Across a bridge crossing in salt water (coastal) environments or other harsh environments;
- .3 In colder locations where salt is used to de-ice roads; and
- .4 Near or crossing a light railway, and/or major oil or natural gas pipelines protected by impressed current.

For further information on external corrosion control guidance, refer to *AWWA's M27 – External Corrosion Control for Infrastructure Sustainability*.

For guidance on optimizing water quality to minimize corrosion, refer to Chapter 12 – Internal Corrosion Control.

16.3.11.3 Permeation by Organic Compounds

When distribution systems are installed in areas where groundwater and/or soils are contaminated with lower molecular weight organic solvents (such as toluene and benzene) or petroleum products, materials which do not allow permeation of the organic compounds should be used for all portions of the system, including pipe, joint materials, O-rings, gaskets, hydrant leads and service connections.

Certain pipe materials - especially polyvinyl chloride (PVC), polyethylene (PE and HDPE), and polybutylene (PB) - are susceptible to permeation by these contaminants. Elastomeric gaskets made of ethylene propylene diene monomer (EPDM) used to join ductile iron pipe are susceptible to permeation as well. However, nitrile-butadiene rubber (NBR) is resistant to permeation by organic solvents and petroleum products, so ductile iron pipe with these types of gaskets should be used if potential permeation is an issue.

16.3.11.4 Re-Use of Materials

Watermains and appurtenances which have been used previously for conveying potable water may be reused, provided they comply with all applicable sections of Chapter 16 – Transmission and Distribution and have been restored practically to their original condition. Additional approval may be required.

16.3.11.5 Joints

The Designer should consider the following when designing joint systems for buried water piping:

- .1 Packing and jointing materials should meet the standards of the CSA/AWWA and the regulator.
- .2 Mechanical joints or plain end pipe in combination with couplings having slip-on joints with rubber gaskets is preferred.
- .3 Welded joints may be provided for carbon steel or stainless steel pipe systems.
- .4 Ductile iron should have push-on joint with gasket, conforming to the latest edition of *AWWA Standard C151 Ductile-Iron Pipe, Centrifugally Cast*.
- .5 PVC pipe should have push-on joint with gasket, conforming to the relevant *AWWA Standard C900* or *C905*.
- .6 High density polyethylene pipe should use flanged, electro-fusion or thermal butt fusion joints.
- .7 Lead-tip gaskets should not be used. Repairs to lead-joint pipe should be made using alternative methods.
- .8 Manufacturer approved transition joints should be used between dissimilar piping materials.
- .9 Flanged joints may be used in conjunction with fittings such as valves and/or bends where thrust restraint is needed.
- .10 Transition coupling should be provided to allow for vertical deflection at structures or where differential settlement of soils is expected to occur. Double joint articulating transition fittings may be needed for installations that could be subject to significant lateral or vertical deflection, as may be experienced under seismic loading.
- .11 Refer to Section 16.7.3 – Thrust Restraint for guidance on thrust restraint design considerations.

16.3.11.6 Pipe Strength

Distribution system piping must be selected to withstand operating and transient pressures, as discussed in Section 16.3.3 – System Pressures. Buried watermains are also subjected to external loads imposed by the trench backfill, frost loading and superimposed loads (static and/or dynamic). The watermain pipe selected for a particular application should be able to withstand, with a minimum safety factor of 2, all of the loading condition combinations to which it is likely to be exposed. Pipe strength designations and the methods for selecting the required pipe strength vary with the types of materials used.

The Designer should evaluate pipe supplier information and consult references such as CSA, AWWA and NSF/ANSI standards, and distribution design manuals.

16.4 Distribution System Components

16.4.1 Watermains

16.4.1.1 Transmission Mains

Transmission mains in water supply systems are typically large in diameter, carry large flows under high pressure and are long in length, therefore their designs should address:

.1 Sizing for ultimate future design flows;
.2 Sizing and layout to ensure adequate supply and turnover at water storage facilities;
.3 Elimination of customer service take-offs;
.4 Minimization of branch take-offs to help maintain flow and pressure control;
.5 Air relief at high points and drain lines at low points;
.6 Isolation valving to reduce the length of pipe required to be drained in a repair or maintenance shut down;
.7 Potential transient pressures;
.8 Master metering; and
.9 Climate change risk and vulnerability.

16.4.1.2 Primary Distribution Mains

Primary distribution mains typically receive flow from transmission mains or pressure control facilities (booster pumps or pressure reducing valves) and supply water to one or several local distribution mains as well as to customer services. Primary distribution mains provide a significant carrying capacity or flow capability to a large area.

For primary distribution mains, the Designer should consider:

.1 Implementing a minimum “dual” feed system of primary distribution mains to supply large distribution systems;
.2 Looping and isolation valving to maintain services with alternate routing in the event of repair or maintenance shut down;
.3 Area metering or individual service metering;
.4 Air relief at significant high points;
.5 Sizing for future extensions; and
.6 Elimination of dead ends.

16.4.1.3 Local Distribution Mains

Local distribution mains typically provide water service to customers through a network of pipelines fed by the primary distribution mains. For local distribution mains, the Designer should consider:

.1 Looping and isolation valving to maintain service with alternate routing in the event of repair or maintenance shut down;
.2 Adequate valving to provide an efficient flushing program;
.3 Elimination of dead ends; and
.4 Pressure surge relief (requirements can be addressed by storage in the distribution system or other acceptable means).

16.4.2 Valves

The Designer should consult with the owner of the system with respect to valve locations at intersections, line valve spacing, types of valves permitted, direction of rotation to open and the maximum size of valve permitted in a valve box.

16.4.2.1 Valve Placement

A sufficient number of valves should be provided on watermains to minimize inconvenience and contamination during repairs. Valves should be located at not more than 150 m intervals in commercial and industrial districts and at not more than one block or 240 m intervals in other districts. Where systems serve rural areas and where future development is not expected, valve spacing should not exceed 2 km.

In distribution system grid patterns, to minimize disruption during repairs, intersecting watermains should be equipped with shut-off valves as indicated in Table 16-3.

Table 16-3 Shut-Off Valves in Distribution System Grid Patterns

Type of Intersection	Number of Valves
"T" intersection	At least 2
Cross intersection	At least 3

16.4.2.2 Valve Standards

There are many different types of valves available and the Designer *s*hould consider the specific application during valve selection. As a minimum, manufacturer recommendations regarding appropriate valves for an application should be considered, with confirmation from the manufacturer that the valves conform to relevant AWWA standards. The Designer *s*hould ensure that open/close directions are consistent throughout the water supply system and meet the requirements of the water supply system owner.

For large diameter water supply or pressure zone isolation valves (400 mm diameter or larger), consideration should be given to providing valved reduced-size bypass piping that can be used to avoid local stagnation and assist with open/close operations. Bypass sizing can be determined according to *AWWA C-500 Metal-Seated Gate Valves for Water Supply Service*.

Valves 300 mm in diameter or less may have access provided to the operating nut via a valve box and stem assembly, but it is recommended that all valves larger than 300 mm in diameter be placed in valve chambers. All air release valves and drain valves should also be located in chambers. To minimize the number of chambers required, combinations of valves can be located within a single chamber.

16.4.2.3 Air Release & Vacuum Relief Valves

Air release/vacuum relief valves should be provided at high points in distribution and transmission lines (relative to the hydraulic gradient) where air can accumulate. The valves should conform to *AWWA Standard C512 Air Release, Air/Vacuum, and Combination Air Valves for Water and Wastewater Service*. Automatic air release valves should not be used in situations where flooding of the access chamber may occur unless equipped with an inflow preventer conforming to *ANSI/AWWA Standard C514 Air Valve and Vent Inflow Preventer Assemblies for Potable Water Distribution System and Storage Facilities*. Where the need for an automatic air release valve is uncertain, a manual air release valve or hydrant can be installed initially and later replaced with an automatic valve if significant air accumulation is found.

The open end of an air release pipe from manually operated valves should be extended to the top of the chamber and provided with a screened downward-facing elbow if drainage is provided for the chamber.

The open end of an air release pipe from automatic valves should be:

- extended to at least 300 mm above grade and provided with a screened downward-facing elbow to ensure it cannot be flooded or blocked, or
- equipped with an inflow preventer conforming to the ANSI/AWWA C514 Standard.

The Designer should ensure the distribution system is protected from backflow contamination through the intended operation of the vacuum relief or combination vacuum/air relief valve. The design should not provide a pathway for distribution system contamination; for example, through backsiphonage from an air-vacuum relief valve with a vent located inside an undrained pit or from a pump house drain.

Discharge piping from air relief valves should not connect directly to any storm drain, storm sewer or sanitary sewer. Vents should be equipped with an appropriate air gap above the highest possible water level. Proper drainage away from the vent outlets is necessary.

16.4.2.4 Drain Valves

With large diameter mains, drain valves positioned at low points may be required to permit main repairs. Small diameter watermains can generally be drained through hydrants by using compressed air and/or by pumping. It is recommended that drain valves are also flood proofed and not connected to storm drain or ditch, or storm sewer or sanitary sewer.

16.4.3 Water Quality Monitoring Stations

The Designer should consider the provision of dedicated sampling stations within the distribution system to facilitate water quality monitoring. When selecting sampling site locations, the Designer should target locations with representative conditions including challenging conditions within the system such as increased hydraulic retention times, dead-ended mains, temperature variations, and materials of construction etc.

The following sampling station features are recommended:

.1 Use of distribution piping, not household plumbing;
.2 The sampling station should be located in a space that:
   1. The water supplier controls or owns;
   2. Is safely accessible for the water sampler; and
   3. Promotes drainage to allow for adequate flushing before sampling;

.3 The length of the connection from the sampling station to the watermain should be as short as possible;
.4 A dedicated standpipe with a smooth-nosed sample tap is preferable; and
.5 The sample tap should be in a lockable enclosure and be otherwise protected from the weather and tampering.

16.4.4 Kiosks and Chambers for Valves, Meters and Blow-offs

16.4.4.1 Location and Drainage of Chambers

Kiosks, chambers, or access points containing valves, blow-offs, meters or other such appurtenances to a distribution system should be designed to reduce or eliminate confined spaces and not be located in areas subject to flooding or in areas of high groundwater. Where such locations are unavoidable, measures should be taken to prevent infiltration of surface water or groundwater.

Chambers should be drained, if possible, to the surface of the ground where they are not subject to flooding by surface water, or to underground absorption pits. Drains should be equipped with a backflow prevention device and screening to prevent the entry of insects, birds, and rodents.

16.4.4.2 Kiosk and Chamber Construction

Kiosk and chambers for air relief and vacuum valves, flow monitoring/measuring devices and pressure reducing valves should:

.1 Provide a durable, watertight structure with easy and safe access;
.2 Include watertight gaskets where a pipe passes through a chamber wall: flexible rubber "A-Lok" type for cast-in-place concrete or mechanical expansion insert type for pre-cast concrete;
.3 Be protected against freezing and frost heave;
.4 Include gravity or pump drainage;
.5 Be lockable to avoid safety and vandalism concerns; and
.6 Not connect directly to any storm or sanitary sewer.

The Designer *s*hould consider venting and drain appurtenances between line valves to eliminate air locks during watermain disinfection procedures and watermain restoration procedures.

16.4.4.3 Pressure Reducing Valve Stations

Pressure reducing valve stations should be designed and constructed to provide:

.1 By-pass capability;
.2 Isolation valves on the upstream and downstream piping for the pressure reducing valve;
.3 Above ground if possible to prevent confined space entry requirements; and
.4 Upstream and downstream pressure gauges.

16.4.5 Hydrants

All fire hydrants should be of the "self-draining" dry-barrel type and should conform to the latest edition of *AWWA Standard C502: Dry-Barrel Fire Hydrants*. Designers should coordinate with the local bylaw requirements for acceptable products when designing and selecting water hydrants and ensure all components are lead free. Watermains that are not designed to carry fire flows should not have fire hydrants installed.

All fire hydrants should be provided with adequate thrust blocking to prevent movement caused by thrust forces.

16.4.5.1 Location and Spacing

Fire hydrants should be provided at each street intersection, in the middle of long blocks and at the end of long dead-end streets. The required hydrant spacing decreases as the fire flow requirement increases. Hydrants should, therefore, be placed much closer together in high risk, high density areas than in low density residential areas. The maximum lineal spacing between hydrants should be 300 m for rural areas, 50 m for single family land use zones and 100 m for multi-family and commercial zones, unless otherwise specified by municipal bylaw or Water Supplier design standards.

For more detailed information on hydrant spacing, the Designer should refer to *Water Supply for Public Fire Protection* by the Fire Underwriters Survey and the Owner for municipal requirements.

16.4.5.2 Valves and Nozzles

Fire hydrants should have a bottom valve size of at least 125 mm, one 113 mm pumper outlet and two 63 mm outlets.

Outlet and nozzle sizes should be standardized throughout the water distribution system. Specific requirements should be coordinated with the local Fire Authority.

16.4.5.3 Hydrant Leads

The hydrant lead should be a minimum of 150 mm in diameter. Auxiliary valves should be installed on all hydrant leads to allow for hydrant maintenance and repair with a minimum of disruption.

16.4.5.4 Drainage

In areas where the water table will rise above the hydrant drain ports, the drain ports should be plugged. The barrels should be kept dry to prevent water contamination and freezing from damaging the barrel. Where hydrant drains are not plugged, they should drain to the ground if soil conditions allow, or to a dry well/drainage pit provided for that purpose. Hydrant drains should not be connected to or located within 3 m of sanitary sewers or storm drains.

16.4.6 Services and Associated Plumbing

16.4.6.1 Plumbing

Water services and plumbing should conform to relevant local bylaws, *BC Plumbing Code*, or to the applicable *National Plumbing Code*. Solders and flux should be lead free.

16.4.6.2 Consumer Connections (Laterals and Curb-Stops)

In selecting the diameter of a service connection, the Designer *s*hould consider the following factors:

- .1 Peak water consumption in the building serviced;
- .2 Total length of service line from the watermain to the building connection;
- .3 Watermain pressure under peak demand conditions;
- .4 Loss of head resulting from length and condition of pipe, fittings, and backflows preventers and meters;
- .5 Maximum velocity of flow should not exceed 4.5 m/s, the Designer *s*hould confirm the maximum velocity does not exceed that of the valves, fittings and pipe;
- .6 A stop and drain curb stop should not be used if the groundwater table is high as it could

create a cross connection; and

.7 There should be no joints between the curb stop and the building, if possible.

The recommended minimum size of service line for single-family residences is 19 mm. Larger residences and buildings located far from the watermain connection should have a 25 mm or larger service. Considerations should also be made for the anticipated water demand of the property when sizing the service line, such as the use of automatic sprinklers. For details on proper water sizing of service lines, refer to a publication such as *AWWA Manual of Water Supply Practices M22 – Sizing Water Service Lines and Meters*.

The Designer should consider the provision of two services with an isolation valve between the connections to help ensure redundancy to sensitive users (such as hospitals, long-term care facilities, etc.) in the event of a service line failure.

Water service lines should be constructed of materials conforming to *AWWA Standard C800: Underground Service Line Valves and Fittings*. Municipalities should be consulted regarding local preferences and requirements.

All water services should be equipped with a corporation stop and a curb stop. The curb stop should be provided with a curb box. Backflow prevention devices should be installed on service connections where there is a high risk of contamination to the potable supply system resulting from backflow or back pressure. The Water Supplier should be consulted to determine specific cross connection control program requirements.

All consumer connections should be a minimum separation distance of 3 m from outdoor fuel tanks.

16.4.6.3 Booster Pumps

Refer to Chapter 18 – Pumping Facilities.

16.4.6.4 Service Meters

Consideration for service metering with an approved metering device should be made based on the Water Supplier’s billing and data collection needs.

16.4.7 Bulk Fill Stations

Water loading stations and temporary water services should be protected against potential backflow, which may allow contamination to enter the distribution system, in accordance with the requirements of *CAN/CSA-B64.10-01/B64.10.1-01 Manual for the Selection and Installation of Backflow Prevention Devices/Manual for the Maintenance and Field Testing of Backflow Prevention Devices*.

Bulk water loading stations present unique challenges since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following principles should be met in the design of bulk water loading stations:

.1 Vessels and water hauling equipment should be equipped with an air gap or reduced pressure type backflow preventer in accordance with *CAN/CSA-B64.10/B64.10.1.*

.2 The piping arrangement should prevent contaminants being transferred from a hauling vessel to another subsequently using the station, and:

.1 Hoses should not be contaminated by contact with the ground;
.2 A loading station should be designed to provide access only to authorized personnel; and
.3 Access to a loading station should be strictly controlled to minimize water safety and security concerns.

16.5 Cross Connections and Backflow Prevention

16.5.1 Cross Connections

Precautions should be taken in the design of water distribution and plumbing systems to prevent the entrance of contaminants into the drinking water system. All Water Suppliers should have a cross connection control program.

Contaminants can enter water supply systems from various sources including cooling water systems, pump seal water systems, industrial process piping and groundwater. Steam condensate, cooling water from engine jackets or water used in conjunction with heat exchange devices should not be returned to the drinking water supply.

Deterioration can also occur from entry into the system of untreated water due to watermain de-pressurization conditions allowing contamination through vents or other appurtenances.

To control contamination from non potable piped systems, cross connection control/backflow prevention measures and/or equipment are necessary.

For information on cross connection control, the Designer should refer to the *CSA Standards B64.10/B64.10.1*, and the *BC Plumbing Code*. If further resources are required, the *AWWA Manual of Water Supply Practices M14 – Backflow Prevention and Cross-Connection Control Recommended Practices* and *USEPA Cross-Connection Control Manual*, 2003 can be referenced.

16.5.2 Backflow Prevention

Backflow preventers should be installed at any location where a connection is made to a drinking water system. Backflow preventers should be installed per the latest edition of the *Cross-Connection Control Manual* published by AWWA (Western Canada Section).

There are several types of backflow prevention devices available including air gaps, double check valve assemblies, reduced pressure principle devices, dual check valves, atmospheric vacuum breakers and pressure vacuum breakers. For applications involving health hazards, only air gaps or reduced pressure principle devices should be used.

For information on backflow prevention equipment, the Designer should refer to:

.1 Applicable municipal by-laws;
.2 Canadian Standards Association (CSA) standards:
  - *CAN/CSA-B64 SERIES-01 Backflow Preventers and Vacuum Breakers*;
  - *CAN/CSA-B64.10/B64.10.1 Manual for the Selection and Installation of Backflow*

   - *Prevention Devices/Manual for the Maintenance and Field Testing of Backflow Prevention Devices*; and
   - B64.10S1-04/B64.10.1S1-Supplement #1 to CAN/CSA-B64.10-01/CAN/CSA-B64.10.1-01;

.3 BC Plumbing Code;

.4 AWWA Standards :
   - *C510: Double Check Valve Backflow Prevention Assembly*; and
   - *C511: Reduced-Pressure Principle Backflow Prevention Assembly*; and

.5 *AWWA Manual of Water Supply Practices M14 – Backflow Prevention and Cross-Connection Control Recommended Practices*.

16.6 Separation Distances

This section describes good engineering and construction practice to reduce the potential for contaminated water to enter the distribution system. Contaminated ground and surface water may enter the water distribution system at leaks or breaks in components such as piping, vacuum air release valves, blow-offs, fire hydrants, meter sets, and outlets during negative internal or positive external pressure conditions. Water pressure in part of the system may be reduced to a potentially hazardous level due to shutdowns in the system, main breaks, heavy fire demand, high water usage, pumping, storage or transmission deficiency and negative surge pressures.

The relative location of sewers (including stormwater and sanitary sewers/force mains) and watermains (including appurtenances) and types of material used for each system are important considerations in designing a system to minimize the possibility of contaminants entering the water distribution system. The use of and adherence to good engineering practice will reduce the potential for health hazards.

The Designer should consider the following for adequate separation:

.1 Water and sewer pipe materials, type of joints and pipe identification;
.2 Soil conditions (e.g. in-situ soil and backfilling materials, and compaction techniques);
.3 Additional structural support for pipes;
.4 Service and branch connections into the watermain and sewer line;
.5 Compensating variations in horizontal and vertical separations;
.6 Space for water and sewer pipe repair and alterations;
.7 Pipe off-set around manholes;
.8 Location of the groundwater table and trench drainage techniques; and
.9 Other sanitary facilities such as septic tanks and tile fields.

The Designer should demonstrate reasonable efforts to conform with the separation distances recommended in this section, and should consult with the Issuing Official early in the design process. In exceptional cases, reduced separation distance may be allowed with additional protective measures, as decided on a case-by-case basis.

For the purposes of this section,

.1 Sanitary sewer is defined as 'a gravity pipe carrying untreated wastewater';
.2 Force main is defined as 'a pipeline that conveys wastewater under pressure from the discharge side of a pump to a discharge point';
.3 Stormwater sewer is defined as 'a gravity pipe, natural ditch or roadside ditch (including

highway and driveway culverts if connected to ditch) carrying surface water runoff to a point of discharge'; and

.4 Stormwater management systems are defined as 'management systems for capture, diversion and/or treatment of stormwater runoff' and can include basins, tanks, filters, infiltrators, storm drains, vortex separators, seepage manholes and swales, among other options.

16.6.1 Parallel Installation

16.6.1.1 General Parallel Installation Guidelines

New watermains and raw water supply lines should be laid in separate trenches with at least 3 m horizontally, measured edge to edge, and at least 450 mm vertically above, any parallel pipeline conveying:

.1 Untreated or treated wastewater (sanitary sewer and force mains);
.2 Hazardous fluids such as petroleum products, industrial wastes, and wastewater sludge;
.3 Stormwater sewers; and
.4 Non-potable water ("purple pipe").

Exceptions to these guidelines may be considered only where unusual conditions are present (e.g. bedrock, existing utility congestion, archaeological sites), and where the Designer can demonstrate that all reasonable efforts have been made to avoid the conflict. In these scenarios, consult with the Issuing Official to determine appropriate protective measures.

Examples of situations for parallel construction with gravity sewers are outlined in Table 16-4, with recommended protective measures in Table 16-5. The following definitions apply:

.1 D_{wm} = diameter of watermain;
.2 Horizontal separation = horizontal distance measured from edge-to-edge of pipes;
.3 Vertical separation (V) = Elevation of bottom of watermain minus the elevation of the crown of the parallel pipe. Refer to Figure 16-1; and
.4 Any overlap ($V < 0$) may require protective measures to block any leaked contamination.

Note that:

.1 Horizontal separation of < 1 m is not typically accepted; and
.2 Vertical separation of $< -D_{wm}$ (watermain crown below crown of parallel pipe) is not typically accepted when horizontal separation is < 3 m, and is otherwise discouraged where avoidable.

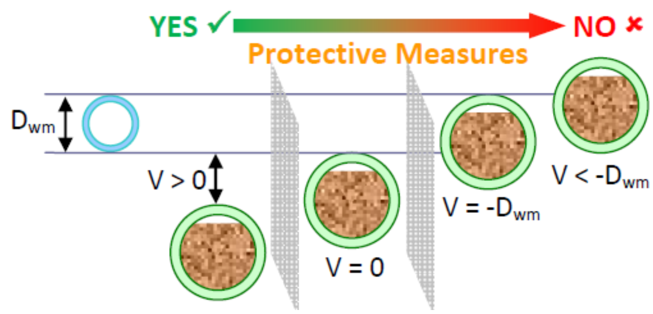
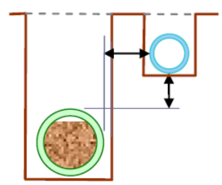
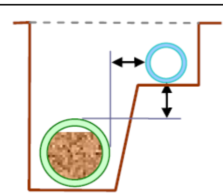
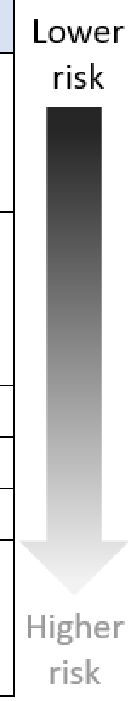


Figure 16-1 Vertical separation of watermain (blue pipe) and parallel pipe (green filled pipe). A continuous hydraulic barrier (grey plane) is shown for different vertical separations between pipes.

Table 16-4 Parallel Installation Configurations for Gravity Sewers

Configuration		**Horizontal separation**	**Vertical separation**	**Scenario for Table 16-5**
Separate trenches (separately dug trenches in undisturbed soil with granular bedding around pipes)		> 3 m	> 450 mm	None, unless site-specific risks present (e.g. high water table)
		> 3 m	< 450 mm Vertical separation < - D_{wm} discouraged where avoidable	None, unless site-specific risks present (e.g. high water table)
		1 to 3 m	> 450 mm	B
		1 to 3 m	- D_{wm} to +450 mm	A, B
Common trench (watermain sits on bench of undisturbed soil)		> 1 m	> 450 mm	B
		> 1 m	0 to +450 mm	A, B



Recommended protective measures are shown in Table 16-5. Note that if the configuration falls into both Scenario A and B, at least one protective measure from both scenarios should be implemented. A specific protective measure (or combination of measures) from Table 16-5 may be required depending on site conditions and specific risks (e.g. soil types, high water table).

Table 16-5 Recommended Protective Measures

Scenario	Recommended Protective Measures
A (inadequate vertical separation when horizontal separation is <3 m)	• Continuous hydraulic barrier (e.g. clay soil, geomembrane) or equivalent between pipes (see Figure 16-1), or • Place water pipe, or parallel pipe, or both, in sleeve or casing pipe with watertight end seals. Casing pipe should be installed in accordance with best practices, including provisions for securing the pipe with spacers, skids or equivalent to protect pipe from movement and provide ease of removal for repair. Casing pipe must be a material that is approved for use as watermain and must be of the same or greater pressure rating as the water line. Isolation valves should also be included, as well as corrosion protection if necessary.
B (inadequate horizontal separation and/or pipes in same trench)	• Increase the pipe strength of watermain, or parallel pipe, or both by a class, or • Wrap watermain joints with heat shrink plastic, or pack watermain joints with compound and wrap with petrolatum tape by qualified installers in accordance with the latest version of *AWWA C217*, and *AWWA C214* or *AWWA C209*,* or • Use jointless pipe (e.g. solid pipe, welded joints, HDPE pipe with fusion-welded joints) for the watermain, parallel pipe, or both.

* It should be noted that the relevant AWWA standards define tapes/coatings in terms of their ability to protect pipes against corrosion. Third party testing against infiltration of waterborne pathogens has not been established for these products, and the use of joint wrapping/packing as a protective measure is at the discretion of the Issuing Official.

16.6.1.2 Force Mains

Due to the increased health risk posed by leakage of force mains and the potential spread of pressurized sewer main breaches, reducing separation distance from watermains is not recommended. Force mains should be positioned with no less than 3 m horizontal separation to watermains. Where watermains and force mains cross, the watermain should be at least 450 mm above the force main (see Section 16.6.2).

16.6.1.3 Bedrock Trenching

Achieving separation distances for parallel piping may be difficult in cases of natural geographical obstacles (i.e. bedrock for trenching or blasting). Reduced separation distance may be allowed with additional protective measures on a case-by-case basis. The Designer should refer to Table 16-5 for protective measures.

In all rock trenches, drainage should be provided to minimize the effects of impounding of surface water and/or the leakage from sewers in the trench.

16.6.1.4 Sewer Manholes, Inlets, and Structures

A watermain should not pass through or come into contact with any part of a sanitary or stormwater sewer manhole, inlet or structure (including stormwater management systems). Watermains should be located at least 3 m horizontally from sewer manholes, inlets and structures.

Where the normal separation distances are not possible, the bottom portion of manholes, manhole connections to sewers, service connections to sewers and joints in sewage service connections should be designed not to leak and confirmed via testing (e.g. hydrostatic tests). If the horizontal separation is less than 3 m, the Designer may need to assess if thermal protection of the watermain is required (e.g. if manhole extends below frost line). Horizontal separation less than 1 m is not recommended.

16.6.1.5 Stormwater Conveyance and Treatment

Stormwater sewers, including stormwater piping and natural ditches, should be considered equivalent to sanitary sewers for parallel separation: 3 m horizontal separation should be maintained from watermains. For natural ditches, horizontal separation may be measured from the bottom of the ditch.

Watermains should also maintain 3 m separation from stormwater management systems. Where a local government has implemented an Integrated Stormwater Management Plan or included stormwater management as part of a Liquid Waste Management Plan, reduced separation distance between green rainwater infrastructure and watermains may be proposed. Protective measures from Table 16-5 may be required.

Watermains should not be installed directly in stormwater ditches or under ditch bottoms; this is also in accordance with the Ministry of Transportation *Utility Policy Manual* (2019) specifications for water and sewer line installations (18.3.2(b)(v)).

16.6.1.6 Tunnel Construction

If a tunnel is of sufficient size to permit a person to enter it, a sewer and watermain may be placed in the tunnel provided the watermain is hung above the sewer. If the tunnel is sized only for the pipes or is subject to flooding, then the installation is only acceptable if both watermain and sewer are sleeved with appropriate pipe casing. Sleeves should extend until the watermain and parallel pipe achieve acceptable horizontal separation outside of the tunnel and should be sealed to the pipes at either end.

16.6.2 Sewer and Stormwater Crossings

16.6.2.1 General Pipe Crossing Guidelines

Where a watermain crosses sanitary or stormwater sewer piping, the watermain should be laid a minimum vertical distance of 450 mm above the sewer, measured between the outside of the watermain and the outside of the sewer. The length of water pipe should be centered at the point of crossing so that joints in the watermain will be equidistant and as far as possible from the sewer, crossing perpendicular if possible.

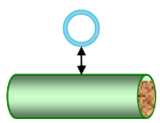
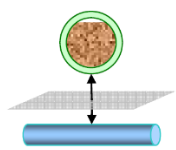
Exceptions to these guidelines will be considered only where unusual conditions are present (e.g. bedrock, existing utility congestion, archaeological sites), and where the Designer can demonstrate that all reasonable efforts have been made to avoid the conflict. In these scenarios, consult with the Issuing Official to determine appropriate protective measures.

Note that:

- .1 Watermains should cross above sewer pipes whenever possible;
- .2 Vertical separation of less than 150 mm is not typically accepted;
- .3 Force mains should not cross above watermains; and
- .4 Watermains should be at least 450 mm above force mains at crossings.

Examples of crossing installation situations for gravity sewers are outlined in Table 16-6.

Table 16-6 Crossing Installation Configurations for Gravity Sewers

Configuration		Vertical Separation	Pipe Joints Requiring Protection	Additional Bedding Structural Support	Additional Notes
Watermain above sewer pipe		> 450 mm	None	No	None
		150 to 450 mm	Watermain joints	Yes	None
Watermain below sewer pipe		> 450 mm	Both watermain and sewer joints	No	**Hydraulic barrier should be installed in trench between sewer and watermain[1]**
		150 to 450 mm	Both watermain and sewer joints	Yes	

1. Continuous hydraulic barrier (e.g. clay soil, geomembrane or equivalent) should extend no less than 300 mm beyond outer edge of watermain on both sides, such that the trench bedding width is protected.

As noted in Table 16-6, additional bedding structural support may be required when vertical separation is between 150 – 450 mm, in order to protect the watermain and sewer from excessive deflection of joints, settling, or breaking.

Protective measures should be applied for all joints within 3 m distance, measured normal (perpendicular) to the opposite pipe (refer to Figure 16-2). Specific protective measure (or combination of measures) from the list below may be required depending on site-specific conditions and risks. Example protective measures for pipe joints are as follows:

.1 Wrap watermain (and sewer, when required) joints with heat shrink plastic or pack watermain joints with compound and wrap with petrolatum tape in accordance with the latest version of *AWWA C217*, and *AWWA C214* or *AWWA C209*. For existing sewers, the distance for protective measures may be reduced to 1.5 m from the new watermain to avoid excessive excavation (see Figure 16-2);
.2 Construct gravity sewer of higher-class pressure pipe (equivalent to watermain) or reinforced concrete pipe using flexible gaskets. Pipe should be pressure and leakage tested manhole-to-manhole in accordance with manufacturer recommendations;
.3 Encase either watermain or sewer inside casing pipe sleeve with watertight end seals. The casing pipe must be a material that is approved for use as watermain;
.4 Use jointless pipe (e.g. solid pipe, welded joints, HDPE pipe with fusion-welded joints) for watermain, or parallel pipe, or both; and
.5 Use mechanically restrained joints.

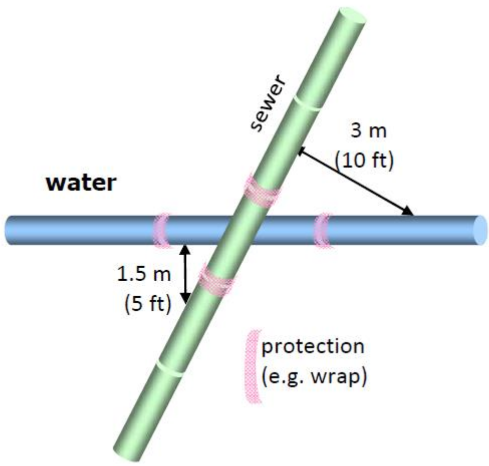


Figure 16-2 Joint wrapping at a crossing of a new watermain (all joints within 3 m perpendicularly from sewer) and an existing sewer (all joints within 1.5 m perpendicularly from watermain).

16.6.2.2 Stormwater Ditch Crossing

For natural or road ditches, 1 m depth of cover is required between the ditch bottom and the watermain, in accordance with the Ministry of Transportation *Utility Policy Manual* (2019) specifications for water and sewer line installations (Table 17-1). If less than 1.0 m depth of cover is provided, the watermain should be insulated for frost protection.

Joint protection and risk mitigation are required for watermains installed below stormwater ditches:

- .1 The length of water pipe should be centered at the point of crossing so that joints in the watermain will be equidistant and as far as possible from the ditch, crossing perpendicular if possible;
- .2 A hydraulic barrier should be installed in the trench between the ditch and watermain; and
- .3 Watermain joints should be protected as described above and in Figure 16-2.

16.6.2.3 Unacceptable Installations

No water pipe should pass through or come in contact with any part of a sewer access/maintenance hole, septic tank, tile field, subsoil treatment system or other source of contamination.

Concrete encasement of sewer or stormwater piping (per 2019 MMCD Vol II *Standard Detail Drawing G6* and as specified in Section 31 23 01) is not recommended for watermain crossing. While the intent is to provide structural support and hydraulic seal, differential soil settlement often leads to stress and failure at pipe joints. A continuous hydraulic barrier (e.g. clay soil, geomembrane or equivalent) and joint protection as listed in Section 16.6.2.1 – General Pipe Crossing Guidelines should be provided instead.

16.6.3 Other Sources of Contamination

Designers should exercise caution when locating watermains at or near certain sites such as sewage treatment plants, industrial complexes, or near water treatment backwash ponds. Minimum horizontal separation distances should be maintained from on-site sewage disposal systems as specified in the *Sewerage System Standard Practice Manual Version 3*:

.1 3 m from dispersal systems, watertight treatment or pump tanks;
   a. May be reduced to 1 m separation if the watermain is sleeved with a suitable continuous pipe, extending to the minimum standard setback distance and sealed to the watermain pipe at each end. No joints for the sleeving pipe (other than fusion welded joints) are to be used within the setback distance. The sleeving pipe is to be of the same or greater pressure rating as the water line; and

.2 7.5 m from BC zero discharge lagoons, regardless of use of pipe sleeving.

New watermains should not be installed within 30 m of the nearest edge of any sanitary landfill or hazardous waste disposal site, within 10 m of any underground hazardous material storage tank, sewage lift station, groundwater recharge project site, or within 7.5 m of municipal wastewater drain fields.

The Designer should establish specific design requirements for locating watermains near any source of contamination and coordinate planned activities with the Issuing Official.

Separation requirements from property service lines (including sewer and stormwater laterals) should conform to BC Building Code and/or the *Design Guidelines for Rural Residential Community Water Systems* (former Ministry of Forests, Lands, Natural Resource Operations & Rural Development).

16.6.4 Utilities

A minimum horizontal separation of 1.0 m should be maintained between watermains and utilities, including electrical conduits, gas mains, and telephone conduits. Bylaws, local engineering specifications, or authorities having jurisdiction may require larger setbacks, especially for deep excavations with wide trenches.

16.7 Installation

16.7.1 Bedding

Continuous and uniform bedding should be provided in the trench for all buried pipe. Pipe and fittings should not be laid when the trench bottom is frozen, under water or when trench conditions or weather are unsuitable.

Granular bedding, pipe surround, backfill material and installation procedures should conform to 2019 MMCD Vol II specifications for waterworks (with the exception that concrete encasement for watermain crossing is not accepted, see Section 16.6.2.3 – Unacceptable Installations). At a minimum, backfill material should be tamped in layers not exceeding 150 to 250 mm around the pipe and to a sufficient height above the pipe to adequately support and protect the pipe. Large stones (75 mm or greater) found in the trench should be removed for a depth of at least 150 mm below the bottom of the pipe.

16.7.2 Cover

With the exception of those watermains which will be taken out of service and drained in winter, the minimum depth of cover over watermains and service connections, including that portion on private property, should be greater than the depth of frost penetration. On services, this depth should be measured to the goose neck when it is vertical. If, for economic or practical reasons, it is not possible to install watermains below the frost line, the design should ensure that the watermain will be unlikely to freeze by insulating around the pipe, and the watermain will not be damaged by heaving or increased trench loads caused by frost penetration. Applicable temperature loss calculations should be performed to ensure the water will not freeze. Large diameter watermains (over 300 mm) without service connections and that are not dead ends may be installed so that the frost-free depth corresponds with the springline of the pipe rather than the crown.

The increased external loads caused by frost may cause beam breaks in the pipe when bedding is non-uniform. For this reason, care should be taken in the selection of pipe materials, pipe classes, bedding types and the proper installation and compaction of the bedding to the springline.

16.7.3 Thrust Restraint

Adequate restraint should be provided in water distribution systems to prevent pipe movement and subsequent joint failure. In the case of non-restraining mechanical and/or slip-on joints, this restraint should be provided by adequately sized thrust blocks positioned at all plugs, caps, tees, line valves, reducers, wyes, hydrants and bends deflecting 22.5⁰ or more. Depending upon internal pressures, pipe sizes, pipe material and soil conditions, bends of lesser deflection may also require thrust blocking.

Calculations to determine the size of thrust blocks and valve support blocks should use the results of soil bearing capacity tests performance by a qualified professional, when such tests are available. In the absence of such test results, the standard soil bearing capacities listed in Table 16-7 may be used.

Table 16-7 Allowable Soil Bearing Capacity (Ontario Building Code)

Scenario	Maximum Allowable Bearing pressure, kPa
Dense or compact sand or gravel	150
Loose sand or gravel	50
Dense or compact silt	100
Stiff clay	150
Firm clay	75
Soft clay	40
Till	200
Clay shale	300
Sound *rock*	500

Thrust block material should resist deterioration from moisture or corrosive soil. Alternative approaches that can be used to prevent joint failure include:

.1 Using pipe and jointing methods capable of resisting the forces involved (such as welded steel pipe, or polyethylene pipe with thermal butt-fusion joints); or
.2 Using joint restraining methods, such as metal tie rods, clamps or harnesses.

When designing thrust blocks and other restraint systems, the Designer should ensure:

.1 That transient pressures are added to the normal operating pressures when calculating the thrust forces (if velocity of flow is very high, dynamic thrust should also be calculated); and
.2 Adequate corrosion protection is provided for external clamps and tie rods.

The safe bearing values of soils should be reduced substantially from the figures in Table 16-7 if shallow trenches are used or if bearing against disturbed soils. For further discussion of thrust blocking and joint restraint design, refer to the pipe manufacturer catalogue and other sources such as AWWA standards.

16.7.4 Watermain Grade

When installing a watermain, grades should be straight lines between defined deflection points. Elevations should be recorded. Where possible, the minimum grade of watermains should be 0.1%. Grading should be designed to minimize the number of high points. When the slope equals or exceeds 10%, provide anchorage, joint restraints, trench dams and trench drainage. Provide geotechnical engineering reports where appropriate.

16.7.5 Horizontal Directional Drilling

Horizontal directional drilling (HDD)/boring is an alternative method of installation for watermains crossing obstacles or in deep installations.

For horizontal directional drilling, pipe wall thickness/strength should be selected in conformance with *ASCE F1962-20 (Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossing)* when pipe diameter is larger than 300 mm. For pipe diameters less than 300 mm, pipe wall thickness/strength should be selected in conformance with *ASCE Manual of Practice 108 (Pipeline Design for Installation by Horizontal Directional Drilling, Second Edition, 2014)*.

16.7.6 Pressure and Leakage Testing

All types of installed pipe should be pressure tested and leakage tested in accordance with the latest edition of *AWWA Standard C600 Installation of Ductile-Iron Mains and their Appurtenances*, or as required by local Authorities.

16.7.7 Disinfection

All new, cleaned or repaired watermains should be disinfected in accordance with *AWWA Standard C651 Disinfecting Watermains.* The specifications should include detailed procedures for the adequate flushing, disinfection, and microbiological testing of all watermains before being put into service. In an emergency or unusual situation, the disinfection procedure should be discussed with the DWO.

16.7.8 Commissioning

Following successful testing and disinfection of watermains, the new system should be commissioned with due consideration of resulting pressure and flow changes and other parameters that may be experienced within the water supply system. Reference should be made to Chapter 3 – General Design Guidance.

17 Water Storage

17.1 General

This chapter provides design guidelines for water storage structures for various stages of treatment, which include but are not limited to applications for raw water intake storage, clear wells, wet wells, and distribution reservoirs. The materials and designs used for water storage structures should provide stability, durability, and protection to the quality of the stored water. Structures should follow the current AWWA standards concerning storage tanks, ground storage reservoirs, clearwells, and elevated tanks wherever they are applicable. Refer to Chapter 21 – Small Systems for guidance on water storage for small systems.

For direction on membrane liners, reference should be made to *AWWA D130, Standard for Flexible-Membrane-Lining and Floating-Cover Materials for Potable Water Storage.*

As part of the preliminary design phase for a water storage facility, the following should be considered:

- .1 Material selection;
- .2 Water storage type;
- .3 Volume;
- .4 Shape;
- .5 Number of cells;
- .6 Geotechnical report on the foundation conditions; and
- .7 Design standards.

17.2 Types of Water Storage

All types of water storage used in treatment plants or for distribution water storage should be designed as treated water storage structures to meet requirements in Section 17.3 – Design Criteria for Treated Water Structures.

Tanks may be exempt from this requirement if they contain water that will receive full treatment for which the plant is designed, such as a pre-sedimentation basin at a surface water treatment plant, or water that will not be returned to the treatment process and is separated from the treatment plant by appropriate cross-connection control measures.

Storage tanks should be sized (together with distribution system storage capacity) to minimize on/off cycling of the downstream equipment. Plant storage should be sized such that distribution system demands and in-plant water use (e.g. filter washing, chemical systems, and domestic use) can be met while maintaining relatively constant flow through the plant rather than fluctuating filtration rates.

17.2.1 Wet Well

A wet well is a below-grade structure often located within the treatment building that provides storage for finished, potable water. Wet wells are typically used to provide a steady volume and operating conditions for pumping purposes to either a distribution system or a distribution reservoir and can also include storage for contact time and backwash water.

When designing a wet well, the following items should be considered:

.1 Wet well storage should be sized in conjunction with the distribution system storage to equalize water use in the system and minimize cycling of the treatment plant;
.2 Wet wells should not be located adjacent to untreated or partially treated water when the two compartments are separated by a single wall;
.3 Pipes carrying non-potable water should not be installed through storage facilities containing drinking water; and
.4 Wet wells should be equipped with an overflow and a vent and be designed as treated water structures per Section 17.3 – Design Criteria for Treated Water Structures.

17.2.2 Clearwell

A clearwell, as defined in *AWWA's M48 Waterborne Pathogens*, is a reservoir of treated water that is relied on to provide chlorine contact time (CT) for primary disinfection. A clearwell is typically required when the minimum required CT cannot be met in the distribution mains prior to consumption.

When designing a clearwell, the following items should be considered:

.1 Baffling factor, minimum operating depth and maximum flow rate selected to provide adequate contact time (T) to meet the required CT value;
.2 A secondary cell to allow maintenance on one cell. Otherwise, the plant should be designed with a means to enable short periods of operation with the clearwell out of service;
.3 When a clearwell is also used to provide filter backwash, consideration should be given to the additional volume required to backwash several filters in rapid succession, and/or at worst-case conditions, such as when peak demand for treated water and backwash water requirements coincide;
.4 Adequate measures to limit or prevent short circuiting or dead spots;
.5 Clearwells should not be located adjacent to untreated or partially treated water when the two compartments are separated by a single wall;
.6 Pipes carrying non-potable water should not be installed through storage facilities containing drinking water; and
.7 Clearwells should be equipped with an overflow and vent and be designed as treated water structures per Section 17.3 – Design Criteria for Treated Water Structures.

17.2.3 Distribution System Storage

A distribution storage tank provides containment for finished potable water that supplies a drinking water distribution system and can often provide storage for fire flow. Distribution storage tanks come in various constructions, e.g. below-grade, above-grade, or elevated water tower structures. The materials of construction can be, and are not limited to, concrete or coated steel. Distribution system storage should be designed as treated water structures per Section 17.3 – Design Criteria for Treated Water Structures.

17.2.4 Hydropneumatic Tanks

Hydropneumatic tanks are pressurized vessels containing water and air or a membrane/bladder that is used to regulate system pressures to meet the system's water demand. Hydropneumatic (pressure) tanks as the main water storage are acceptable only in very small water systems (fewer than 50 connections), Refer to Chapter 21 – Small Systems for small systems applications. Hydropneumatic tanks should not be used for providing equalization, contact time for primary disinfection, or fire protection purposes. Hydropneumatic tanks help to reduce on-off cycling of pumps. Fire flow requirements for systems without fire flow storage are to be provided by a separate fire pump with a capacity that is equal to or greater than the fire flow requirement.

When designing a hydropneumatic system, the following should be considered:

.1 Pressure tanks should meet applicable American Society of Mechanical Engineers (ASME) code requirements or an equivalent requirement for the construction and installation of unfired pressure vessels. Non-ASME, factory-built hydropneumatic tanks may be allowed if approved by the Issuing Official. The maximum allowable working pressure should be marked on each tank;

.2 The capacity of the well or booster pumps in a hydropneumatic system should be equal to the peak instantaneous demand;

.3 The effective drawdown volume of the hydropneumatic tank, should be sized to limit pump cycling to the manufacturer recommendations. The effective drawdown volume, in litres, should be equal to or greater than the volumetric equivalent of 10 minutes of operation of the largest pump. For example, a 750 L/min pump should have a minimum 7,500 L pressure tank, unless other measures (e.g. variable speed drives in conjunction with the pump motors) are provided to meet the maximum demand;

.4 Hydropneumatic tanks without a bladder diaphragm should be sized with a water to air ratio of 2:1;

.5 Tanks should be constructed of non-corroding materials or have suitable protective coating for components in contact with water.

.6 For tanks larger than 500 L, an access manhole should be provided. Where practical, the access manhole should be 600 mm in diameter.

.7 Each tank should include a drain, a pressure gauge, water sight glass (non-bladder tanks only), automatic or manual air blow-off, and a means for adding air;

.8 Bladders to be constructed of heavy duty butyl rubber material suitable for contact with potable water;

.9 A pressure relief valve should be installed on each tank and be capable of handling the full pump flow at the pressure vessel design limit. The pressure relieving device should prevent the pressure from rising more than 10% above the maximum allowable working pressure of the system;

.10 Pressure gauges should have a range of no less than 1.2 times the pressure at which the pressure relieving device is set to function;

.11 Hydropneumatic tanks should have bypass piping to permit operation of the system while a tank is being repaired or maintained;

.12 Control equipment consisting of a pressure gauge and pressure operated start-stop controls for the pumps should be included. A shut-off valve should not be installed between the pump and the pressure operated start-stop controls; and

.13 Hydropneumatic tanks should be located above the normal ground surface and installed with sufficient space around the tanks for inspection and maintenance. Hydropneumatic tanks should be installed in a location under ownership of the Water Supplier, and not at a private residence.

17.3 Design Criteria for Treated Water Structures

Designers should consider the following criteria for the design of treated water structures.

17.3.1 Location

.1 Storage facilities should be located on the highest point of the servicing pressure zone. The lowest elevation of the floor and sump floor of storage structures should be placed above the 200-year flood elevation or the highest flood of record, whichever is higher; and where possible at least 600 mm above the groundwater table. If high groundwater table is an issue, refer to Section 17.3.19 – Drainage to mitigate risks of flooding, hydrostatic uplift, and contamination;

.2 For large distribution systems, the placement of one storage tank at a central location should be evaluated against smaller units with equivalent total volume in other parts of the system;

.3 The Designer should be aware that flow reversals may create sediment uptake and dispersal. This may be a more significant concern when the storage tank is located at an extremity of the distribution system.

.4 Sewers, drains, standing water, and similar sources of possible contamination should be kept at least 15 m from the structure. Gravity sewers constructed of watermain quality pipe, pressure tested in place without leakage, may be used at distances of less than 15 m, but no closer than 6 m;

.5 The bottom of storage structures should be placed at or near the normal ground surface. If the bottom of a storage structure is below the normal ground surface, adequate provisions should be made to protect the structure from hydrostatic uplift forces and surface water contamination;

.6 Consideration should be given to:

- .1 Zoning compliance, building code compliance, and community acceptance;
- .2 Positive site drainage away from the structure to prevent runoff ponding in close proximity to the structure;
- .3 Public access and associated safety and security requirements;
- .4 Site access;
- .5 Vehicle access;
- .6 Disposal of reservoir overflow and drain discharges;
- .7 Geotechnical engineering field investigations including:
  - a. Site drainage;
  - b. Foundation design requirements;
  - c. Soil type and soil-bearing strength;
  - d. Groundwater table elevation;
  - e. Soil stability, liquefaction, or slope failure analysis;
- .8 Natural hazard considerations including:
  - a. Avalanche;
  - b. Earthquake;
  - c. Flood;
  - d. Landslide;
  - e. Tree fall;
  - f. Tsunami; and
  - g. Windstorms.

17.3.2 Sizing of Treated Water Structures

The following provides guidance on sizing, and can fill information gaps where no local bylaws for storage sizing exist:

.1 Storage facilities should have sufficient capacity, as determined from engineering studies, to meet domestic demands, and where fire protection is provided, fire flow demands.
.2 Dimensional requirements for bolted and welded steel tanks are specified in *AWWA Standards D103 Factory-Coated Bolted Carbon Steel Tanks for Water Storage* and *D100 Welded Carbon Steel Tanks for Water Storage*, respectively;
.3 Where possible, two cells should be provided to allow maintenance time on one cell without interrupting the supply of water. Some systems may have adequate redundancy within the distribution system to be capable of supplying water to the service area by alternate means while maintenance is conducted within a storage tank;
.4 Where appropriate for larger distribution systems, hydraulic and water quality models should be used for sizing new storage facilities and for selecting locations for re-chlorination facilities if needed;
.5 Excessive storage capacity should be avoided to prevent potential water quality deterioration problems;
.6 When selecting storage tank configuration and layout, Designers should consider water quality within the tank under seasonal changes in water demand; and
.7 If a storage structure is a type where only the upper portion of the water provides a useful function, the remaining lower portion is considered dead storage. Where dead storage is present, there should adequate measures taken to circulate the water through the tank to maintain water quality and prevent freezing. Unusable dead storage should be avoided wherever possible.

17.3.2.1 Sizing Treated Water Storage for Systems Providing Fire Protection

.1 Fire protection is a municipal responsibility, and the municipality may elect to provide for higher fire flow requirements or entirely forgo fire protection by way of the drinking water distribution system. The Designer *s*hould therefore consult the *Water Supplier* and relevant legislation to be aware of all applicable requirements;
.2 Where fire protection is provided, fire flow storage requirements should be considered within the storage facility sizing. Fire protection storage capacity is indicated in *Water Supply for Public Fire Protection* by Fire Underwriters Survey. The required total effective storage should be based on the following formula:

Total Treated Water Storage Required = A + B + C (as per MMCD)

Where,

A = Fire protection storage capacity, as required above;
B = Equalization Storage (25% of maximum day demand);
C = Emergency Storage (25% of A + B); and

.3 The maximum day demand in the previous equation should be calculated using the factors in Table 17-1, unless there is existing flow data available to support the use of different factors. Where existing data is available, the required storage should be calculated based on an evaluation of the flow characteristics within the system.

Maximum Day Demand (MDD) = Average Day Demand (ADD) x Maximum Day Factor

Table 17-1 Maximum Day Peaking Factors

Equivalent Population [1]	Maximum Day Factor
500 – 1000	2.75
1,001 – 2,000	2.50
2,001 – 3,000	2.25
3,001 – 10,000	2.00
10,001 – 25,000	1.90
25,001 – 50,000	1.80
50,001 – 75,000	1.75
75,001 – 150,000	1.65
Greater than 150,000	1.50

Note [1]: When determining the equivalent population for commercial or industrial areas, it is recommended that the area occupied by the commercial/industrial complex be considered at an equivalent population density to the surrounding residential lands.

.4 Configure water storage facilities such that:

a. The equalization storage volume (B) is located between the top water level (TWL) of the storage facility and the elevation necessary to satisfy the minimum and maximum static pressures within the distribution system.

b. The fire (A) and emergency (C) component volumes (i.e. A + C) are located at the elevation required to achieve minimum allowable system pressures under the maximum day plus fire flow conditions; and

c. Should an elevated tank with a booster pumping station at the base be proposed, the equalization volume (B) would be similar to the above. The fire (A) and emergency (C) components can be below the minimum static requirements elevation provided the booster pump is designed/sized to increase system pressures to the minimum required system pressures under the maximum day plus fire flow condition.

d. Refer to Section 16.3.3 – System Pressures for guidance on distribution system pressure requirements.

17.3.2.2 Sizing Treated Water Storage for Systems Not Providing Fire Protection

The minimum storage capacity (or equivalent capacity) for systems not providing fire protection should be equal to the maximum daily demand. This requirement may be reduced when the source and treatment facilities have sufficient capacity with standby power to supplement the peak demands of the system.

17.3.3 Pressure Considerations

Storage facilities should be designed to maintain adequate pressure in the distribution system at the peak water demand in the event of a power failure or other emergency to lessen the potential for system contamination. The maximum variation between high and low levels in elevated distribution system storage tanks should be such that the normal pressures in the distribution system do not exceed the minimum and maximum static and dynamic pressure requirements listed in Section 16.3.3 – System Pressures. The Designer *s*hould coordinate with local by-laws for the required supply-side management to maintain the required static and dynamic pressures within the distribution system.

17.3.4 Controls & Implementation

.1 Adequate instrumentation to:
- Monitor and control water levels in each cell of the storage facilities;
- Control pump on-off cycles or gravity flow to and from the tank to maintain the system pressure and avoid overflow;
- Provide notification of overflow and low-level alarms in a central or remote location with 24-hour surveillance (i.e. SCADA or audible);
- Alarms should be activated by separate and independent devices;
- Local level indicators should be provided by a pressure gauge on the tank piping, a level indicating transmitter, or other means; and

.2 For elevated tanks, level control instrumentation should be sufficiently precise to prevent wasting storage or tank overflows. Altitude valves or equivalent controls should be installed on elevated storage when more than one tank is required within a single supply pressure zone or where the storage facility would overflow at the allowable high distribution system pressure.

17.3.5 Management of Water Quality and Age

Water quality degradation in distribution system storage facilities, such as loss of disinfectant residual, microbial growth, formation of disinfection by-products, nitrification, and taste and odour problems can result from short-circuiting, incomplete mixing, high water age, or a combination thereof. Distribution system storage facilities should be designed to eliminate short-circuiting and stratification and achieve adequate mixing.

The Designer should consider the following to prevent water quality degradation within water storage facilities:

.1 Size, locate and orient the inlet piping to facilitate proper mixing by jet theory during the filling cycle;

.2 Inlet piping may include:
  a. Multiple orifices to facilitate even mixing during filling cycles; or
  b. Orifices which are sized and oriented to achieve a sufficient mixing energy at the fill point to promote good mixing within the storage facility;

.3 Adequate mixing to avoid stagnation and/or freezing due to seasonal variations in water temperatures, turn-over rates and operational setpoints;

.4 A maximum turn-over rate of 3 to 5 days should be targeted, or as required to prevent disinfectant residual loss during low demand periods;

.5 Supplemental mixing may be provided by way of a recirculation pump or submersible mixer;

.6 CFD modelling should be used to inform the piping design for non-standard configurations or large water storage facilities (i.e. > 10 ML);

.7 Tracer studies may be used to verify the mixing performance and adequacy of the design;

a. Complete mixing can be defined as when the tracer coefficient of variation (COV) is less than 5% (Rossman and Grayman, 1999) where COV is defined as:

$$COV = \frac{Standard\ deviation\ of\ tracer\ concentration\ in\ storage\ cell}{Mean\ tracer\ concentration\ in\ storage\ cell}$$

.8 Treated water storage design should facilitate fire flow and pressure requirements and meet maximum daily demand, while maximizing daily volume turnover to minimize water age. The Designer should exercise informed judgement in deciding the appropriate turnover time in the storage facility to maintain biological stability throughout the distribution network. Supplemental disinfection of water leaving storage may be required to maintain secondary disinfection within the distribution network.

.9 Supplemental mixing for floating storage systems to maintain homogeneous mixing under all operating conditions.

Designers may refer to the publication "*Maintaining Water Quality in Finished Water Storage Facilities*" by the AWWA Research Foundation for additional design considerations to maintain stored water quality through design.

17.3.6 Protection from Contamination

The Designer should consider the following to protect against contamination:

.1 All treated water storage structures should have suitable watertight roofs which exclude birds, animals, insects, and excessive dust. Waterproofing the tank below grade; flexible membrane materials meeting the requirements of *AWWA D130 Geomembrane Materials for Potable Water and/or concrete admixtures* may be considered as possible waterproofing alternatives;

.2 Gravity underdrains to capture surface water runoff may be considered, provided that pumping of the drainage water will not be required and underdrains discharge to daylight; and

.3 The installation of appurtenances, such as antenna, should be done in a manner that ensures no damage to the tank, coatings or water quality, or corrects any damage that previously occurred.

17.3.7 Inlet and Outlet

The Designer should consider the following:

.1 Separate inlet and outlet pipes should be provided that facilitate the positive circulation of water within the reservoir;

.2 Inlet and outlet pipes should be located on opposite sides to each other to minimize short-circuiting and optimize mixing in the tank. If they cannot be placed on opposite sides, consideration should be given to maximize mixing within the reservoir; for example, including multi-orifice inlet piping or inlet jet propagation to achieve adequate mixing during a standard filling cycle;

.3 Where there is more than one cell, each cell should include an inlet and an outlet to facilitate operation of either cell. Sufficient provisions should be provided to operate with one cell out of service; and

.4 Piping material should be used for pipelines constructed directly below the reservoir and extending to at least 3 m from the perimeter. The pipe material should be chosen for longevity, with corrosion and seismic considerations in mind, as replacement of this pipe will be costly.

17.3.8 Overflow

The following should be considered in the design of the storage overflow:

.1 The possibility of downstream contamination should be assessed, and the appropriate permitting authority should be consulted prior to design, refer to Chapter 1 – Introduction;

.2 All water storage structures should be provided with an overflow which is brought down to an elevation between 300 and 600 mm above the ground surface, and discharges over a drainage inlet structure or a splash plate. The overflow discharge location should be located so that any discharge is visible. The discharge of the overflow pipe must not be directed to natural water bodies nor connected directly to any drain, sanitary sewer or storm sewer;

.3 All overflow pipes should be equipped with an alarm to alert the operator of an overflow event;

.4 All overflow pipes should be equipped with a backflow preventer. Use of a solid flapper or duckbill valve should be considered to minimize air movement and ice formation in the tank. When a solid flapper is used, a screen should be provided inside the overflow. If a duckbill valve is used, a screen is not required. Provisions should be included to prevent the flapper or duckbill from freezing shut;

.5 When an internal overflow pipe is used on elevated tanks, it should be located within or adjacent to the access manway, such that it is visible from the outside when the access hatch is open. For vertical drops on other types of storage facilities, the overflow pipe should be located on the outside of the structure;

.6 The overflow should open downward and be equipped with a twenty-four mesh (0.70 mm openings) non-corrodible insect screen and a suitable rodent guard, installed within the pipe at a location least susceptible to damage by vandalism. A mesh-fitted mechanical flap valve is acceptable provided the flapper is supplied with non-corroding and non-seizing hinges. The flap valve should be spring loaded or counterweighted, so it closes and forms a tight seal after the overflow event;

.7 The overflow pipe should be of sufficient diameter to permit waste of water in excess of the maximum filling rate; and

.8 Discharge of chlorinated water to ground or surface water must be avoided. Dechlorination should be provided as required to meet the discharge requirements of the authority having jurisdiction.

17.3.9 Drains

Treated water storage structures which provide pressure directly to the distribution system should be designed so they can be isolated from the distribution system and drained for cleaning or maintenance without causing a loss of pressure in the distribution system.

As much as possible without adversely affecting distribution water quality, the storage structure should be drained into the distribution system to minimize wasting of potable water. However, drains should be provided with provisions for dechlorination prior to ground-surface discharge for water which cannot be drained into a distribution system. There should be no direct connection to a sewer or storm drain allowed in a water storage structure. If a gravity drain is provided, an air gap should be maintained at the outlet. Floors should be sloped towards the sump to facilitate cleaning.

17.3.10 Access

Treated water storage structures should be designed with reasonably convenient access to the interior for cleaning and maintenance. At least two access hatches should be provided where space permits. A minimum 900 mm x 1050 mm opening is recommended. The number and location of access hatches should comply with WorkSafeBC requirements.

.1 For elevated storage tanks,
- The roof access hatches should be:
  - framed at least 100 mm above the surface of the roof at the opening; and
  - fitted with a solid watertight cover, which overlaps the framed opening and extends down around the frame at least 50 mm, be hinged on one side and have a locking device.
- All other access ways should be bolted and gasketed;

.2 For ground-level facilities,
- The roof access hatch should be:
  - elevated at least 600 mm above the top of the tank or groundcover;
  - equipped with frame that is at least 100 mm high and fitted with a solid, watertight, non-removable hinged cover(s) which overlaps the framed opening and extends down around the frame at least 50 mm.
    - Alternatively, the cover should have a perimeter trough and drain to allow drainage away from the reservoir; and
  - equipped with vandal-proof locking device.
- All accesses should have a high degree of security to prevent unauthorized access, such as tamper-proof locks, intrusion alarms and cameras.

17.3.11 Vents

Treated water storage structures should be vented. The overflow pipe should not be considered a vent. Open construction between the sidewall and roof is not permissible.

Vents for reservoirs should:

.1 Allow air into the tank at a rate greater than the rate at which water is filled and withdrawn in order to avoid the development of vacuum/pressure within the tank;
.2 Prevent the entrance of surface water and rainwater;
.3 Be fitted with fine aperture (less than 1.0 mm) non-corrodible screen to prevent the entrance of insects, birds and other animals. The screen should be installed within the pipe at a location least susceptible to vandalism;
.4 Open downward with the opening at least 600 mm above the roof or sod. For cold-climate installations, vents should be made tall enough to overcome the design snow depth in the area to prevent clogging; and

.5 On elevated tanks, be fitted with an automatically resetting pressure-vacuum relief mechanism.

17.3.12 Roof and Sidewall

The roof and sidewalls of all water storage structures should be watertight with no openings except properly constructed vents, manholes, overflows, risers, drains, pump mountings, control ports, or piping for inflow and outflow. Particular attention should be given to the sealing of roof structures which are not integral to the tank body, including access tubes.

The following should be considered in the design of the roof and sidewalls:

.1 Any pipes running through the roof or sidewall of a metal storage structure should be welded or properly gasketed. In concrete tanks, these pipes should be connected to standard wall castings which were poured in place during the forming of the concrete. These wall castings should have seepage rings imbedded in the concrete;

.2 Openings in the roof of a storage structure designed to accommodate control apparatus or pump columns should be curbed and sleeved with proper additional shielding to prevent contamination from surface or floor drainage;

.3 Valves and controls should be located outside the storage structure so that the valve stems and similar projections will not pass through the roof or top of the reservoir;

.4 The roof of the storage structure should be sloped to facilitate drainage. Downspout pipes should not enter or pass through the reservoir. Parapets, or similar construction which would tend to hold water and snow on the roof, will not be approved unless adequate waterproofing and drainage are provided;

.5 For reservoirs with concrete roofs, if a minimum slope of 2% is not provided, reservoir roofs should be made watertight with the use of a waterproof membrane or similar product. If used, the coating or roofing system should allow for relief of vapour pressure. The Designer should refer to *AWWA D115 Tendon-Prestressed Concrete Water Tanks for concrete dome roof design* and *D130-11(R19) for Geomembrane Materials for Potable Water Applications*;

.6 For elevated tanks, the use of heat trace cables on the roof may be necessary to prevent the build-up of ice;

.7 Metal and domed roofs should be inspected closely for leaks during commissioning and during operation. The Designer should refer to *AWWA D103 Factory-Coated Bolted Carbon Steel Tanks for Water Storage* for structurally supported aluminum dome roof design; and

.8 When earthen cover is used on concrete reservoirs, it should be sloped to facilitate drainage.

17.3.13 Construction Materials

The material used in reservoir construction should meet *NSF/ANSI Standard 61*: at a minimum, the cement and additives should meet *NSF/ANSI 61 Drinking Water System Components – Health Effects*. Porous materials, including galvanized corrugated steel, wood and concrete block, are not suitable for treated water contact applications.

Pre-manufactured tanks, including those made from polyethylene, fiberglass, and steel, should be constructed in compliance with the design criteria in Section 17.3 – Design Criteria for Treated Water Structures. All tank penetrations should be factory-installed to ensure watertightness.

The following building codes and design guidelines should be referenced:

.1 *The BC Building Code*;
.2 *ACI 350/350R Code Requirements for Environmental Engineering Concrete Structures, and Commentary*;
.3 *PCA: Circular Concrete Tanks Without Prestressing*;
.4 *AWWA D110 Wire- and Strand-Wound Circular Prestressed-Concrete Water Tanks*;
.5 *AWWA D115 Tendon-Prestressed Concrete Water Tanks*;
.6 *AWWA D100 Welded Carbon Steel Tanks for Water Storage*;
.7 *AWWA D103 Factory-Coated Bolted Carbon Steel Tanks for Water Storage*; and
.8 *ACI 350.3/350.3R Seismic Design of Liquid Containing Concrete Structures*, and Commentary

17.3.14 Seismic Design

The following should be considered for seismic design:

.1 Watertight structure and fully operational mechanical equipment, following a 475-year return period earthquake; and
.2 Repairable damage and no uncontrolled release of water following a 2475-year return period earthquake.

17.3.15 Safety

Safety should be considered in the design of the storage structure. As a minimum, the design should conform to the *BC Building Code* and any applicable municipal bylaws.

.1 Ladders, ladder guards, balcony railings, and safely located entrance hatches should be provided. Access to roof hatches and vents should be provided. The design should incorporate easily accessible fall arrest systems for use by employees or emergency response workers to access the exterior and interior of the storage tank. When a fixed ladder is used, the bottom should be located at least 3.5 m above ground to prevent the entrance of unauthorized personnel. Design of tank access, including platform, railings, ladders, and fall arrest systems, should conform to WorkSafeBC;
.2 Riser pipes over 200 mm in diameter located inside the tank should have protective bars over the openings for fall prevention;
.3 Railings or handholds should be provided where persons must transfer from the access tube to the water compartment. Fall protection should be provided in accordance with WorkSafeBC standards; and
.4 Confined space entry should be avoided where possible. If not possible, design should include risk management systems that satisfy the WorkSafeBC confined space requirements *(OHS Regulation, Part 9: Confined Space)*.

17.3.16 Freezing

Treated water storage structures and their appurtenances, especially the riser pipes, overflows, and vents, should be designed to prevent freezing which will interfere with proper functioning. Equipment used for freeze protection that will come into contact with the treated water should meet *NSF/ANSI Standard 61 Drinking Water System Components – Health Effects*. If a water circulation system is used, it is recommended that the circulation pipe be located separately from the riser pipe.

17.3.17 Internal Catwalk

Every catwalk over treated water in a storage structure should be located above the top water level and have a solid floor with sealed raised edges to 100 mm, and should be designed to prevent contamination from shoe scrapings and dirt.

17.3.18 Silt Stop

The discharge pipes from water storage structures should be located in a manner that will prevent the flow of sediment into the distribution system. Removable silt stops should be provided.

17.3.19 Drainage

The area surrounding a ground-level structure should be graded in a manner that will prevent surface water from standing within 15 m. Perimeter and underdrain systems may be required to prevent hydrostatic uplift under the tank floor when empty. Drainage from this system should be directed into a manhole to provide an effective means of monitoring any leakage from the tank. If a gravity drain is insufficient to prevent hydrostatic uplift, other means such as observation wells and pumping down the water table may also be considered to prevent groundwater entry into the tank.

17.3.20 Painting and/or Cathodic Protection

Proper protection should be given to metal surfaces by paints or other protective coatings, by cathodic protective devices, or by both.

.1 Paint systems should meet *AWWA Standard D102 Coating Steel Water-Storage Tanks* and be certified to *NSF/ANSI Standard 61 Drinking Water System Components – Health Effects*. Interior paint should be applied, cured, and used in a manner consistent with the NSF/ANSI approval. After curing, the coating should not transfer any substance to the water which will be toxic or cause taste or odour problems. Prior to placing in service, an analysis for volatile organic compounds is advisable to establish that the coating is properly cured. Consideration should be given to 100% solids coatings;

.2 Wax coatings for the tank interior should not be used on new tanks. Recoating with a wax system is strongly discouraged. Old wax coatings should be completely removed before using another tank coating; and

.3 Cathodic protection of steel water structures should be provided and conform to the provisions of *AWWA Standards D104* and *D106* for corrosion protection standards for steel reservoirs. Consideration should be given to potential ice damage to cathodic protection equipment. Cathodic protection should be designed and installed by competent technical personnel, and a maintenance contract should be provided.

17.3.21 Disinfection

The following should be considered when disinfecting treated water structures:

.1 Treated water storage structures should be disinfected in accordance with *AWWA Standard C652 Disinfection of Water Storage Facilities*. Two or more successive sets of samples taken at 24-hour intervals should indicate that the water is microbiologically satisfactory before the facility is placed into operation. Following disinfection and prior to placing the tank into service, water should be tested for total coliform bacteria and chlorine residual. If the test for total coliforms is negative and the chlorine residual meets the requirements of the Issuing Official, the tank may be placed into service. If the test shows the presence of coliform bacteria, two or more successive sets of samples, taken at 24-hour intervals, should indicate the water is microbiologically satisfactory before the storage facility is placed into operation;

.2 The disinfection procedure specified in *AWWA Standard C652 Chlorination Method 3*, which allows use of the highly chlorinated water held in the storage tank for disinfection purposes, is not recommended. The chlorinated water may contain various disinfection by-products which should be kept out of the distribution system. If this procedure is used, it is recommended that the initial heavily chlorinated water be neutralized and discharged to waste; and

.3 Disposal of heavily chlorinated water from the tank disinfection process should be discussed with the Ministry of Environment and Climate Change Strategy and/or the Ministry of Water, Land and Resource Stewardship prior to disposal; dechlorination to below 0.02 mg/L total residual chlorine before discharge is often required.

17.3.22 Provisions for Water Quality Monitoring

Smooth-nosed sampling tap(s) should be provided to facilitate collection of water samples for both bacteriological and chemical analyses. The sample tap(s) should be easily accessible. Sample lines should be stainless steel from the sampling point to the sampling tap. Sample tap(s) should be located to collect representative samples.

Provision for online water quality monitoring should be considered in relation to the overall system characteristics and monitoring program.

17.3.23 Security

Fencing, locks on access manholes, and other necessary precautions (e.g. alarms and security cameras) should be provided to prevent trespassing, vandalism, and sabotage. Consideration should be given to the installation of high strength, cut resistant locks or lock covers to prevent the direct cutting of a lock. Reference should be made to Section 5.10 – Site, Building and Digital Security for more information.

18 Pumping Facilities

18.1 General

This chapter provides design considerations for pumping facilities, including general pump station design as well as guidance for raw water, treated or booster pumping stations. Pumping facilities should be designed to maintain the quality of pumped water, the hydraulics of the system and to protect against interruption of service by natural hazards. Subsurface pits or pump rooms and inaccessible installations should be avoided. No pumping station should be subject to flooding.

The design of a pumping facility must conform to the latest applicable *BC Building Code* (BCBC) and to post-disaster standard as described within the BCBC.

18.1.1 Preliminary Design

The following should be considered during the preliminary design phase:

.1 Location;
.2 Capacity;
.3 Number and type of pumps;
.4 Operator requirements;
.5 Preliminary piping layout;
.6 Type and appearance of structure;
.7 Foundation conditions;
.8 Maintenance requirements and access;
.9 Energy requirements;
.10 Standby power;
.11 HVAC; and
.12 Controls and monitoring.

18.2 Pump Stations

18.2.1 General Pump Station Design Considerations

Both raw and treated water pumping stations should:

.1 Have adequate space for the installation of additional units if needed, and for the safe servicing of all equipment;
.2 Be of durable construction, fire, and weather resistant and with outward-opening doors;
.3 Have floor elevation of at least 150 mm above finished grade;
.4 Provide a suitable outlet for drainage without allowing discharge across the floor, including pumping glands, vacuum air relief valves, or other appurtenances with liquid discharges;
.5 Piping should be designed such that each pump has an individual suction line or that the lines should be so manifolded that they will ensure similar hydraulic and operating conditions;
.6 Building floors should be sloped to a suitable drain, and drain in such a manner that the pumped water will not be contaminated;
.7 Building drains should be constructed in such a way as to prevent any potential break or leakage from contaminating the pumped water and should not be built within water-bearing structures; and

.8 Have a sump pump supplied to ensure that any miscellaneous water entering the station is removed. Sump pump systems should be alarmed for flood conditions (i.e. high water level alarms).

18.2.2 Location

The following should be considered when selecting the location of the pump station:

.1 The pump station should be elevated to a minimum of 1 m above the 100-year flood elevation, or 1 m above the highest recorded flood elevation, whichever is higher, or protected to such elevations; unless a hydraulic analysis is completed to identify a more appropriate elevation. The impact of climate change should be considered when locating a pumping station. See Chapter 4 – Climate Change Risk Assessment and Adaptation for further climate change considerations;
.2 The site should be readily accessible at all times unless permitted to be out of service for the period of inaccessibility;
.3 The site should be graded around the station to lead surface drainage away from the station and away from the source water; and
.4 The pump station should be protected to prevent vandalism and entrance by animals or unauthorized persons. The pump station should be located within a secure area such as a locked building or fenced area.

18.2.3 Wet Well Design

The following should be considered in the design of a wet well:

.1 The floor should be sloped to a sump for easy cleaning and draining;
.2 The well should be covered and protected from contamination;
.3 Well access routes should be adequately sealed against liquid penetration;
.4 A 100 mm curb should surround any floor openings to prevent floor drainage entering the well, and the well should be adequately vented;
.5 Design should include two pumping compartments or other means to allow the well to be taken out of service for inspection, maintenance or repair, while still maintaining a portion of the station capacity in service;
.6 Be watertight; and
.7 Suction pipe inlets should be designed in accordance with good design practice to prevent vortexing, air-entrainment, inlet interference and other phenomena that may interfere with proper operation and pumping.

18.2.4 Equipment Servicing

Pump stations should be provided with:

.1 Space around all of the equipment to allow for safe servicing;
.2 Crane-ways, hoist beams, eyebolts, or other adequate facilities for servicing or removal of pumps, motors, or other heavy equipment;
.3 Openings in floors, roofs or wherever else is needed for the removal of heavy or bulky equipment;
.4 Equipment or other facilities as needed, for the proper maintenance of the equipment; and

.5 Equipment should be labeled such that the pumps and valves in the station are tagged to correspond to the maintenance record and for proper identification.

18.2.5 Stairways and Ladders

Stairs are preferred in areas where there is frequent traffic or where supplies are transported by hand. Ladders can be used when access is required less than once per year. Stairways or ladders should:

.1 Be provided between all floors, and in pits or compartments which will be entered;
.2 Conform to the requirements of the *BC Building Code*;
.3 Be provided with adequate safety equipment;
.4 Have handrails on both sides, and treads of non-slip materials;
.5 Comply with Occupational Health and Safety requirements; and
.6 Be designed to facility proper egress from the space in the event of an emergency.

18.2.6 Heating

Provisions should be made for adequate heating for:

.1 The comfort of the operator;
.2 The safe and efficient operation of the equipment; and
.3 Preventing freezing.

18.2.7 Ventilation

Adequate ventilation should be provided to manage the climate conditions within all facilities. Ventilation systems should be designed to conform to relevant provincial and/or local codes and ASHRAE standards. Adequate ventilation should be provided for all facilities for operator comfort and dissipation of excess heat from the equipment. Forced ventilation of at least six changes of air per hour should be provided for:

.1 All confined rooms, compartments, pits and other enclosures below ground floor; and
.2 Any area where an unsafe atmosphere may develop or where excessive heat may build up.

A vent or a vent system should be provided for all structures containing process equipment. The vents should be equipped with a 180° bend with an insect screen at the outlet. For vents on critical structures, the design should incorporate solid/liquid protection against entry into the vent by vandalism or sabotage.

18.2.8 Dehumidification

Dehumidification should be provided in areas where excess moisture could cause hazards for operator safety, or damage to equipment and piping.

18.2.9 Lighting

The following should be considered in the design of pump station lighting:

.1 Pump stations should be adequately lighted throughout to facilitate proper operation and maintenance of the equipment;
.2 Moisture resistant lighting should be considered;

.3 Provision of multiple lighting levels may also be considered for various duties, such as minimum lighting for walkthroughs and minor checks and high-level lights for major maintenance;
.4 Emergency lighting and illuminated exit signs should be provided at appropriate locations in case of power failure;
.5 Exterior lighting should be provided in accordance with local bylaws with consideration to deter vandalism and facilitate maintenance; and
.6 All electrical work should conform to the requirements of the *Canadian Electrical Code* or to relevant provincial and/or local codes.

18.2.10 Sanitary and Other Conveniences

All pumping stations that are manned for extended periods should be provided with potable water, and lavatory and toilet facilities as allowed by provincial and/or local codes. Plumbing must be installed using backflow prevention devices to prevent contamination of a public water supply. Acceptable options for the disposal of wastewater include, but are not limited to, a municipal system, on-site sewage disposal systems, or a holding tank.

18.2.11 Standby Power

Refer to Section 19.4 – Standby Power and Uninterruptable Power Supply (UPS) for design recommendations.

18.2.12 Fire Pumps

Fire pumps are only required for closed systems or systems without adequate storage. Where required, the Designer should provide fire pump drivers equipped with a secondary power source demonstrated to meet an acceptable performance standard similar to NFPA 20 Standard for the *Installation of Stationary Pumps for Fire Protection*.

18.2.13 Safety

Pump stations should be designed in such a manner as to ensure the safety of the operators and maintenance staff in accordance with the *B.C. Occupational Health and Safety Regulation*. Eyewash and safety showers should be provided where potentially harmful chemicals are present in the pumping facility. Refer to safety design considerations in Chapter 5 – Facility Recommendations.

When designing a pump station, the following should be considered for safety:

.1 Any moving equipment should be covered with suitable guards to prevent accidental contact;
.2 Equipment that starts automatically should be suitably signed to ensure operator awareness;
.3 Local lockouts on all equipment should be supplied so that personnel can ensure that they are completely out of service during maintenance;
.4 Local emergency stops should be provided;
.5 Provision of fire/smoke detectors, fire extinguishers and sprinkler systems (where appropriate);
.6 All stairways and walkways should be properly designed with guardrails; and
.7 Confined spaces should be minimized, where applicable.

18.2.14 Controls

The Designer should consider the following in the design of pump station controls:

.1 Pumps, their prime movers, and accessories should be controlled to ensure that they will operate in a manner that will prevent motor overload or prevent over pressurization of the pipe system;
.2 Control systems should limit the number of start/stop sequences (according to the pump and electrical equipment manufacturer recommendations);
.3 Where duplicate pumps are installed, provision should be made for the inclusion of a P1-alternate-P2 selector on the pump control panel. This would allow for the lead status to alternate whenever a pumping cycle is completed or allow for a particular pump to be selected as continuous lead if more consistent operation is desired for a single unit;
.4 Provision should be made to prevent energizing the motor in the event of a backspin cycle;
.5 Electrical controls should be located above grade;
.6 Equipment should be provided, or other arrangements made to prevent surge pressures from activating controls for pumps or activating other equipment outside the normal design cycle of operation; and
.7 In closed systems (treated water, booster pumping), a control valve (not normally supplied by the pump manufacturer) should be provided to ensure proper operation of the pump. An air release valve should also be provided in the pump discharge to let the air out of the discharge pipe at pump start-up.

Pressure control is commonly used for pump operation in both open systems and closed systems. However, care should be taken for pump selection when this type of control is used as it can have a significant effect on the operation of a pump; specifically, the Designer should aim to select a process pump characterized with a steep flow rate versus total dynamic head curve (pump curve) or ensure that the pump does not operate on the flat part of the curve. A combination of flow control and pressure control may be used in smaller systems. Temperature and level sensing controls may also be required. Whatever control system is used, operation of the pumps near their maximum efficiency points should be maintained.

An adequately sized pressure relief bypass may be required to minimize pump cycling and prevent pump damage for pumps operating in the shut-off head condition.

18.2.15 Hydraulic Surge Protection

Pumping station headers should be adequately protected from transient pressure surges which may occur if pumps stop on power failure. Protection may be provided either by appropriate control sequencing, valves or hydraulic transient surge tanks. An alarm to the SCADA system should be provided for high pressure and if the pressure relief valve opens.

18.2.16 Meters and Gauges

To help ensure that pumps perform as designed, each pump should have:

.1 Pressure indicating transmitters and/or pressure switches on the inlet and discharge headers;
.2 A compound gauge on the suction line;

.3 Pressure gauges on the pump suction and between the pump and the discharge check valve;
.4 Flow meter on the discharge from the pump station capable of measuring total and instantaneous pumping rate, and a method of recording the total volume of water pumped; and
.5 Flow meters should provide a signal suitable for input to a SCADA system and/or a data logger. A straight section of pipe should be installed upstream and downstream of the meter per the meter manufacturer's recommendation to improve accuracy where required.

18.2.17 Valves

Each pump should have valves adequate to permit satisfactory operation, maintenance, and equipment repair. This should include:

.1 Isolation gate valves or AWWA butterfly valves on the suction and discharge side of each pump;
.2 A check valve on the discharge side of each pump;
.3 End connections for pumps, pressure vessels, and large equipment should have dismantling joints or flanged pipe with grooved end couplings. Threaded unions are acceptable for smaller units;
.4 Pressure relief surge anticipation valves, as needed, to prevent destructive hydraulic transients from occurring in the system;
.5 Air relief valves at any high points in the piping; and
.6 Foot valves if necessary. Foot valves should have a net valve area of at least 2.5 times the area of the suction pipe and they should be screened.

18.2.18 Piping Material

The strength, stiffness, ductility, and resistance to water hammer or pump cycling make steel or stainless steel the most suitable choices for exposed piping in pump stations. Plastic pipe such as PVC and HDPE are prone to fatigue failure from pump cycling, become brittle at low temperatures, or lose strength at temperatures that can occur normally in pump stations. For those reasons, if considering the use of PVC or HDPE pipe inside a booster pump station, the Designer should approach with caution.

The design should also address special anchoring or support requirements for equipment and piping. Piping should be protected against surge or water hammer and should be provided with suitable restraints where necessary. Special attention should be made to materials installed beneath building slabs and foundations as these components will be costly and difficult to replace if damaged. The Designer should evaluate these pipes for corrosion potential and provide corrosion mitigation, as appropriate.

All material in contact with the water should meet the *NSF 61 Drinking Water System Components – Health Effects* requirements.

18.2.19 Water Pre-lubrication

When automatic pre-lubrication of pump bearings is necessary and an auxiliary power supply is provided, the design should ensure that pre-lubrication is provided when auxiliary power is in use, or that bearings can be lubricated manually before the pump is started.

18.2.20 Oil or Grease Lubrication

All lubricants which come into contact with the potable water should meet NSF rating H1, H2, or H3.

18.2.21 Seismic Piping Connections

Designers should use seismically appropriate pipe materials and connections for all pipes located within the pump station, directly below it, and within 1 m of the pump station foundation before transitioning with couplings.

18.2.22 Taps on Discharge Piping

Booster pump stations are convenient places to provide water quality monitoring and, if necessary, provide booster chlorination or other water quality adjustments. The Designer should consider installing at least two taps on the common discharge line:

.1 A sample tap to allow for monitoring water quality; and
.2 A tap to allow for booster disinfection in an emergency.

18.2.23 Access for Pipe Cleaning and Condition Assessment Tools

As distribution pipes age, they gradually accumulate solids and experience corrosion. As a result, it may be useful to install a pig-launch or other access points (e.g. for examination via CCTV cameras) on the pump station discharge piping.

18.2.24 Pump Station Commissioning

Pumps should be installed properly, vibration levels tested, and pump operation tested at the rated performance. Measured vibration levels can be compared to allowable values listed in *Hydraulic Institute Standard 9.6.4 Rotodynamic Pumps for Vibration Measurements and Allowable Values*. An operational field pump test consists of measuring the pump suction and discharge pressure or head, discharge flow, power input, and speed. Designers then use this information to determine whether there are operational issues with the pumps as outlined in *AWWA E103 - Horizontal and Vertical Line-Shaft Pumps*.

Before a pump station can be placed into service, it must be properly tested, inspected, and disinfected. The specifications for the pump station should clearly identify the disinfection and bacteriological testing requirements. *AWWA C651 Disinfecting Water Mains* can be used for this purpose.

18.3 Raw Water Pumping Stations

18.3.1 Pump Selection

Pumps should be specified so that the full range of flows anticipated can be provided with pumps operating in the vicinity of their optimum efficiency points, with due regard to the hydraulic design of the discharge piping. Pump and component materials should be resistant to abrasive materials within the raw water.

Pumps should be selected to maximize efficiencies at the average head condition, but which can meet the maximum flow and pressure conditions. Adequate control should be provided which is capable of controlling pump operation over the entire range of flows expected.

The pumping units should:

.1 Have ample capacity to supply the peak demand against the required distribution system pressure without dangerous overloading;
.2 Be driven by motors able to meet the maximum horsepower condition of the pumps;
.3 Be provided with readily available spare parts and tools;
.4 Be served by control equipment that has proper heater and overload protection for the air temperatures encountered;
.5 Be selected to operate at flows within ± 10% of the Best Efficiency Point (BEP) of the pump. Operating within this range the hydraulic efficiency and the operational reliability of the pump are not substantially degraded. Within this region, the design service life of the pump will not be affected by the internal hydraulic loads or flow induced vibration; and
.6 Have a hydraulic efficiency above 80%.

18.3.2 Number of Pumps

The number of pumps should be consistent with the pattern of flow required and the method of flow control. A minimum of two pumps should be provided, where one pump is standby. Where practical, it is recommended that at least three pumps be provided for increased operating flexibility. Pump capacities should determined based on achieving treatment capacity with the largest unit out of service.

18.3.3 Flow Control

Pumps should be capable of supplying water over the entire range of flows to be treated. This can be achieved through the provision of pumps with variable speed motors or through control valves. Where substantial seasonal variations in flow exist, it may be necessary to provide duplicate flow control systems - one suitable for very low flows (which normally occur in winter) and one suitable for the plant design flow.

18.4 Well Pumping

Refer to Section 6.3.2 – Well Construction

18.5 Treated Water Pumping Stations

The design criteria for treated water pumping stations generally follow those presented for raw surface water pumping. In addition, the following special considerations apply for treated water pumping stations:

.1 The pumping station should be designed with at least two pumps. With one pump out of service, the remaining pump(s) should be able to deliver the maximum daily design flow, when storage is provided, or peak hourly design flow, when distribution storage is not provided, at the required minimum system pressure defined in Chapter 3 – General Design Guidance;
.2 In order to supply water economically during low demand periods, at least one pump should be provided with a variable speed motor or an appropriately sized, small pump may be installed;
.3 Standby power or an auxiliary gas or diesel powered pump should be provided to supply water during power outages or other emergencies. Fuel should be stored above ground and outside the water treatment plant building;

.4 Pumping facilities should be designed to maintain the potable quality of pumped water;
.5 Subsurface pits or pump rooms and inaccessible installation should be avoided; and
.6 No pumping station should be subject to flooding.

18.6 Additional Design Considerations for Pumps

18.6.1 Suction Lift

The design of suction lift pumps should be avoided, if possible. If unavoidable, suction lift should be within the allowable limits for the pump, preferably less than 5 m.

If suction lift is necessary, provision should be made for priming the pumps. To avoid cavitation, it is important to compare the net positive suction head required (NPSHr) to the net positive suction head available (NPSHa). Total suction head calculated for NPSHr should account for geodetic differences and suction pipe losses.

18.6.2 Pump Priming

Prime water must not be of lesser quality than that of the water being pumped. Means should be provided to prevent either backpressure or backsiphonage backflow. When an air-operated ejector is used, the screened intake should draw clean air from a point at least 3 m above the ground or other source of possible contamination, unless the air is filtered by an approved apparatus. Vacuum priming may be used.

18.6.3 Water Seals

Water seals should not be supplied with water of a lesser quality than that of the water being pumped. Where pumps are sealed with treated water and are pumping water of lesser quality, either an approved reduced pressure principle backflow preventer or a break tank open to atmospheric pressure should be provided. Where a break tank is provided, an air gap of at least 150 mm or two pipe diameters, whichever is greater, should be provided between the feeder line and the flood rim of the tank.

18.6.4 Variable Frequency Drives (VFDs)

Designers should consider VFD pump control. It provides many advantages including energy savings, improved pressure and flow control, and elimination of pressure transients associated with abrupt start/stop of single-speed pumps. Chapter 19 – Electrical should be reviewed for harmonic monitoring and mitigation considerations.

18.7 Booster Pumps

18.7.1 General Design Considerations

The purpose of booster pumping stations is to maintain adequate pressures and flows in water distribution systems as a result of both changes in ground elevation and distance from the source of supply. Temporary booster stations may be provided to maintain adequate system pressure during capital project phasing.

Booster pumps should be located or controlled so that:

.1 They will not produce negative pressure in their suction lines;
.2 Pumps installed in the distribution system should maintain inlet pressure as required in Chapter 16 – Transmission and Distribution under all operating conditions. Pumps taking suction from storage tanks should be provided adequate net positive suction head;
.3 Automatic shutoff or a low-pressure controller should maintain at least 140 kPa (20 psi) in the suction line under all operating conditions. Pumps taking suction from ground storage tanks should be equipped with automatic shutoffs or low-pressure controllers as recommended by the pump manufacturer;
.4 Automatic or remote-control devices should have a range between the start and cut-off pressure which will prevent excessive cycling; and
.5 A bypass is available, and alarms are installed for such conditions.

18.7.2 Redundancy

Each booster pumping station should contain not less than two pumps with capacities such that peak demand can be satisfied with the largest pump out of service.

18.7.3 Metering

All booster pumping stations should be fitted with a flow rate indicator and a totalizer meter which provide signals suitable for input to a SCADA system or data logger.

18.7.4 Inline Booster Pumps

In addition to the other requirements of this section, inline booster pumps should be accessible for servicing and repairs.

18.7.5 Individual Residential Booster Pumps

Private booster pumps should not be allowed for any individual residential service from the public water supply main. Exceptions may be permitted if the design, installation, and operation/management of booster pumps is approved by the Water Supplier, the Water Supplier ensures that booster pumps do not adversely affect pressure in the rest of the distribution system, and the Water Supplier addresses all cross connection concerns.

19 Electrical

19.1 General

This chapter describes design considerations for electrical components of water supply systems. Electrical design should be coordinated with process system requirements to ensure stable and reliable treatment performance. The Designer should refer to relevant industry standards and manufacturer requirements for specific design considerations, and is responsible for compliance with the applicable codes, standards and good engineering practices of the electrical industry.

Electrical design should be based on the following criteria:

.1 Efficiency;
.2 Redundancy/Reliability; and
.3 Safety.

19.1.1 Efficiency

Energy efficient equipment should be selected wherever possible to minimize electrical loading. The Designer should refer to the *BC Energy Efficiency Act* for applicable standards and requirements relating to specific electrical equipment. Where possible, the design should minimize the footprint of electrical equipment.

19.1.2 Redundancy/Reliability

The design should incorporate redundancy to account for failure of critical equipment and to improve reliability. Critical equipment should be identified at the start of design so that redundancy can be incorporated into the design.

19.1.3 Safety

Electrical design should conform to all required safety standards and should incorporate controls to minimize electrical risk where required.

Main switch gear electrical controls should be located above grade in areas not subject to flooding. The Designer should coordinate with the appropriate discipline Designer to determine the flood level and required factor of safety for the area.

The Designer should consider switchgear facility sizing requirements if variable frequency drive (VFD) type equipment is to be employed.

Consideration should be given to providing voltage stabilization in the electrical services to laboratory and/or sensitive process control equipment (for example, UV reactors), since a relatively constant voltage may be required for proper operation.

19.2 Codes and Standards

All electrical work should conform to the requirements of the latest editions of the following codes and standards:

.1 *Canadian Electrical Code (CEC Part 1 and Part 2);*

.2 *Canadian National Building Code (NBC);*
.3 *Canadian National Fire Code (NFC) and applicable sections for the National Fire Protection Association Standards (NFPA);*
.4 *Institute of Electrical and Electronic Engineers (IEEE);*
.5 *American National Standards Institute (ANSI);*
.6 All applicable CSA standards; and
.7 All applicable provincial and local codes and standards.

19.3 Power Distribution

19.3.1 Voltage and Phase

System voltage and phase should be determined by the size of the connected equipment and should take into consideration factors such as cable sizing (voltage drop), ease of installation of conduits and cables, and utility service voltages available in the area. Additional considerations include:

.1 Whenever motor loads are present, three phase power should always be used;
.2 Where larger motor loads are present, generally greater than 25 hp, the use of 600 V should be considered to minimize cable sizing; and
.3 Voltage drops should be minimized to 3% whenever possible to ensure stable operation of equipment.

19.3.2 Power Monitoring and Protection

Power monitoring and protection is required to ensure stable power is being supplied to the site. Power surges, voltage spikes, and dirty power can lead to equipment damage and failure and should be prevented whenever possible. The following should be considered:

.1 Where motors are controlled by variable frequency drives (VFD), harmonic monitoring and mitigation should be considered to reduce the impacts on the utility grid.
.2 A voltage monitor should be used to monitor and alarm on undervoltage, phase loss, phase reversal and phase unbalanced conditions;
.3 Where larger motor loads are present (service sizes greater than 200 amps), a power quality meter should be considered for monitoring and protection. The power quality meter should be capable of measuring harmonic distortions where variable frequency drives or soft starters are used for motor control; and
.4 Surge protection devices (SPDs) should be used to protect sensitive electronic equipment from power surges.

19.3.3 Service Size and Equipment Ratings

In general, equipment should be rated to exceed the operating system parameters. Oversizing of equipment should be considered where future expansion may be a possibility; the Water Supplier should be consulted.

The Designer should consider the following when sizing electrical equipment:

.1 The main electrical service should be sized to run the full operating loads at peak treatment and pumping capacity for the design life, plus an allowance for future load growths;

.2 Overcurrent protective devices should have an interrupting capacity that exceeds the maximum calculated short circuit levels;
.3 Voltage ratings of equipment should meet or exceed system operating voltage;
.4 Distribution equipment should be sized for their downstream loads. Consideration should be given for allowance for future load growths where necessary; and
.5 Space should be provided for future electrical equipment, including Motor Control Centers (MCCs).

19.4 Standby Power and Uninterruptable Power Supply (UPS)

19.4.1 Standby Power

The need for standby power and the extent of equipment requiring operation by standby power should be individually assessed for each facility. A plan should be developed to ensure that average day demand can be met during a power outage, and at a minimum, emergency level lighting and process control operations can be maintained. The following factors should be considered when developing a plan:

.1 Frequency and length of power outages in the area;
.2 Reliability of primary power source;
.3 Available treated water storage capacity within the system;
.4 Type of water storage (underground or elevated); and
.5 Requirements for fire protection.

The standby power supply should be capable of providing continuous electrical power during any interruption of the utility power supply. The standby power supply should be designed with adequate capacity to operate fire and domestic pumps, chemical dosing systems, control and monitoring systems, and heating and lighting systems. Automatic transfer equipment should be provided to make the transition from utility power to the backup power as seamless as possible during power outages.

Adequate fuel supply should be provided for the backup power system. Fuel capacity should be sized to maintain a minimum run time of 8 hours. In remote locations, consideration should be given to a minimum run time of 24 to 48 hours depending on the risk factors associated with the utility power.

For fuel storage, a subbase tank type setup should be used to minimize the installation footprint. The Designer should refer to *CAN/UCL-S601 Standard for Shop Fabricated Steel Aboveground Tanks for Flammable and Combustible Liquids* for tank fabrication and CSA B139 *Installation Code for Oil-Burning Equipment* for tank installation. If additional tanks are required, these may be located underground or inside. Factors such as corrosion potential, leakage and spill protection, and the need for fuel pumps should be evaluated. The design for fuel storage tanks and supply lines must conform to all applicable federal and provincial legislation and regulations.

Fuel storage tanks and generator units should not be located above any water treatment process unit or raw or treated water reservoir.

Where the backup power system is to be installed indoors, proper consideration should be given to the ventilation requirements. The ventilation system should be fully automated and should be sized to the requirements of the backup power system. External pad mounted units in a separate enclosure can also be considered if space, ventilation, or noise requirements cannot be met when installed indoors. Carbon monoxide detectors should be used when fuel-fired generators are used for standby power.

When the facility is located in a residential district, soundproof enclosures should be used to limit sound levels while the standby generator is in operation. The acceptable sound level must be determined by consulting with the local authorities and local bylaws.

Generator units should be mounted on a pad and surrounded by a containment system to retain any fuel spills. A clear space for inspection and servicing of at least one meter on all sides of the unit should be provided.

Standby power systems have peripheral requirements to ensure the backup power system is maintained in operational service. These peripheral requirements should be considered in the design and adequate circuits should be provided. At a minimum, the following accessories should be included:

.1 Battery chargers;
.2 Block heaters;
.3 Remote communications (and/or);
.4 Hard-wired alarm signals.

For small pumping facilities, portable standby units may be used and a fixed exterior electrical connection point should be provided for connection of the portable standby power system.

19.4.2 Uninterruptable Power Supply (UPS)

A UPS system should be provided for all critical controls and instrumentation. The UPS system should be designed to operate by using a true online double conversion system. Protection against voltage variations and surges should be included in the design.

UPS systems should include a bypass system and should provide a battery backup time of at least 30 minutes at full load.

19.5 Site Services

Power outlets should be provided at convenient spacing throughout the facility to provide power for purposes such as maintenance of equipment and extension lighting. Ground fault interrupter (GFI) type outlets should be used in process areas or when located outside.

Outlets supplied by uninterruptible power supply (UPS) or emergency power systems should be located such that they are easily accessible during a power outage.

19.6 Motors

The following should be considered when designing motors:

.1 Each pump should be operated by a motor capable of operating the pump at any point on the head discharge curve. Pump motors rated 1-200 hp should meet the CSA minimum motor efficiency standard. If available, motors should be “premium” energy efficient;
.2 Generally, motors greater than 50 hp should use soft starters or variable frequency drives to minimize motor starting impact to the utility power and mechanical components of the

system. Where a soft starter is used, a bypass contactor should be inherent in the design. Line and load filters should be used with variable frequency drives to limit harmonic effects;

.3 Motors should be located at such a level in the pumping station that they cannot be flooded. Alternatively, immersible motors can be used;

.4 A suitable time delay between pump stop and the subsequent pump start should be provided to allow the shaft to come to a complete stop;

.5 Motors greater than 5 hp should include motor thermostats for motor protection;

.6 Motor space heaters should be considered where motors are located outdoors, in unheated rooms, or in damp areas; and

.7 Power factor correction capacitors should be considered where all direct utility powered motors are used to avoid power use charges due to poor power factors.

19.7 Electrical Controls

The following should be considered when designing electrical controls:

.1 Electrical controls should be located above grade, in areas not subject to flooding. All electrical work should conform to the requirements of the *Canadian Electrical Code* or to relevant provincial and/or local codes;

.2 Pumps, their prime movers and accessories should be controlled in such a manner that they will operate at the rated capacity without dangerous overload. Where multiple pumps are required to run simultaneously, sequential starting should be used to minimize impacts to standby power capacity. Provision should also be made to allow for alternation of pumps either automatically or manually;

.3 Where critical equipment is being controlled, consideration should be given to providing redundant control systems;

.4 Local control panels and stations should be located near their respective equipment and should be easily accessible with adequate clearance around equipment; and

.5 Electrical control equipment located in process and outdoor areas should be rated suitably for use in those conditions.

19.8 Grounding

A complete, permanent, and continuous grounding system should be provided for the electrical system. The grounding system should meet the requirements of the *Canadian Electrical Code*.

19.9 Lighting

The following should be considered when designing facility lighting:

.1 Buildings should be adequately lighted throughout by means of natural light and artificial lighting. Control switches should be conveniently placed at each entrance to each room or area;

.2 Emergency lighting should be provided and should have a minimum run time of 30 minutes after power failure;

.3 Energy efficient lighting should be used, and all process areas should use moisture resistant lighting;

.4 Design lighting levels should be in accordance with the *Illuminating Engineering Society of North America (IESNA)* guidelines;

.5 Exterior lighting should be provided and should be:

a. LED and rated for outdoor and wet locations;
b. Located over entrances and any location where high activity is anticipated (such as parking lots); and
c. Should be operated automatically (timer or photocell) with manual override.

19.10 Power Study

Electrical power studies are performed by Designers to analyze the safety and reliability of electrical networks. These studies can provide valuable insight into a power system and can help to identify areas which require further design engineering.

The following power studies should be conducted:

.1 Short circuit analysis – Electrical faults can lead to severe damage and/or injury to equipment and staff. A short circuit analysis of the power system will allow Designers to determine the interrupting capacities required for individual pieces of equipment in order to withstand the anticipated fault levels;
.2 Protective device coordination – These studies allow Designers to determine settings required for breakers and protective devices so that the system can be designed for optimal reliability. A properly configured protective electrical system ensures all electrical equipment is protected in case of failure;
.3 Arc flash analysis (for systems 240 V or over) – Whenever energized electrical equipment is present, arc flash hazards could exist. An arc flash analysis allows Designers to determine the arc fault currents and arc flash incident energy that could be reduced and controlled during the design. These studies help to improve personnel safety, reliability, and equipment protection;
.4 Harmonic analysis – When nonlinear loads such as VFDs are present in an electrical system, harmonic frequencies may be produced by these devices which could result in power quality issues. Harmonic analysis of the power system helps to determine if these devices are causing power quality problems that could affect other equipment or even the utility grid. Many utilities require a limit to the amount of harmonic distortion that a power system can apply to the grid, and a harmonic study will allow Designers to find and mitigate these power quality issues; and
.5 Grounding study – This study will allow engineers to determine if the substation ground grid design is adequate and meets code requirements. A good grounding grid system is required to ensure personnel safety.

20 Instrumentation and Controls

20.1 General

This chapter describes design considerations for instrumentation and control systems for water supply systems. The Designer should refer to relevant industry standards and manufacturer requirements for specific design considerations, and is responsible for compliance with the applicable codes, standards and good engineering practices of the electrical industry.

The objectives of instrumentation and control are to support the continuous operation of process systems and provide monitoring, protection, and control functions. Process control tools, including monitoring, instrumentation, and alarms ensure that equipment and treatment processes operate safely and reliably. In addition to meeting regulatory monitoring requirements, these tools allow Operators to adjust equipment or process operation and alert Operators when a system may not be functioning properly.

Process/treatment equipment is sometimes supplied with proprietary instrumentation and controls. The WTP instrumentation and control design will need to be able to integrate with these proprietary systems.

Controls should be located above the 200-year flood level to prevent damage to the system.

For considerations on cybersecurity, refer to Section 5.10 – Site, Building, and Digital Security.

20.2 Process Control Narrative

A process control narrative should be produced for all automated process operations. The process control narrative should briefly describe each component of the process system, including treatment and pumping equipment, distribution system components, instrumentation, and sampling monitoring, and recording equipment as applicable. The process control narrative should also identify and explain the basis of control for the system.

Piping and instrumentation diagrams (P&ID) should be developed for all process systems and should include all major and minor processes along with all ancillary process equipment.

Controls and instrumentation should be appropriate for the facility size, complexity, criticality, and number of staff and their skills. To achieve this, the Designer should develop a control philosophy that enables the operations staff to effectively monitor and control the facility and major equipment, the treatment process, water production, and plant wastes, as applicable.

20.3 Instrumentation

Selection of the level of instrumentation and control should be made in conjunction with the Water Supplier, considering factors such as:

.1 Level of maintenance and calibration required;
.2 Desired versus required level of automation;
.3 Data recording, retrieval and storage requirements; and
.4 Capital costs.

20.3.1 General Instrumentation Design Considerations

Instrumentation design considerations include:

.1 Where analyzers are part of an automatic control loop, the system lag time should be minimized to avoid hunting or other instabilities. Sample line length and transport time to the analyzer should be taken into account for proper loop control.

.2 Designers should keep sample lines as short as possible and use small diameter non-translucent piping or tubing. In general, the sample delay should be less than two minutes between the pipe and instrumentation, as determined based on the criticality (i.e. if the parameter is being used for reporting compared to if the parameter is being used for trending) of the sampled parameter. The sample piping should be configured and adequate appurtenances provided to prevent nuisance readings due to air bubbles or other interference.

.3 Parts in contact with drinking water should be easy to clean and disinfect;

.4 Parts in contact with fluids should be suitable for the conditions, including aggressive chemicals or solids that can cause abrasion;

.5 Instruments should be compatible with the environment in which they are located (e.g. high humidity, temperature, outdoors, and electromagnetic interference);

.6 Instruments should be located so that they provide accurate and reliable data (e.g. straight pipe requirements upstream and downstream) according to the manufacturer specifications;

.7 Provision should be made to measure and control pressure and flow to instruments to ensure these parameters are within the manufacturer's specifications;

.8 Convenient and safe access to the instruments should be provided for monitoring, maintenance, calibration, and testing purposes. Isolation should be provided so that an instrument can be removed and serviced or replaced. A bypass, pipe spool piece or standby unit should be provided if servicing or calibration will disrupt the production of treated water;

.9 Instruments should include a local display or a remote display if instruments are placed in difficult to access or hazardous areas;

.10 Sample points should be located to collect representative and well mixed samples (e.g. after reaction of chemicals has occurred).;

.11 Instruments should be selected to provide reliable data over the entire range required; the turndown of the instrument should be considered in instrument selection. The accuracy and precision required for the process should also be considered (cost generally increases as accuracy increases);

.12 Lifecycle cost, including maintenance and calibration requirements, and hydraulic head loss (pumping costs), should be considered;

.13 Instrumentation should be protected electrically with equipment such as surge protectors and uninterruptable power supplies. Some instrumentation in particular are very sensitive to small changes in the power supply;

.14 Instrumentation should not be located near large electrical motors; and

.15 The use of single analyzers or primary devices on a time-share basis for monitoring multiple points is discouraged especially when the measurement is being used for loop control. However, if adopted, the rate of sample flow to the instrument should be sufficient to give a true indication of the sample value within the time allotted to that sample.

20.3.2 Process Control Instrumentation Considerations

Some processes or parameters require additional considerations, including:

.1 **Flow Rates:** Main process flows are usually measured using mass flow meters, magnetic, ultrasonic, or differential pressure (e.g. venturi) flow meters. Where low head loss is needed, magnetic or ultrasonic meters are preferred. Rotameters are suitable for small flows of liquids and gases.

.2 **Streaming Current Monitors or Zeta Potential Meters**: Water systems use these types of instruments for coagulation control. For on-line instruments, there should be a 1- to 3-minute lag time between coagulant addition and when the sample reaches the sensor;

.3 **Turbidimeters and Particle Counters**: Sample lines to these online instruments should be kept short to keep the delay between sample collection and the instrument to one minute or less. In addition, Designers should provide bench-top equipment for turbidimeters so that operators can perform weekly verification checks. Turbidimeters should be placed in a location that also allows measurement of turbidity during filter to waste;

.4 **Turbidity data recording and trending for filtration plants:** The data logging system should have the capacity to handle long-term turbidity data storage needs. The SCADA should continually monitor turbidity from each individual filter effluent and record the data at least every 5 minutes.

20.4 Control System

A Programmable Logic Controller (PLC) or Distributed Control System (DCS) should be used for monitoring and control of all process systems. Where critical operation is needed, redundant PLC/DCS control systems should be provided. The control system should be designed to supply maximum reliability and safety. A minimum of 10% spare I/O should be provided for the control system to account for future expansion.

The type of control provided for the operation of a facility or process can vary from simple manual control without any automatic function (either local or remote), through semi-automatic control which combines manual control with automatic control for a single piece of equipment, to a fully automatic control system which turns equipment on and off or adjusts operating status in response to signals from instruments and sensors.

In selecting a control system, the Designer and the Owner should consider the following factors:

.1 Manual control systems:
   a. Are simpler to maintain and repair than automatic systems and are lower in initial cost, but require the on-site presence of an operator when producing drinking water; and
   b. The initial low costs may be outweighed by high labour and operating costs, including chemical and energy costs incurred by poorer process control;

.2 Automatic control systems:
   a. Provide a more consistent product with lower labour costs;
   b. Require skilled maintenance;
   c. Should provide a level of reliability appropriate for the control function; and
   d. Should be designed to have the capability to manage any set of conditions which may occur.

The Designer should select a control system based on the risks to public health, the complexity of the processes to be controlled, and should take into consideration the capability and limitations of the knowledge and skill of regular operating staff. If using automatic controls, manual override of critical operation electrical equipment should be included. Evaluation of critical controls should be determined at the start of the project so that adequate manual override controls can be integrated into the overall design.

Automatic remote-control systems should include means for detecting communication failure (e.g. by using “heartbeat” communication integrity confirmation). If communication failure occurs, the Designer should ensure safe mode operation or safe shutdown of the remote part of the system is provided. The Designer should make provisions for the system to resume operation automatically when communication is restored or remain shutdown until attended by an operator. Redundant communication pathways should be considered for critical remote controls, with either automatic or manual switching. Primary instruments (sensors or analyzers) which form part of an automatic control loop (e.g. chemical dosing systems) should have appropriate redundant means of avoiding unsafe operation in case of instrument failure. The design should minimize pressure transients in the water distribution system following shutdowns.

The control system should provide complete monitoring and alarming of all process systems. Trending and recording of major process variables should be implemented. Alarms should be clearly visible on operator Human Machine Interface (HMI) when active and should be recorded in history. An alarm log should be provided and should be accessible through the HMI.

Where process equipment can be directly controlled, an HMI should be available to view effects of any changes to the process. Secondary HMI(s) should be located, as required, to provide the necessary supervisory requirements of the facility. The HMI graphics should be consistent throughout the Water Supplier’s system and conform to the *International Society of Automation’s ISA101 Human Machine Interfaces for Process Automation Systems*.

20.4.1 Automated Operation

The Designer should consider the consequences and operational response to treatment challenges, equipment failure, and loss of communications or power.

Automated monitoring of all critical functions with major and minor alarm features should be provided; dual or secondary alarms may be necessary for critical functions. The Designer should consider and document if automatic shutdown and manual restart is necessary or desirable, to ensure the safety of the water supply. The control system should have response adjustment capability on all minor alarms. Built-in control system challenge test capability should be provided to verify operational status of major and minor alarms throughout the extreme conditions that can reasonably be expected during facility operation.

Automated shutdowns of high lift pumps due to low concentrations of chlorine residual or other water quality alarms or operational procedures, when sustained, may result in health risks similar to those experienced during power failure. Automated shutdowns should be alarmed and require operator response as quickly as possible.

20.5 Monitoring and Alarming

20.5.1 Monitoring

Facilities should be provided with equipment (including recorders, where applicable) to monitor the equipment as follows:

.1 General:
   a. Containment/chemical spill;
   b. Hazardous gas(es);
   c. Off-specification volume;
   d. Overflow;

.2 Raw water instrumentation:
   a. Low-level switches to shutdown the raw water pumps. These should be hard-wired to the starters;
   b. Running and trip indication for raw water pumps;
   c. System pressure;
   d. Instantaneous flow rate and totalized volume per day;

.3 Rapid mixer:
   a. Running and trip indication;

.4 Flocculators:
   a. Running and trip indication;
   b. Speed (if variable speed type);

.5 Clarification systems:
   a. Flow rate
   b. Re-circulator speed indication;
   c. Speed (if variable speed type)
   d. Running and trip indication;
   e. Level indication;
   f. Blowdown valve status;
   g. Sludge level;
   h. Instrumentation for proprietary types of clarifiers, including ballasted flocculation and DAF, should be as recommended by the manufacturer. However, effluent turbidity and pH are recommended in all cases;

.6 Filtration:
   a. Pressure differential or head loss;
   b. Effluent control valve position;
   c. Filter run time;
   d. Filter status (e.g. on-line, backwash required, in backwash, ready, off-line);
   e. Filtration rate/flow rate;
   f. Totalized flow;
   g. Water level in filters;

.7 Backwash for filtration:
   a. Backwash flow rate and totalized volume;
   b. Air scour/surface wash status;
   c. Air scour flow rate;
   d. Control sequence status, when automated;
   e. Surge protection for air blowers;

.8 Chemical systems:
   a. Running and trip indication for chemical loading, batching and pumping equipment;
   b. Low and high-level alarms in storage bins, silos or tanks;
   c. Level indication for tanks;
   d. Weigh scales for hydrofluosilicic acid day tanks or storage (if no day tank is used);
   e. Weigh scales for gaseous feed chemicals, such as chlorine or sulphur dioxide;
   f. Speed indication on variable speed pumps;
   g. Rotameters for carrier water feed systems;
   h. Chemical feed flow rate is mandatory unless day tank is provided;
   i. Ambient gas alarms (chlorine, ozone);
   j. Gas scrubber indication;

.9 Pumps, mixer and motors:
   a. Bearing temperature;
   b. Mixers speed/power;
   c. Moisture detection (submersible motors);
   d. Power draw;
   e. Run time;
   f. Running and trip indication;
   g. Running status;
   h. Speed (if variable speed type);

.10 UV disinfection:
   a. Ballast power;
   b. Flow rate;
   c. Lamp status;
   d. Off-specification volume;
   e. Run status;
   f. Run time;
   g. UV intensity;
   h. Refer to the Guidelines for UV Disinfection of Drinking Water;

.11 Clear well & distribution pump instrumentation:
   a. Level indication for clear well and other tanks;
   b. Low-level switches to shut down the distribution pumps. These should be hard-wired to the motor starters;
   c. High lift discharge pressure;
   d. Instantaneous flow rate and totalized volume per day;
   e. Minimum water level where it is required for confirmation of primary disinfection CT;
   f. For variable speed pumps, indicate the pump speed;

.12 Miscellaneous instrumentation:
   a. Run time meters on all pumps and major electrically-driven equipment;
   b. Speed, run time, oil pressure and temperature gauges, fault signal switches and manual start and shutdown on engines;
   c. Where the plant is automated or operated remotely from either within the plant or outside, provide open and close limit switches or position on all major valves, status on all major equipment and security instruments including door switches, remote resets, building temperature switches and smoke alarms;

d. All water supplies should have an acceptable means of measuring the flow from each source, backwash water, recycled water, any blended water of different quality, and finished water; and
e. Any additional instrumentation recommended by equipment manufacturers.

For water quality parameters that should be monitored, refer to Chapter 22 – Water Quality Monitoring.

Remote operation of the water treatment facility using supervisory control and data acquisition (SCADA) systems should be considered. The SCADA system should:

.1 Be capable of monitoring and recording on-line instrumentation data;
.2 Be capable of adjusting set points of critical functions and key parameters within the plant;
.3 Be designed with adjustable alarms for monitoring of critical plant functions, key process parameters and/or equipment status;
.4 Be capable of remotely notifying the appropriate individual when problems arise, in addition to the nature of the problem;
.5 Be provided with off-site controls for adjusting critical plant functions;
.6 Only be provided in-conjunction with an available off-site operator with an adequate response time; and
.7 Include appropriate security controls. Refer to Section 5.10 – Site, Building, and Digital Security for more information.

20.5.2 Alarms

Designers should identify alarm conditions, especially for critical process components, where very high or very low levels could lead to unsafe water delivered to customers. Critical alarm conditions for drinking water treatment and supply facilities can include water quality and physical parameters; refer to Chapter 22 – Water Quality Monitoring for guidance on implementing water quality monitoring.

All alarms should be latched until the operator has acknowledged them. If the alarm is indicated by a lamp, it should flash until acknowledged then remain steady until the alarm clears. If it is indicated on a computer screen, an appropriate colour code or symbol should be used to indicate whether it has been acknowledged. Automated systems should log the time at which the alarm occurred, the time it was acknowledged, and the time it cleared. Logs may be printed on paper or recorded electronically.

Valve and equipment status should use a consistent method of symbols and colours, whether the status is indicated through lamps or on a colour computer screen. The colour-coding scheme should be consistent with any existing equipment displays elsewhere in the plant.

As a minimum, the following alarms should be provided:

.1 Raw water
  a. High turbidity
  b. High and low pressure on the raw water line
  c. High and low flow rate
  d. High and low pH (if on-line measurements are provided)
.2 Clarification
  a. High and low water level in clarifiers or flocculators

   b. High torque on process rotating elements (e.g. basin mixers, flocculators, solids contact clarifier recirculator and rakes)
   c. High water level in process basins and open surface channels
   d. High turbidity in clarifier effluent

.3 Chemical systems
   a. High and low level in chemical storage tanks
   b. High and low chemical feed rates
   c. Chlorine gas detection in the chlorine storage, metering and injector rooms
   d. Chlorine scale low weight (where scales are equipped with transmitters)

.4 Filters
   a. High flow rate on each individual filter (also low flow rate on declining rate filters)
   b. High head loss on the filters (if influent flow splitter or constant rate type)
   c. High turbidity on filter effluent and combined effluent

.5 UV disinfection
   a. Refer to *the Guidelines for UV Disinfection of Drinking Water*

.6 Pumps
   a. High and low water levels in each clear well, pump well, and reservoir
   b. Trip or failure to run on each pump and process motor

.7 Residuals management
   a. Sludge density
   b. Flow rate
   c. Temperature

.8 Treated water
   a. High and low pH (if on-line measurements are provided)
   b. High and low chlorine residual on the plant discharge (where on-line measurements are provided)
   c. High and low pressure on the plant discharge line
   d. High and low flow rate
   e. High turbidity
   f. Valve operation failure (where valves are provided with limit switches)

More alarms may be recommended or required where additional treatment processes are provided and/or if pathogen log reduction credits are assigned. Reference should be made to the *Guidelines for Pathogen Log Reduction Credit Assignment* for criteria for each treatment process.

Alarms should be provided for all control system interlocks that can shut down equipment or systems. In plants that are left unattended, an automatic telephone dialler, cellular communication or pager system should be provided for annunciation of alarms.

20.6 Reliability and Security

The design of facilities should be based on the premise that failure of any single component must not prevent the drinking water system from satisfying all applicable regulatory requirements and other site-specific treated water quality and quantity criteria, while operating at design flows.

A water treatment process that is designed with a limited number of treatment barriers, and/or has less treatment contact time than conventional processes, must have a commensurate level of reliability and redundancy of its components.

The Designer should consider the following for designing and documenting the reliability of the proposed drinking water system:

.1 Regulatory requirements and other site-specific treated water quality and quantity criteria during the full range of design flows and operating conditions;
.2 Likelihood of the system having reduced levels of treatment/performance;
.3 Risk to the performance of the system and in turn to the environment;
.4 Risk to public health and safety if the level of treatment and performance of system components are reduced;
.5 Local conditions and constraints, such as accessibility of the site, reliability and redundancy of the power supply, etc.;
.6 Manner and methods by which reliability is provided so that reduced treatment or performance and bypasses can be eliminated;
.7 Individual process unit/equipment reliability and redundancy analysis to define the following:
   a. Critical process units/equipment;
   b. Critical events;
   c. Estimated event duration;
   d. Actions/safeguards;
   e. Effect on treated water quality and/or quantity;
.8 Hardware and software should be selected based on reliability, compatibility and vendor support. Equipment should be robust enough for continuous operation in the plant environment. Hardware and software necessary to facilitate back up of both the system and the collected data should be provided locally. A system and data recovery procedure should be included in the project documentation, which should also be remotely accessible; and
.9 Response capabilities of operations staff, including response times and operation knowledge and skill levels.

The Designer should consider methods of improving reliability through transient protection wherever possible (e.g. mains, filters and transient surge protectors). Radio modem and other data transmission equipment should use methods to ensure the integrity of the data transmitted against corruption/interference. Encryption of signals for data/control security may be considered. When long instrument or equipment wiring is present, induced current protection should be installed.

Network configurations should be designed with security in mind. Protection of fibre optic or local area network (LAN) cabling in conduits should be considered to protect from physical damage. Harmonics and other electrical related disturbances to signal integrity should be taken into consideration.

Power supply design should include back up power by using true online uninterruptible power supply (UPS) or equivalent power systems. Buffered direct current (DC) power supply should be selected. Critical instrumentation should be connected when possible to the same back up power as the control system to allow monitoring during power outages. Consideration of the impacts of power failures on critical instrumentation and control should be taken into account, especially with respect to the reset conditions of the devices.

Surge protection devices should be provided to protect sensitive electronic equipment.

20.7 Communication Networks

Communication networks may assist operations and maintenance personnel with the following functions:

.1 Device diagnostic data;
.2 Remote calibration;
.3 Device alarm status;
.4 Distributed control by locating PLC/DCS in close proximity to devices being monitored;
.5 Plant data can be made available for use by management; and
.6 Loop error is reduced.

20.7.1 Internal Communication Networks

Networks used within the site for controls should be provided as follows:

.1 Control network for PLC/DCS control system using ethernet communications;
.2 Facilities with large numbers of instrumentation and field devices should use device networks utilizing Profibus, HART, or Modbus communications when available, for easier calibration and monitoring of equipment. Smaller and simpler facilities with limited instrumentation or instrumentation not capable of digital communications should use digital and/or analog hardwired signals (i.e. 4-20 mA current loops);
.3 SCADA network utilizing ethernet communications;
.4 Ethernet based networks should use CAT6 connections. Fibre optic cables should be used whenever ethernet cables exceed 90 meters in length; and
.5 Profibus networks should use Profibus PA (Process Automation) instrumentation whenever possible and Profibus DP (Decentralized Peripheral) only if Profibus PA is not available. Provide appropriate Profibus PA to DP gateways or Profibus to Ethernet/IP gateways, as required, to connect Profibus instrumentation to PLCs.

20.7.2 External Communication Networks

The following external networks should be provided as follows:

.1 A telephone line should be provided for site communications, and a second telephone line should be provided for critical alarming functions. If possible, these should be dedicated lines;
.2 Radio communications should be considered for communications to SCADA networks. Alternatively, private cellular communications can also be considered where available; and
.3 If available, internet access to the site should be provided, but should not be used as an emergency line. Internet access can be used for remote access functions where necessary. The Designer should ensure that the necessary security measures are considered when using internet access in this manner.

20.7.3 External Communications Network Reliability

Dedicated networks provide the greatest reliability as communication on the line is reserved entirely for the site. Dedicated lines, however, are becoming increasingly rare and may not be provided by local communications utilities. A private dedicated line can be considered if cost implications can be justified.

Radio communication networks can be extremely reliable as redundancy can be easily incorporated into the design through the addition of multiple radio paths and redundant equipment. The Designer will have to determine the level of redundancy required based on how critical the operation of the site is considered to be, and on local site conditions. A well-designed radio network should be able to provide better than 99.9% reliability.

Reliability of the telephone line is dependent on the provider, location of the site, local conditions, and amount and type of information being transmitted. The Designer *s*hould consider these factors when determining if a telephone system would be adequate for the communication requirements to the site.

21 Small Systems

21.1 General

The recommendations discussed throughout the *Design Guidelines* are applicable to all water systems; however, this section of the *Design Guidelines* provides recommendations specifically for small systems. The DWPR defines a small system as "a water supply system that serves up to 500 individuals during any 24 hour period".

The majority of water systems in B.C. are small systems. Sometimes these systems have limited financial, administrative, and management capacity which creates operational and management challenges that limit their ability to maintain and improve system infrastructure, install adequate treatment to provide potable water, comply with regulatory standards, or to appreciate the health risks associated with their water supply. Given these challenges and wherever possible, small systems should be designed to minimize operational complexity and O&M costs. In general, highly complex treatment systems are not suitable for small systems.

Before designing a new small water system, other options for water supply should be considered: where feasible, amalgamation with regional districts or connection to nearby municipal-scale drinking water systems is highly recommended over a new construction.

The *Small Water System Guidebook* by the Ministry of Health provides extensive guidance to small systems Owners on owning, operating and maintaining a small water system. This chapter in the *Design Guidelines* provides considerations and design recommendations specifically for small systems recognizing the challenges that these systems face. For detailed design guidance on specific treatment technologies, the previous chapters in the *Design Guidelines* should be referenced.

21.2 Approval Process

The approvals needed for small systems are similar to those for larger systems. Proponents planning a small system should consult with their Issuing Official to discuss the scope of the project, the approvals process that should be followed and to determine applicable regulatory requirements. The Issuing Official may choose to simplify the approvals process based on the complexity of the water supply system.

21.2.1 Construction Waiver Request

Under Section 6(3)(c) of the Drinking Water Protection Regulation, an Issuing Official may waive the requirement for a Construction Permit in the case of a small system. The *Drinking Water Officers' Guide* recommends that the Issuing Official consider whether, and to what extent, a Construction Permit is necessary to address potential risks to public health. This may include consideration of all relevant information, such as:

.1 The nature and complexity of the proposed water system;
.2 The source of water that will be used by the system and the potential for a health risk to arise;

.3 The likelihood that the applicant is prepared to accommodate suggestions or requests of the Issuing Official in the absence of any formal legal requirement for the approval of a Construction Permit;
.4 The knowledge and experience of the people undertaking the construction; and
.5 In the case of systems using point-of-entry (POE) or point-of-use (POU) treatment, whether the Issuing Official believes it is necessary to impose conditions respecting construction, design or equipment in order provide reasonable confidence that the POE/POU devices will be able to provide potable water, and where such conditions could not likely be addressed through an Operating Permit.

21.3 EOCP Certification and Operator Training

Under Section 4(2) of the DWPR, small systems are not required to have a Certified Operator to operate, maintain or repair their system because small systems are not prescribed for the purposes of Section 9 of the DWPA which sets out qualification standards for persons operating water supply systems. Despite Section 4(2) and under Section 12(4) of the DWPR, an Operating Permit may require a person to be certified to operate, maintain or repair a small system. For these systems, Designers should contact the Environmental Operators Certification Program (EOCP) early in the design process to discuss operator certification requirements.

For all water supply systems, regardless of size and operational complexity, operators should have the necessary competencies to operate and maintain their drinking water systems. For small systems, small water system courses are available that provide drinking water treatment and distribution training.

21.4 Water Demand

21.4.1 Domestic Water Demand

When determining domestic water demands for a small system, refer to Chapter 3 – General Design Guidance. For consideration, peaking factors are generally higher for small systems and irrigation districts.

As a minimum, the water supply/treatment facility should be designed to meet the projected maximum daily flow requirement of the service area with peak hourly, outdoor use and fire demands met from storage. Where it is possible to develop the water source to meet more than the projected maximum daily flow, the storage volume can be reduced accordingly.

For design purposes, existing reliable records should be used wherever possible. In the absence of local bylaws, reliable records, or information from neighbouring systems, the Designer should calculate the critical demands using the following basic demand parameters:

.1 Average Day Demand (ADD) – The quantity of water used in a system in an average day. The ADD is used to verify source capacity, and to derive peak demands from metering data.

In the absence of metering data, ADD can be estimated using the population served by the water system and values for domestic water demand (volume per person per day):

ADD = population* x domestic water demand

* population value should reflect the design horizon (i.e. expected population change over design period)

Domestic water demand values historically used in system design have ranged from 180 to 1,500 L/(cap·d). With increased use of water metering, conservation and low-use fixtures, the Designer may find values at the low end of this range to be better representative of the system needs.

These values represent the average flow over a 24-hour period; they do not reflect the daily or hourly maximum demands which will exceed the average value by a significant amount. It is essential that the source of supply and the distribution system is capable of meeting these maximum and peak demand rates without overtaxing the source or resulting in excessive pressure loss in the distribution system.

.2 Maximum Day Demand (MDD) – the maximum water flow rate supplied to the system on any given day within a calendar year. A small water system should be designed to supply at least the MDD. The MDD can be calculated as:

MDD = MDF x ADD

Where the maximum day factor (MDF) can be found in Table 21-1;

.3 Peak Hourly Demand (PHD) – The maximum hourly flow rate supplied by a water system. The PHD is a critical design parameter for sizing pipes, pumps and treatment works between balancing storage and customers. The PHD can be calculated as:

PHD = PHF x (ADD ÷ 24)

The peak hour factor (PHF) can be found in Table 21-1.

.4 Fire Flow Demand – the rate of water flow, at a required pressure and for a specified duration, that is necessary to control a major fire. Fire flow demand is calculated based on the Fire Underwriters Survey (FUS) document *Water Supply For Public Fire Protection – A Guide to Recommended Practice*. Fire flow demand is a critical design parameter for determining maximum network flows, verifying minimum system pressures, sizing pipes/pumps/treatment works between fire storage and customers/fire hydrants. Refer to Section 21.4.2 – Fire Flow Demand for more information.

Table 21-1 Small Systems Peaking Factors (sourced from Ontario Design Guidelines 2008)

Population	Dwelling Units Serviced	Night Minimum Hour Factor	Maximum Day Factor (MDF)	Peak Hour Factor (PHF)
30	10	0.1	9.5	14.3
150	50	0.1	4.9	7.4
300	100	0.2	3.6	5.4
450	150	0.3	3.0	4.5
500	167	0.4	2.9	4.3

The MDD and PHD may need to include consideration of outdoor water use (i.e. for gardening or cleaning). For outdoor water use, it should be assumed that a maximum of 25% of the homeowners could be using an outdoor tap at any one time, at a rate of 20 L/min for one hour per day. Where fire protection is provided, then this outdoor use need not be considered.

21.4.2 Fire Flow Demand

When deciding if a small system should be sized for fire flow, the following should be considered:

.1 Availability of an adequate supply of water;
.2 Additional capital and operating costs associated with such a system;
.3 Availability of an adequate fire department, fire service communication and fire safety control facility; and
.4 Alternatives to a piped communal fire facility such as residential sprinkler systems.

For small systems, the Designer should also consider that provision of fire flow can impact residual chlorine in the distribution system due to the need for increased pipe sizes and additional water storage volume.

A small system may often get fire protection from a neighbouring larger municipality if it falls inside a Fire Protection District. The Fire Underwriters Survey™ makes special provisions for classifying the level of fire protection in these cases.

21.4.3 Non-Residential Water Demand

Institutional and commercial flows should be determined by using historical records, where available. Where no records are available, the values in Table 21-2 should be used. For other commercial and tourist-commercial areas, an allowance of 28 $m^3/(ha\cdot d)$ average flow should be used to calculate ADD in the absence of reliable flow data.

Table 21-2 Typical Water Demands for Selected Commercial and Institutional Users

Type of Establishment	Maximum Daily Demand (L/d)
Boarding house (per boarder) **Additional kitchen requirements for non-resident boarders**	190 40
Camp: Construction, semi-permanent (per worker) Day, no meals served (per camper) Luxury (per camper) Resort, day and night, limited plumbing (per camper) Tourist, central bath and toilet facilities (per person)	 190 60 380 - 570 190 135
Factory (litres per person per shift)	60 - 135
Highway rest area (per person)	20
Hotel: Private baths (2 persons per room) No private baths (per person)	 190 190
Institution other than hospital (per person)	285 - 475
Laundry, self-serviced (litres per washing (per customer))	190
Motel: Bath, toilet, and kitchen facilities (per bed space) Bed and toilet (per bed space)	 190 155
Park: Overnight, flush toilets (per camper) Trailer, individual bath units, no sewer connection (per trailer) Trailer, individual baths, connected to sewer (per person)	 95 95 190
Restaurant: Toilet facilities (per patron) No toilet facilities (per patron) Bar and cocktail lounge (additional quantity per patron)	 40 12 10
School: Day, cafeteria, gymnasiums, and showers (per pupil) Day, cafeteria, no gymnasiums or showers (per pupil) Day, no cafeteria, gymnasiums or showers (per pupil)	 95 80 60
Service station (per vehicle)	50
Store (per toilet room)	1550
Worker: Construction (per person per shift) Day (school or offices, per person per shift)	 190 60

21.4.3.1 Campground Water Systems

The peak water usage rates in campgrounds will vary with the type of facilities provided (e.g. showers, flush toilets and clothes washers) and the ratio of these facilities to the number of campsites. A peak hour factor of 4 is recommended, and this factor should be applied to the average expected water usage at full occupancy of the campground.

21.4.3.2 Ski and Mountain Resorts

For ski and mountain resorts, the critical peak water demand period typically includes the two weeks over the winter holiday season. Maximum day demands should be considered for at least this entire period (14 consecutive days) and at 100% occupancy rate. Due to the timing of the peak demand period, the MDD is calculated without irrigation provisions. However, water demands for snow making may be applicable *(FLNRORD, 2012)*.

21.4.3.3 Summer Resorts

Golf and other summer use resorts differ from mainly winter use resorts in that the peak demand period typically occurs in the summer season. Therefore, irrigation demands for golf courses, park facilities and other irrigable areas need to be added to indoor demands to derive design parameters. Irrigation demands for golf courses should be determined by a qualified golf course designer. The use of reclaimed water following all applicable sewage regulations and health standards may be applied towards irrigation demands for golf courses and similar facilities *(FLNRORD, 2012)*.

21.4.4 Industrial and Agricultural Water Demand

Industrial water demands are often expressed in terms of water requirements per gross hectare of industrial development when the type of industry is unknown (e.g. new industrial parks). These demands will vary greatly with the type of industry, but common allowances to calculate ADD for industrial areas range from 35 $m^3/(ha \cdot d)$ for light industry, to 55 $m^3/(ha \cdot d)$ for heavy industry. Peak usage rates will generally be 2 to 4 times the average rate depending on factors such as the type of industry and production schedule. When the type of industry is known, discussions should be held with representatives of the industry to determine water requirements.

Agricultural water demands depend on several different parameters such as evapotranspiration, type of crop, number and type of animals serviced, size of area, soil types, the climatic zone which the Water Supplier is in, and irrigation efficiency. Reference should be made to the *Design Guidelines for Rural Residential Community Water Systems* (FLNRORD, 2012) for guidance on irrigation calculations.

21.5 Source Water Development

The Designer should demonstrate that an adequate quantity of water is available to meet the demands of the water supply system. Chapter 6 – Source Water should be reviewed for recommended best practices on source water selection. This section provides the Designer with information specific to source water development for small systems.

21.5.1 Surface Water

Subject to the source and the requirements of the regulator, a hydrology study by a professional hydrologist may be required to confirm water availability.

The reliable yield of the source, after the flow has been regulated by seasonal balancing storage, should be adequate to supply the maximum day demand during moderate dry periods. A moderate drought is considered to be a 7-day period with streamflow at 10-year drought levels (i.e. the lowest flow rate expected in a 10 year period).

21.5.1.1 Intakes

Intake works should be designed to optimize water quality, minimize maintenance and minimize adverse environmental impacts. They should not obstruct the passage of vessels in navigable waters.

Intakes should be sized to the ultimate capacity of the small system to limit disturbance to the aquatic environment. The capacity of the intake should be the MDD anticipated for the next 50 years. Screens should be easy to clean and designed to meet the requirements of the Department of Fisheries and Oceans regulations. If the flow rate is less than 150 L/s, the intake screens should be designed to meet the requirements set out in the *Freshwater Intake End-of-Pipe Fish Screen Guideline* by the Federal Department of Fisheries and Oceans (DFO).

Submerged intake pipes in rivers and lakes should be graded to prevent accumulation of gases and be adequately anchored and buried. Stream intakes should be sited in a stable reach of the channel, where erosion or deposition will not endanger the works and in such a way that the natural regime of the stream will not be upset. Provision should be made to remove sediment from the pipe by incorporating a back-flushing device. Intakes should also be protected from ice build-up.

Intake works should be protected against unauthorized persons and contamination from domestic, industrial or other harmful wastes or runoff. A fence with signage around the intake is recommended to deter unauthorized personnel. The intake works should be reasonably accessible in all seasons so that the intake can be regularly inspected.

21.5.2 Groundwater

Wells must be designed, located, constructed, tested and disinfected in accordance with the requirements of the Groundwater Protection Regulation (GWPR).Refer to Section 6.3 – Groundwater for more information.

Two wells are recommended, with at least one being capable of providing the MDD. The well(s) should be capable of sustaining the MDD continuously for 100 days without recharge by precipitation. Both wells should be on-line and alternating in use. If both wells cannot provide MDD, at least one day of storage should be provided. Where only a single well is available, provide backup power and shelf spares for the well pump.

21.5.2.1 Well Drilling

Well drilling should be completed by (or under the direct supervision of) a Qualified Well Driller (QWD) registered in British Columbia. The QWD will work in conjunction with (or be supervised by) a

Professional Geoscientist or Engineer registered in British Columbia. Drill cuttings should be collected at regular intervals to determine the depth, thickness and characteristics of aquifers and aquitards (confining layers).

A pumping test is required for each new production well. The objective of the test is to document the actual performance of the well (yield and water quality) and ideally, stress it beyond the desired capacity.

21.5.2.2 Well Location

Production wells should be fully accessible at all times using a statutory right of way written in favour of the Water Supplier. Well sites should not be subject to flooding and site grading should direct surface runoff away from the wellhead. Additionally, wellheads should be extended at least 300 mm above final ground elevation or 1 m above the 100-year flood level or the highest known flood elevation, whichever is higher. Additionally, well casing should extend above typical snow accumulation levels. Provincial regulations stipulate specific construction details for wellheads.

Well location should consider ease of future access for rehabilitation. Specialized well covers are available for cold climates. Electrical equipment, water treatment and disinfection can be incorporated into an adjacent (or centralized) enclosure. Kiosks in lieu of pump houses may be an acceptable alternative.

All wells, pump houses and kiosks should be located within a secure fenced area to prevent vandalism and unauthorized access.

Reference should be made to Chapter 6 – Source Water and the GWPR Handbook for well construction, set back and siting requirements.

21.5.3 Rainwater

Rainwater is defined as water collected from natural precipitation. It is typically harvested by collecting runoff from a catchment area/roof or a capture device designed to intercept rainwater, which is directed into a cistern or storage container, prior to treatment. When using rainwater as a source water, the *Guidance for Treatment of Rainwater Harvested for Potable Use in British Columbia* by the Ministry of Health and the *CSA Rainwater Harvesting Systems Standard* (CSA B805-18/ICC 805-2018) should be referenced. The Canada Mortgage and Housing Corporation (CMHC) *Guidelines for Residential Rainwater Harvesting Systems Handbook* provides additional considerations.

Table 21-3 provides general design considerations for rainwater harvesting systems.

Table 21-3 Rainwater Harvesting Water System Design Considerations (Sourced from Ministry of Health, 2020)

Design Considerations	Reasoning
Collection potential	Amount of available precipitation in the area.
Output demand	Required storage volume for intended use.
NSF/ANSI 61, NSF/ANSI 372, and NSF P151 materials (or third party certification)	Ensures materials adhere to minimum established health effects requirements for any chemical contaminants or impurities that are imparted to the water.
Air gap or backflow preventer	Prevent potential cross contamination with other water supply system(s).
Inlet pre-filter and inlet cover	Prevent entry of debris, roof contaminants and pests into water supply.
First flush diverter*	Reduce contaminants in the harvested water supply.
Food-grade plastic storage	Retains acidic nature of harvested rainwater which can inhibit microbial growth.
Covered or shaded storage	Retains cool temperatures of stored water which can slow microbial growth.
Calmed inlet	Brings oxygenated water to lower levels of tank, preventing stagnation and disturbance of debris at bottom of tank.
Floating intake	Extracts water from just below the surface, where it is cleanest.
Alarm systems	Systems to monitor, alert or shut-off supply when intake or output water quality standards are not being achieved due to power failure or other incidents.
Secured access	Prevents unauthorized access to water supply.

* A first flush diverter, as per Section 3.1 of the CSA/ICC *Rainwater Harvesting Systems* standard, is a device or method for removal of sediment and debris from collection surface by diverting initial rainfall from entry into the storage tank. *NSF/ANSI 61* provides further guidance on how to perform an effective flush. First flush diverters should be installed correctly and maintained regularly to work properly.

21.5.3.1 Quantity

In determining if rainwater is a suitable source water, the Designer should use rainfall data collected over many years, using monthly rainfall data. The size of the catchment area (the size of the roof being used) should be confirmed. The quantity analysis should also include a safety factor to account for potential climate change impacts. Rainfall may not be adequate during all parts of the year and may need to be supplemented with an alternative source (such as bulk filling the storage cistern or providing make-up water from a potable source with an air gap) during the dry season. A feasibility analysis for an alternative source should be conducted.

Figure 21-1 demonstrates how to calculate the volume of water that can be collected from a roof catchment, where the height is the estimated depth of rainfall.

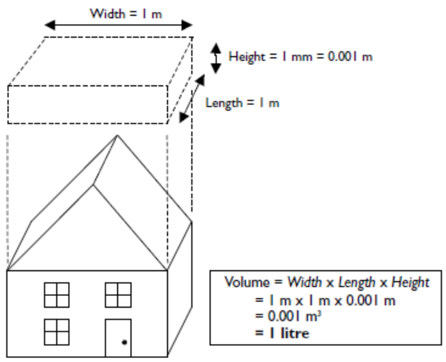


Figure 21-1 Rainwater Catchment Sizing (adopted from Guidelines for Residential Rainwater Harvesting Systems Handbook, CMHC)

For general considerations on small water system demand and system sizing, refer to Section 21.4 – Water Demand. Additional considerations for rainwater quantity forecasting and storage recommendations can be found in the CSA B805-18/ICC 805-2018 standard and the CMHC Handbook.

21.5.3.2 Quality

Rain is acidic and extremely low in dissolved solids and alkalinity. These properties could lead to increased leaching of contaminants from contact materials; therefore, all materials in contact with rainfall, including paints, linings, and coatings, should be certified under *NSF/ANSI 61 Drinking Water System Components – Health Effects* or *NSF P151 Certification of Rainwater Catchment System Components*. Corrosion control measures, such as pH adjustment, should also be considered.

Off-site and on-site contaminants may impact the water quality; as such, it is recommended that a risk identification and assessment is conducted as described in Section 4.4 of the *Guidance for Treatment of Rainwater Harvested for Potable Use*. Sampling should occur during the initial portion of a storm event following arid conditions.

Additionally, the material and cleanliness of the rainfall catchment will directly impact the quality of the water. Due to this, inclusion of a first flush diverter is recommended. Refer to Table 21-3 for more information.

21.5.3.3 Rainwater Harvesting Systems

A rainwater harvesting system is any system used to collect, convey, store, treat and distribute rainwater for use.

Rainwater catchment system design should consider the following:

.1 Smooth and impervious materials are the most efficient for conveying rainwater;
.2 Stormwater design guidelines should be referred to for determining the runoff coefficient of the catchment material;
.3 Systems should be protected against access from unauthorized persons;
.4 Gutters should have leaf screens to prevent debris from entering the system; and

.5 First flush diverters should be installed and maintained regularly.

The *CSA Standard B128.1/B128.2 Design and Installation of Non-Potable Water Systems/Maintenance and Field Testing of Non-Potable Water Systems* should also be referenced for rainwater storage guidance. The following should be considered when storing untreated rainwater:

.1 The inlets, outlets and overflows should have a screen;
.2 Provisions for ongoing inspection, water quality sampling, cleaning and maintenance should be incorporated into the design;
.3 Completely opaque storage should be used to store rainwater to prevent algae growth;
.4 Storage time, excessive stagnation times can adversely affect water quality;
.5 The storage should be accessible for bulk refills;
.6 Storage should be thermally resistant and a light colour to prevent temperature fluctuations in stored water;
.7 Storage tanks should not be placed directly under sanitary, waste or storm drains; and
.8 Storage should be covered and not located in direct sunlight.

21.6 Facilities

Small system facility design and construction should allow convenient, and safe access for removal and service of equipment. A simple layout should be used to minimize operational and maintenance procedures, consider operator health and safety, and limit system replacement costs. Facilities should be in compliance with the *BC Building Code*, the requirements of the *Workers Compensation Board* (WCB) and all other applicable codes, standards and regulations.

21.6.1 Facility Siting

The following should be considered when choosing the site of the facility:

.1 Operator safety, including proximity to high pressure watermains and pumped wells;
.2 Zoning and building code compliance and community acceptance;
.3 Noise pollution considerations if the system is likely to produce significant noise;
.4 Room for expansion;
.5 Operator access for equipment maintenance and operator safety, including space for equipment removal and crane or other lifting aid access;
.6 Reliable power supply and electrical distribution system capacity; and
.7 Geotechnical considerations, including soil stability, slope failure analysis, site drainage etc.

Refer to Chapter 4 – Climate Change Risk Assessment and Adaptation for considerations for the siting of a facility related to climate change.

21.6.2 Facility Design

The following should be considered when designing a facility for a small system:

.1 Provisions for future expansions: for example, providing additional room in the facilities, installing spare pump bases and blind flanges to simplify installation of future equipment;
.2 Provision of adequate space to enable access and working space for all equipment. This includes space required to maneuver tools and equipment necessary to perform the entire spectrum of operation and maintenance procedures. Aisle widths of minimum 1.0 m should be maintained (measured with doors and panel doors swung open) for access ways

throughout to the exit doors. The vertical clearance of the building interior should be 2.4 m minimum;

.3 Provide a wall-mounted thermostat-controlled unit heater to prevent freezing;

.4 Provide adequate ventilation to prevent excessive humidity and maintain safe environmental conditions. Ventilation rates should be based on achieving a minimum of two air changes per hour in unoccupied conditions. Chemical storage rooms should have at least 12 air changes per hour;

.5 A keyed lock should be installed on the door; and

.6 Provide hazard signage on the door to any room containing chemicals warning of the presence and hazard(s) of the chemicals.

21.6.3 Mechanical Equipment

The following should be considered for mechanical equipment for small systems:

.1 PVC and copper piping are the most common process pipe material used in small systems;

.2 All internal piping should be properly supported, using corrosion resistant materials;

.3 Unions and isolation valves should be installed at pressure tanks, booster pumps, and other equipment to allow for equipment removal;

.4 All equipment should be secured to concrete housekeeping pads a minimum of 100 mm above the floor;

.5 The following should be installed:

- a. ASME pressure relief valve(s) properly sized based on flow;
- b. A totalizing source meter inside the facility;
- c. House keeping pads, if pressure tanks are used;
- d. Raw water and treated water sampling taps in an accessible location at least 200 mm above the floor;
- e. Drain port and valving at low points in internal piping systems. If chemicals are used, drain valves should be contained within sumps;

.6 Pressure gauges should be positioned so they are easily readable;

.7 Gate or ball valves, especially for suction isolation, may be used for smaller sized piping;

.8 Mechanical piping should minimize the number of high points. Any high points in the piping system should be equipped with an automatically operated air release valve; and

.9 Operator facilities, including drinking water and sanitary facilities, may lead to a significant increase in cost for small systems. Where such facilities may be available elsewhere, the Designer should consult with the Owner to determine whether such facilities are necessary.

21.7 Treatment

21.7.1 General Treatment Guidance

Section 6 of the DWPA states that subject to the regulations, a water supplier must provide, to the users served by its water supply system, drinking water from the water supply system that (a) is potable water, and (b) meets any additional requirements established by the regulations or its Operating Permit.

Section 5 (2) of the DWPR states that drinking water from a water supply system must be disinfected by a water supplier if the water originates from (a) surface water, or (b) groundwater that, in the opinion of a drinking water officer, is at risk of containing pathogens.

Table 21-4 provides some general guidance specific to treatment and disinfection for small systems. The respective chapters or guideline documents should be reviewed for detailed guidance on the design of any of the systems.

Table 21-4 General Treatment Guidance for Small Systems

Treatment Method	Small System Treatment Design Considerations	Reference Chapter
UV disinfection	UV reactors should be validated using an accepted validation protocol or certified to NSF Standard 55 Class A. NSF Standard 55 Class B certified systems should not be used for the production of potable water.	Chapter 11 – Disinfection and Ministry of Health *Guidelines for Ultraviolet Disinfection of Drinking Water*
	The NSF Standard 55 does not require Class A certified systems to have a UV monitor. However, provision of a UV monitor and a reference UV sensor may be required to allow for monthly calibration verification checks of the duty UV sensor.	
	For a surface water or GARP water supply, filtration should be installed upstream of UV disinfection to pre-treat water entering the UV reactor, or the water supply should receive a filtration exemption from a Drinking Water Officer.	
	Water entering a UV reactor should meet water quality requirements specified by the UV equipment manufacturer or values listed in the *Guidelines for Ultraviolet Disinfection of Drinking Water*. Pre-treatment or on-site determination of the combined aging and fouling factor may be required.	
Clarification	Plate settlers are the preferred method of clarification; check that the hydraulic upflow rate conforms to the *Design Guidelines* based on projected area.	Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification
	Static mixers are the preferred type of flash mixer. A water flushing feature should be provided for the flash mixer. The flash mixer design should consider the full range of anticipated flowrates.	
	Hydraulic flocculation is the preferred option. The flocculation design should consider the full range of anticipated flowrates and in cold-water conditions.	
	Check to ensure flushing lines, drains and sludge disposal features are included in the design for flocculators and clarifiers.	
Chemical systems	Sizing a chemical system for a small system is dependent on site-specific criteria, including: 1. Demand of the system; 2. Reserve volume requirements and typical chemical delivery lag times; 3. The rate of decay of the chemical; and	Chapter 13 – Chemical Application

Treatment Method	Small System Treatment Design Considerations	Reference Chapter
	4. Emergency scenarios, where a delay in delivery may affect the availability of the chemical.	
Filtration	Slow sand filters are the preferred method of filtration for small systems if filtration is deemed necessary, followed by rapid rate gravity filters. Pressure filters may be used for contaminant-specific treatment but will not be awarded pathogen log reduction credits.	Chapter 8 – Filtration
	Cartridge filters are suitable low maintenance systems for small systems where the water quality permits their use. Bag filters may be used for pretreatment but will not be awarded pathogen log reduction credits.	
Softening	Confirm if there are other raw water sources available before proceeding with softening. Hardness levels of 250 mg/L or less may not require softening. Where hardness levels exceed this level, consider split treatment and blending. Only ion-exchange softening should be considered.	Chapter 15 – Parameter Specific Treatment
	Check TDS and sodium levels in treated water following ion exchange with respect to health concerns.	
	Check whether pre-treatment is required, particularly if there are high levels of turbidity, iron and manganese in the raw water supply.	
	Review disposal of spent brine during regeneration.	
	Ensure that there is sufficient storage space for sodium chloride in the plant design.	
	Ensure that construction materials are compatible with the aggressive nature of salt.	
Aeration	Consider aeration for taste and odour removal, air stripping of volatile organics, hydrogen sulphide and pre-oxidation of iron and manganese if the pH of the water permits a weak oxidant.	Chapter 9 – Aeration
	A natural or forced draft air system may be used.	
	All aerators should be housed in a heated and protected enclosure.	
	Noise control features should be included if a forced air system is used.	
	Consider a range of water temperatures due to effect on contaminant removal efficiency.	
	Conduct a pilot study to determine the minimum volumetric air to water ratio if there is limited past performance data available.	
	Use corrosion resistant materials in the construction of all aeration equipment.	

Treatment Method	Small System Treatment Design Considerations	Reference Chapter
Iron and manganese control	Recommended oxidizing methods are aeration and the use of strong oxidizers such as sodium hypochlorite. Potassium permanganate is not recommended for small system iron and manganese removal plants due to the safety concerns and the complexity of working with the chemical. The pH of the raw water is a significant parameter for the type of treatment selected.	Chapter 15 – Parameter Specific Treatment
	Cation ion exchange methods are acceptable if the combined raw water iron and manganese levels do not exceed 0.3 mg/L.	
	Silica sand with a blend of manganese dioxide is an acceptable filtration media combination; a minimum cap of 400 mm of anthracite should overlay the silica sand/pyrolusite blend. The filter should act as a contactor and filter, and operational targets should be based on previous pilot work.	
	Check hydraulic loading rates of filters and backwash rates.	
pH adjustment	pH adjustment of water is required if the alkalinity is too low to ensure effective coagulation for subsequent treatment or the water is so aggressive that serious corrosion could occur in the distribution piping or in internal plumbing systems in homes.	Chapter 7 – Pre-sedimentation, Coagulation, Flocculation and Clarification
	When using potassium permanganate, depending on the required dose, solutions should be made up in batch modes using storage tanks with mixers and a metering pump for small feed systems.	
	Where coagulation and flocculation treatment are required, the preferred form of conditioning is through the use of a limestone contactor.	
	Check empty bed contact time and configuration of tank shape, ensure that each contactor has a drain for de-watering.	
	Pre-screening is required for all contactors and a bypass is necessary for blending raw water with conditioned water.	
	Include provision for an efficient air wash and water backwash to remove inert material and sediments from the contactor basin.	
	Where pH adjustment is required for reducing corrosivity, only then alternative treatment solutions should be reviewed such as the addition of sodium hydroxide (caustic soda) or sodium carbonate (soda ash).	Chapter 12 – Internal Corrosion Control
	Final sodium content in water should be tested. If sodium levels are increased to >20 mg/L, it is recommended that the water supplier should inform users, as this could affect those on sodium-restricted diets.	

Treatment Method	Small System Treatment Design Considerations	Reference Chapter
Arsenic removal	Where levels of arsenic exceed 0.025 mg/L in any one raw water sample, an alternative raw water source should be sought. If there is no other source available, then arsenic treatment should be applied to reduce the levels below 0.010 mg/L.	Chapter 15 – Parameter Specific Treatment
	At least two arsenic removal treatment processes should be piloted to determine the optimal form of treatment.	
	Review life cycle costs and complexity of operation in the feasibility analysis. Ensure that accurate test equipment is available to readily measure and record arsenic levels in the raw and treated water.	
	Arsenic is most easily removed when it exists in the pentavalent form, which is related to the pH of the water. Several treatment methods are available; however, the following methods should be explored: 1. Adsorption onto a granular ferric oxide medium; 2. Reverse osmosis; 3. Alum chemical coagulation and sedimentation with pre-oxidation as necessary; and 4. Activated alumina. Removal and handling of rejects and waste streams generated from the treatment process should be assessed for efficiency and safety.	
Residuals Handling and Treatment	Sanitary waste should receive treatment and should be discharged directly to a sanitary sewer system or on-site waste treatment facility.	Chapter 14 – Waste Residuals Handling and Treatment
	Aluminum hydroxide sludge can be discharged to a lagoon. If lagoons/holding ponds/drainage pits are used for filter backwash water, ensure that lagoons are an adequate distance from treatment facilities and do not pose a contamination risk to treated water or the surrounding surface water/aquifer.	
	For sedimentation/clarification residuals, if sufficient land area is available, natural freeze/thaw methods may be considered for dewatering sludge.	
	When designing filtration systems for small systems, backwash volume requirements should be evaluated and considered when designing storage and/or raw water pumping.	
	Waste recycling may be possible, but not if the presence of algae, protozoa, or elevated disinfection by-products is likely.	
	Waste filter backwash water from iron and manganese removal plants can be discharged to a lagoon or a community sanitary sewer (if the Owner of the wastewater system gives approval).	

21.7.2 Pre-engineered Systems

Pre-engineered water treatment systems are especially applicable for small systems where individually engineered treatment plants may not be cost effective. Pre-engineered water treatment components are normally modular process units which are pre-designed for specific process applications and flows. Multiple units may be installed in parallel to accommodate larger flows. Factors to be considered when selecting a pre-engineered water treatment component include:

.1 Demonstration of treatment train/unit process effectiveness under all raw water conditions and system flow demands, especially for winter conditions and northern waters;
.2 Means to optimize treatment and flexibility to handle the process residuals generated;
.3 Sophistication of equipment and the reliability and experience record of the proposed treatment equipment/controls;
.4 Operational oversight that is necessary (i.e. full time operators or automation plan);
.5 Formal commissioning, start-up and follow-up training, operations and maintenance manuals and troubleshooting available from the manufacturer or contractor;
.6 Manufacturer warranty, replacement guarantee and confirmation of meeting performance objectives;
.7 Timely availability of parts and service; and
.8 Estimated annual operating and maintenance costs.

Pre-engineered treatment components may require significant engineering and integration with other components, such as chemical feed, system hydraulics and storage systems, building, electrical and plumbing systems, as well as instrumentation and controls.

21.7.3 Disinfection

Chapter 11 – Disinfection and Chapter 13 – Chemical Application should be reviewed for the design of disinfection systems. The *Guidelines for Pathogen Log Reduction Credit Assignmen*t should be referred to for calculating CT and the assignment of pathogen log reduction credits. The following provides guidance unique to small systems.

21.7.3.1 Chlorination

Chlorination is a recommended method of disinfection for small systems: it is a relatively straightforward chemical addition for primary disinfection, and can also be used to provide a measurable disinfectant residual in the distribution system for secondary disinfection (which helps protect against pathogen contamination and reduces pathogen regrowth in distribution system piping).

The following should be considered in the design of a chlorination system for a small system:

.1 The building should have signs on the doors indicating the presence and hazard of chlorine in the room and in the building;
.2 Chlorine liquid, powder, or pellets should meet AWWA standards and *NSF/ANSI Standard 60 Drinking Water Treatment Chemicals – Health Effects*;
.3 If secondary disinfection is being considered, chlorination equipment should be capable of maintaining a minimum free chlorine residual concentration of 0.2 mg/L in treated water;
.4 CT should be calculated and reviewed against CT requirements to ensure that the system can achieve the targeted pathogen log reduction (refer to the *Guidelines for Pathogen Log*

Reduction Credit Assignment);

.5 Chlorination may be accomplished with a sodium or calcium hypochlorite solution. The use of 6% sodium hypochlorite is the preferred method of chlorination for small systems because it is easy to operate and maintain, and it reduces the need for dilution;

.6 The use of gas chlorination facilities is not recommended for small systems. Gas chlorination should be restricted to water systems that have Operators who are available to operate and maintain the equipment on an ongoing basis, and who are trained and equipped to handle any emergency;

.7 The feed system should be interlocked with the plant system controls to shut down automatically when raw water flows stop;

.8 Spare parts should be made available to replace parts subject to wear and breakage;

.9 The facilities should include a cool, dark, dry, clean, above ground and vented area for the storage and for the use of hypochlorite disinfectant. The facilities should also include covered make-up and feed solution tanks;

.10 Chemical-contact materials and surfaces should be resistant to the aggressiveness of the chemical solution;

.11 Corrosive chemicals should be introduced in such a manner as to minimize the potential for corrosion;

.12 Chemicals that are incompatible should not be stored or handled together;

.13 All chemicals should be conducted from the feeder to the point of application in separate pipes; and

.14 Gravity may be used where practical.

21.7.3.2 Chlorine Feed Pumps

The following should be considered in the design of chlorine feed pumps:

.1 Positive displacement type solution feed pumps should be provided;

.2 Pumps should be capable of operating at the required maximum rate against the maximum head conditions found at the point of injection;

.3 To avoid air locking, small diameter suction lines should be used with foot valves and degassing pump heads;

.4 There should be 100% redundancy in the design of the chlorine feed equipment;

.5 A flooded suction line should be considered for all positive displacement pumps;

.6 Feeders will be able to supply the necessary amounts of chemicals at an accurate rate throughout the range of feed at all times;

.7 Chemical feeders should be as near as practical to the feed point;

.8 Chemical feeders and pumps operate at no lower than 20% of the feed range unless two fully independent adjustment mechanisms, such as pump pulse rate and stroke length, are fitted when the pump operates at no less than 10% of the rated maximum;

.9 The chlorine solution injector/diffuser should be compatible with the point of application to provide a rapid and thorough mix with all the water being treated. The center of a pipeline is the preferred application point. If a variable frequency drive well pump is used, the chlorine dose should be proportional to the flow;

.10 Rubber, PVC, polyethylene, or other materials recommended by the Chlorine Institute should be used for chlorine solution piping and fittings. Nylon products are not acceptable for any part of the chlorine solution piping system; and

.11 The initial feeder pumps should be designed for twice the maximum day demand and at the maximum calculated dosage rate that will be achieved at the plant five years following pump installation. Every five years the feeder pumps should be replaced with pumps of higher capacity to meet twice the maximum day demand that will be reached five years after installation at the maximum dosage rate. The capacity of the replacement feeder pumps would increase until the plant design capacity has been reached. This will allow the pumps to operate more effectively during the low flows the plant will experience during the initial years of plant operation. The replacement of the feeder pumps every five years with greater capacity pumps should be included in maintenance cost estimates for the treatment facilities.

21.7.3.3 Siphon Control

Liquid chemical feeders should be such that chemical solutions cannot be siphoned into the water supply by:

.1 Ensuring discharge at a point of positive pressure;
.2 Providing vacuum relief;
.3 Providing a suitable air gap or anti-siphon device; or
.4 Other suitable means or combinations as necessary.

21.7.3.4 Storage Tanks

Liquid chemical storage tanks should consider the following:

.1 Have a liquid level indicator;
.2 Have an overflow and a receiving basin or drain capable of receiving accidental spills or overflows without uncontrolled discharge. A common receiving basin may be provided for each group of compatible chemicals that provides sufficient containment volume to prevent accidental discharge in the event of failure of the largest tank;
.3 Have ventilation that discharges to the outside atmosphere above grade and remote from air intakes;
.4 Should be stored in compatible liquid storage tanks or the original shipping containers; and
.5 Reusable sodium hypochlorite storage containers should be reserved for use with sodium hypochlorite only and should not be rinsed out or otherwise exposed to internal contamination.

21.7.3.5 Calcium Hypochlorite Puck Feeder and Wellhead Pellet Chlorinators

A calcium hypochlorite puck feeder should be installed in accordance with the manufacturer recommendations.

Similarly, wellhead pellet chlorinators should be installed in accordance with manufacturer recommendations and should have a frost-free hydrant or other means of evacuating the well volume to ensure source water samples may be collected. Frost-free hydrants should be located more than 8 m from the wellhead. Consideration should be given to lining of the well casing if iron precipitation is expected.

21.7.4 UV Disinfection

Ultraviolet (UV) disinfection may be used for small systems. When UV disinfection is used, filtration and/or chemical disinfection might also be necessary depending upon the type of source water being treated and the recommended minimum pathogen log reduction. The *Guidelines for Ultraviolet Disinfection of Drinking Water* and *Guidelines for Pathogen Log Reduction Credit Assignment* should be referenced for further guidance.

21.7.5 Residuals Handling

The Designer should consider the preferred method for management of residual waste streams generated by the proposed water treatment processes based on capital and operational costs, operational complexity, and potential environmental impacts. Consideration to on-site management and treatment or off-site disposal should be informed by the availability of and proximity to off-site facilities such as centralized collection and wastewater treatment systems. For smaller waste volumes, use of on-site storage and truck hauling may be permissible.

The Designer should make provisions for proper handling and disposal of all water treatment plant wastes such as sanitary and laboratory wastes, clarification sludge, softening sludge, iron sludge, filter backwash water, backwash sludge, brines (including softener and ion exchange regeneration wastes and membrane and reverse osmosis wastes), spent filtration media or cartridges, hazardous wastes (including radioactive and arsenic waste), and all other potential process waste streams that may impact the environment and drinking water supply.

For discharge to a ditch, the Designer should refer to the *British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife & Agriculture* by the Ministry of Environment and Climate Change Strategy and the *Canadian Council of Ministers of the Environment (CCME) Canadian Environmental Quality Guidelines* for discharge water quality guidance.

Backflow prevention measures must be provided as needed to protect the public water supply when designing residuals handling facilities. Reference should be made to Chapter 14 – Waste Residuals Handling and Treatment.

21.7.6 Point-of-Entry and Point-of-Use

For some small systems, it can be cost-prohibitive to provide centralized water treatment to the water users. In this case, a point-of-entry (POE) or a point-of-use (POU) treatment system may be considered. Section 3.1(a) of the DWPR states that a small system is exempt from section 6 of the Act (water supply systems must provide potable water), if (1) each recipient of the water from the small system has a point of entry or point of use treatment system that makes the water potable, and (ii) the water supplier ensures that the location of non-potable water discharge and non-potable water piping are identified by markings that are permanent, distinct and easily recognized.

A POE system is a treatment device applied where drinking water enters a house or building to make the water distributed throughout the house or building potable. A POU system is a treatment device applied to a single tap to make the water distributed by that tap potable. POU devices do not treat all the water taps in a house, and therefore there is a potential health risk to household residents who consume untreated water. As a result, pathogen log reduction credits should not be assigned to POU devices.

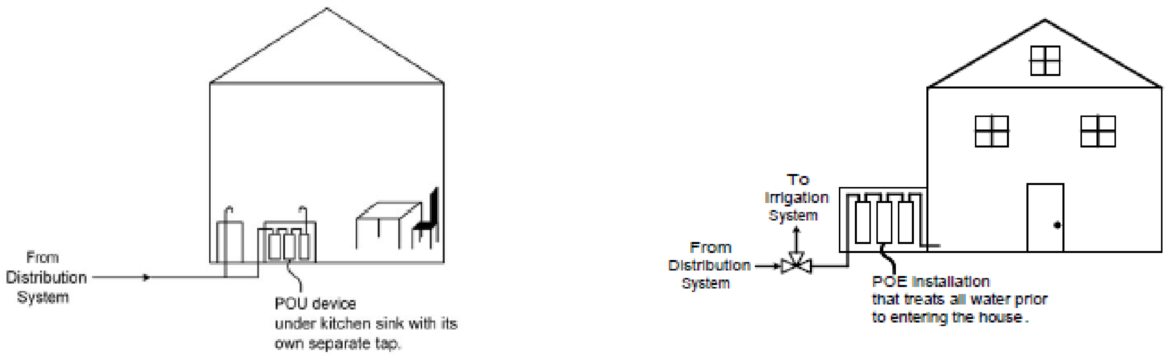


Figure 21-2 Typical Point of Use and Point of Entry systems (sourced from USEPA Point-of-Use or Point-of-Entry Treatment Options for Small Drinking Water Systems)

Before a POE/POU treatment system is implemented, it is important to have a long-term plan in place to manage the risks of using such a system. The administrative tasks required to manage a successful POU or POE treatment strategy, including customer outreach, scheduling, and record keeping, can be time-consuming. The costs associated with these additional tasks should be considered when implementing a POU or POE treatment strategy. As these units are installed and maintained on customer property, frequent interaction with homeowners is required and good public relations are important. A POU user agreement should identify the roles, responsibilities and accountabilities of the Water Supplier and residential consumer.

When considering a POE/POU approach the following should be considered:

- .1 Homeowner buy-in is required to install the equipment on homeowner properties;
- .2 Access by the Water Supplier is required for maintenance and sampling;
- .3 Ownership of the equipment should be agreed upon prior to installation; and
- .4 Treatment objectives should be pre-determined.

Refer to the *Application of "Point of Entry" and "Point of Use" Water Treatment Technology in British Columbia* and the USEPA's *Point of Use or Point of Entry Treatment Options for Small Drinking Water Systems* for further information.

Table 21-5 provides commonly used POE and POU treatment technologies for various water quality parameters of concern. For further guidance on the treatment technology, refer to the respective chapter.

Table 21-5 Commonly Used POE and POU Treatment Technologies

Water Quality Parameter of Concern	Technology	Operational Issues	Chapter Reference
Iron, manganese, copper	Ion exchange	Fouling, competing ions	Chapter 15 – Parameter Specific Treatment
Silica, fluoride, phosphate, sulphate, dissolved iron and manganese	Adsorptive media	Interfering/competing ions	Chapter 15 – Parameter Specific Treatment

Water Quality Parameter of Concern	Technology	Operational Issues	Chapter Reference
Hardness, iron, manganese	Reverse osmosis	Fouling	Chapter 15 – Parameter Specific Treatment
Iron, manganese	Aeration	Fouling, scaling	Chapter 15 – Parameter Specific Treatment
Organics, multiple SOCs or VOCs present	Granular activated carbon	Competing ions	Chapter 15 – Parameter Specific Treatment
Microbial pathogens	UV disinfection	Sleeve fouling and bulb replacement	Chapter 11 – Disinfection

21.7.6.1 POE/POU Certification

When selecting a POU or POE treatment device, the unit should be appropriately certified. The following NSF standards apply to POE/POU devices:

.1 Standard 42: Drinking Water Treatment Units — Aesthetic Effects;
.2 Standard 44: Cation Exchange Water Softeners;
.3 Standard 53: Drinking Water Treatment Units — Health Effects;
.4 Standard 55: Ultraviolet Microbiological Water Treatment Systems (Class A);
.5 Standard 58: Reverse Osmosis Drinking Water Treatment Systems; and,
.6 Standard 62: Drinking Water Distillation Systems.

21.8 Transmission and Distribution

Refer to Chapter 16 – Transmission and Distribution for detailed recommendations. The following design considerations should be made for small systems:

21.8.1 Watermain Layout

Wherever feasible, the Water Supplier's components should be installed within public rights-of-way, existing or planned. Distribution system layouts are usually designed in one of three configurations, including arterial-loop systems, grid systems and tree systems. Tree systems often have more dead ends, and this type of layout is generally not recommended, except for where the alternative would result in significant stagnation times for small systems. Where dead-end sections cannot be avoided, they should be designed with means to provide adequate flushing.

21.8.2 Provision for Cleaning of Rural Pipelines

A means to easily facilitate the cleaning of the interior surface of watermains (such as installing launch points for conducting swabbing or pigging of watermains) should be provided in rural long-distance low-flow pipelines where it is not practical to obtain adequate cleaning with flushing alone.

For small diameter mains without hydrants, swab launching and retrieval ports should be included in the design if swabbing is contemplated in the operations. Valve specifications also need to be considered. Butterfly valves cannot be used as they will trap the swab.

21.8.3 System Pressure

The system should be designed on the basis of providing a minimum pressure of 140 kPa (20 psi) at ground level at all points of the system under all conditions of flow, including MDD plus critical fire flow conditions. Individual PRV devices can be used at each house when the pressure in the house plumbing exceeds 550 kPa (80 psi).

The maximum pressures in the distribution system should not exceed 700 kPa (100 psi) to avoid damage to household plumbing and unnecessary water and energy consumption. When static pressures exceed 700 kPa (100 psi), pressure reducing devices should be provided on mains or service connections in the distribution system. Typically, PRV stations with fire flows should have a fire line PRV for large flows and a smaller bypass PRV for regular flows.

All waterworks should be designed to withstand the maximum working pressure plus the transient pressure to which they may be subjected.

21.8.4 Velocity

Pipe diameters should be such that a flushing velocity of 0.8 m/s can be achieved for cleaning and flushing procedures.

The maximum flow velocity at PHD should not exceed 1.5 m/s. The maximum flow velocity during MDD and fire flow conditions should not exceed 3.0 m/s.

21.8.5 Pipe Material

The pipe materials selected for particular applications should be able to withstand, with a margin of safety, all combinations of loading conditions to which they are likely to be exposed. Water pipes and fittings made of the following materials and meeting the applicable quality standards and specifications set by the AWWA are acceptable for buried applications: PVC, HDPE, ductile iron and reinforced concrete.

21.8.6 Diameter

Pipe sizing should be designed to maintain the appropriate flow and pressure. Minimum diameter should be 150 mm for fire flows and 75 mm for systems without fire flow. Smaller diameters may be considered for dead end mains where water demands are very low, provided the maximum flow velocity remains below 3 m/s and system pressures are maintained per Section 21.8.3 – System Pressure.

21.8.7 Burial Depth

The minimum pipe cover should be greater than the depth of frost penetration but minimum 1.0 m. Minimum pipe cover at ditch crossings should be 0.6 m. Non-buried pipes should be housed in a heated enclosure or protected from freezing through heat tracing.

21.8.8 Services

The minimum diameter of service pipes should be 20 mm and should conform to *AWWA Manual of Water Supply Practices M22 – Sizing Water Service Lines and Meters*. Service pipes should be constructed of standard materials such as PVC, HDPE or copper and should conform to the *AWWA Standard C800: Underground Service Line Valves and Fittings*.

21.8.9 Fire Hydrants

Fire hydrants should only be installed on watermains capable of supplying fire flows. Hydrant leads should have a minimum diameter of 150 mm and should incorporate a hydrant isolation valve. In areas where the groundwater table will rise above the hydrant drain port, the drain port should be plugged.

Flushing hydrants or flushing devices are recommended for small systems that are not designed for fire flows. Flushing devices should be sized to provide flows of at least 0.8 m/s.

21.8.10 Valves

Line valves should be placed throughout the distribution system at each intersection's downstream pipe branch and at maximum linear intervals of 150 m. Where systems serve rural areas and where future development is not expected, the valve spacing should not exceed 2 km. All valves should conform to the relevant AWWA standards. Thrust blocking or other restraints should be provided for online valves.

21.8.11 Separation

Refer to Section 16.6 – Separation Distances for guidance on proper separation of water pipes to possible sources of contamination such as sewers, storm drains, etc.

21.8.12 Air Relief Valves: Valve Meter and Blow-Off Chambers

21.8.12.1 Air Relief Valves

At high points in watermains where air can accumulate, provisions should be made to remove the air by means of hydrants or air relief valves. Automatic air relief valves should not be used in situations where flooding of the maintenance hole or chamber may occur.

21.8.12.2 Air Relief Valve Piping

The open end of an air relief pipe from automatic valves should be extended to at least 300 mm above grade and provided with a 16-mesh screened, downward-facing elbow. The pipe from a manually operated valve should be extended to the top of the pit. Use of manual air relief valves is recommended wherever possible. Discharge piping from air relief valves should not connect directly to any storm drain, storm sewer or sanitary sewer.

21.8.12.3 Chamber Drainage

Chambers, pits or manholes containing valves, blow-offs, meters, or other such appurtenances to a distribution system, should not be connected directly to any storm drain or sanitary sewer. Such chambers or pits should be drained to the surface of the ground where they are not subject to flooding by surface water, or to absorption pits underground (if soil conditions are suitable) at sites not subject to a seasonally high groundwater table.

21.8.13 Truck Loading and Truck Delivery Stations

Water loading stations present increased risk since the fill line may be used for filling both potable water vessels and other tanks or contaminated vessels. To prevent contamination of both the public supply and potable water vessels being filled, the following should be considered when designing water loading stations:

.1 There should be no risk of backflow to the public water supply;
.2 A device should be installed on the fill line to provide an air break and prevent a submerged discharge line; and
.3 The piping arrangement should prevent contaminant transfer from a hauling vessel to others subsequently using the station.

Vehicles and mechanisms for trucked water should conform to the relevant federal and provincial standards and regulations for water vending.

21.9 Treated Water Pumping

Refer to Chapter 18 – Pumping Facilities for complete guidance on pump stations. The following should be considered when designing a treated water pump station for a small system:

.1 For systems that provide inline treatment or do not require treatment, the source water supply pump (e.g. groundwater well or raw water intake supply pumps) may act as the treated water supply pump;
.2 At least two pumps are recommended, with each pump designed to deliver a minimum of the design maximum day demand at the desired head;
.3 Where substantial seasonal variations in flow exist, it may be necessary to provide duplicate flow and pressure pump control systems – one suitable for very low flows (which normally occur in winter) and one suitable for the design maximum flows;
    a. It may be desirable to provide a third domestic high lift pump with this pump sized to meet a lesser flow than the maximum day requirement of the system. In this case, this pump should be designed to lead during lower flow conditions;
    b. During normal periods of domestic demand, the smaller pump would provide an adequate supply of water, while the large pumps would only operate to accommodate higher demands or in the event of failure of the lead pump; and
.4 Where fire protection is to be provided via the communal water supply/distribution facility, an additional high lift pump (fire pump) should be provided and the capacity of that pump should be at least equal to the minimum required fire flow.

In instances where the water balancing storage is not provided in the distribution system, it may be necessary to provide pump(s) sized for the peak domestic demand, or maximum day demand plus the required level of fire flow. In this case, pump operations should be controlled by pressure switches. Pressure regulating valves (PRVs) with pressure relief to the storage reservoir should be provided for relief of high pressures in the distribution system. In many instances, it may be advisable to provide pressure tanks for pump control in order to minimize the number of start-stop cycles (and hence, wear and tear) on the pumping equipment.

21.9.1 Pump Stations

Pump stations should be located and designed accessible, preferably above ground, protected against service interruptions due to fire, flood, lightning strike, vandalism or other hazards, and adjacent to vehicular access. A fence should be provided around the building. Reference should be made to Chapter 5 – Facility Recommendations and Section 21.6 – Facilities for further guidance on facility design.

All pump stations should be designed to provide 100% system capacity redundancy in order to meet the critical design demands in a situation where any one pump is out of service.

The building floor should be sloped and provided with a floor drain sufficiently designed to keep the station functioning and accessible during emergency spill/leakage situations. Aisle widths of minimum 1.0 m should be maintained (measured with doors and panel doors swung open) for access ways throughout to the exit doors. The vertical clearance of the building interior should be 2.4 m minimum.

Electrical controls and panels should be located away from the wet installations but where visual access can be maintained. In larger stations, electrical controls and panels can be located in a separate dry room or compartments with visual access to the installations through glass windows.

Where a well pumping station and chlorine and/or chemical system is to be installed, the preferred layout is for a three-room building which includes a separate chlorine or chemical room, pump room and electrical room. Access to the chlorine or chemical room will be from the outside only with a viewing window between the pump room and chlorine or chemical room. Figure 21-3 below provides a general layout for a chlorination system.

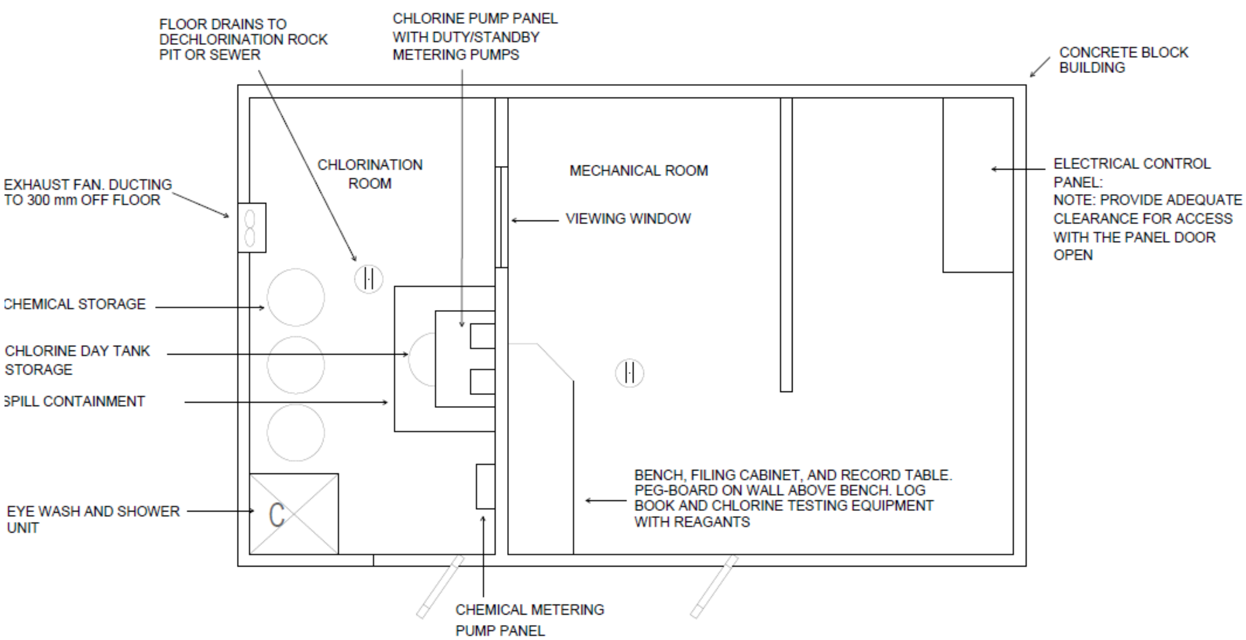


Figure 21-3 Example well pump, chlorine and control building layout, showing details for chlorination room (sourced from Design Guidelines for First Nations Water Works, ISC, 2006)

21.9.2 Controls

The following controls may be provided between the storage reservoir and the high lift and low lift pumping equipment:

.1 A high-level set-point to shut down the low lift pumps when the water level in the reservoir has reached a pre-determined high level; and
.2 Level sensors to operate the low lift pumps sequentially.

Pressure switches should be mounted on the discharge line from the high lift pumping station to operate the high lift pumping equipment sequentially. A pressure gauge should also be installed on the discharge of each high lift pump. Elapsed time meters should be provided for all high lift pumps. Output from the high lift pumping station to the distribution system should be metered with a recording type flow meter. The start-stop operation of the fire pump should be arranged between the Owner and the local fire officials. Indication of the operation status of the pump should be relayed to a central operating point where 24-hour surveillance is provided.

21.10 Treated Water Storage

In sizing storage facilities for small systems, the Designer should also consider the importance of maintaining water quality, preventing freezing during the winter and excessive warming of the water during the summer. Consideration should also be made for the addition of new reservoir cells or tanks in the future, should demand change.

For complete direction on the design of water storage see Chapter 17 – Water Storage. For sizing of the storage, municipal bylaws should be referenced, in the absence of municipal bylaws the Designer can consider the following:

If fire flow is not being provided the following should be considered in sizing treated water storage for small systems:

.1 The minimum effective storage to be provided should be the average day demand flow;
.2 Appropriate allowances for lawn watering and in-plant process requirements, as needed should be added to the minimum volume; and,
.3 An additional emergency storage volume of 25% of the volume calculated for .1 and .2.

If fire flow is being provided, the following should be considered when designing treated water storage for small systems:

1. The minimum volume of the storage facility should be increased by an amount equal to the fire flow demand; and
2. The allowance for lawn watering is not needed where fire protection is provided via the communal water supply and distribution system.
3. An additional emergency storage volume of 25% of the volume calculated for .1 and .2.

21.10.1 Reservoirs

The following should be considered when designing a reservoir for a small system:

.1 Tank materials in contact with potable water should meet *NSF/ANSI Standard 61 Drinking Water System Components – Health Effects*;
.2 Leakage testing and disinfection per accepted standards, such as *AWWA C652 Disinfection of Water Storage Facilities*;
.3 Overflows:
   a. Designed and installed overflow pipe with atmospheric discharge or other suitable means to prevent cross connection contamination;
   b. Overflows should be covered with a 24-mesh non-corrodible screen or mechanical device, such as a flap valve or duckbill valve, to keep animals, insects or other contamination sources out of the reservoir;
   c. Overflows should have a capacity greater than the maximum reservoir influent rate;
   d. Dechlorination should be provided at each overflow;
   e. Designed and installed drain facilities that drain to daylight;
.4 Reservoir roof:
   a. Reservoir roof atmospheric vent, with a non-corroding 24-mesh insect screen;
   b. Watertight roof;
   c. The slope of the reservoir roof should be at least 2% and drained;
.5 Hatches:
   a. Locking mechanism on each point of access into the reservoir;
   b. Weatherproof, insect-proof access hatch and vent;
.6 Accessories:
   a. Reservoir isolation valve(s), which permit isolating the tank from the water system;
   b. Smooth-nosed sample tap on the tank side of the isolation valve;
   c. Access ways and ladders necessary to provide access for safe maintenance;
.7 Inlet and outlet:
   a. A silt-stop on the outlet pipe to keep sediment from entering the distribution system;
   b. Separate inlet and outlet pipes that facilitate a positive circulation of water within the reservoir;
.8 Controls:
   a. High, low-level and overflow alarm system that directly notifies operations personnel; and
   b. A low-level set-point to shut-off the high lift and fire pumping equipment when the water level in the reservoir drops to a pre-determined low level.

21.10.2 Hydropneumatic Tanks

Hydropneumatic tanks are used in small closed systems to maintain acceptable system pressures without the need for frequent stops and starts of the pumps. They should only be used in very small systems.

When considering the use of hydropneumatic tanks, the Designer should consider the implications of loss of pressure in the distribution system in the event of a power outage or pump failure (i.e. the need to issue a boil water advisory). Hydropneumatic tank storage should not be used for chlorine contact or fire protection purposes; fire flows typically by-pass the pressure tanks. The Designer should also consider the impacts of changes in pressure on the operation of the fire pump(s).

Hydropneumatic tanks should meet applicable American Society of Mechanical Engineers (ASME) code requirements. The maximum allowable working pressure should be marked on each tank.

21.11 Electrical

All new electrical installations should be inspected and approved by the local Electrical Inspector. Reference should be made to Chapter 19 – Electrical. Each electrical system should have:

- .1 A kilowatt-hour meter owned by the electric utility;
- .2 A service switch (circuit breaker type) that allows the whole of the electrical system to be disconnected from the supply;
- .3 A surge protector on the main service;
- .4 Power distribution and control equipment for the pumps;
- .5 Adequate lighting for safe access and maintenance;
- .6 Adequate heat and ventilation;
- .7 Control system for monitoring and operation of equipment;
- .8 A Supervisory Control and Data Acquisition System (SCADA) for larger or more sophisticated water systems (multiple reservoirs and/or multiple pump stations); and
- .9 A standby generator if utility power in the area is determined to be unreliable or at the least, provision for a portable standby power generator connection.

21.11.1 Pumped System Electrical Considerations

The electrical system for pumps, either raw or treated, should have the following controls:

- .1 Adjustable motor circuit interrupter for short circuit protection;
- .2 Magnetic contactor which incorporates an adjustable, manually re-settable, overload protection relay to monitor the motor current and shut down the pump if the current exceeds the motor manufacturer's recommended values;
- .3 Hands-off automatic control selector switch;
- .4 Elapsed time meter to total the hours of operation of the pump;
- .5 Green indicator light which turns on when the pump is running;
- .6 Control power-on light to allow the operator to determine if power is available;
- .7 Red alarm indicator light which turns on to indicate pump trouble;
- .8 Single phase protection for three phase systems;
- .9 Amp meter and phase switch (optional); and
- .10 Manual control/override for testing purposes and to allow for equipment to run in case of failure of automatic control systems.

Single phasing, which can cause motor burnout, often results when one of the electric utility's distribution lines are broken and the other phases remain energized. A motor might continue to run when this occurs, although it cannot be started. Higher-than-normal current and overheating of the motor can result. Overload protectors are generally designed to provide single phase protection. The Designer should confirm that the protector selected is adequate or should provide a separate voltage-sensing type of relay to detect loss of one or more phases and shut down the motors.

A "lead-lag" pump-sequence manual selector switch or an automatic control alternator should be installed to even out the wear of pumps of similar size in a multiple-pump installation, instead of leaving a particular pump in the leading (first started) control position.

Multiple pump systems should have controls designed for time-delayed automatic restarting of the pumps which ensures staggered starting of the pumps after a power outage. This will avoid low voltage which could result in motor overheating, or magnetic controllers and relays dropping out (i.e. failing to maintain their contacts closed).

To reduce inrush currents during pump starts, pumps/motors of 7.5 kW or 10 hp or more should be controlled through a soft starter or a variable frequency drive (VFD). Soft starters should not be used to slowly ramp down pump motors during pump stops (soft stops). For water hammer mitigation during pump stops, VFDs should be used.

A well pump should be provided with a protection device that will shut it off in the event that the well water level drops below a level that will adversely affect the pump operation. A number of methods are available to perform this protective function. A red alarm light requiring manual resetting should be provided to draw attention to the problem if it occurs. All other pumps should be provided with protective devices that will shut them off if there is a loss of water supply to the pump.

For booster pumping systems that do not include balancing storage, pumps should be controlled in a manner that does not adversely affect pump operation pump life and that does not consume excessive electrical energy.

21.11.2 Standby Power

The frequency and length of power outages and the treated water storage capacity and drawdown rate of reservoirs are factors determining the need for standby electric generators (diesel or gas engine driven). A standby system should meet all codes and standards as specified in Chapter 19 – Electrical.

If standby power is required, it should be provided by means of an emergency standby generator set. The Designer should refer to the *AWWA Emergency Power Source Planning for Water and Wastewater* publication.

21.11.3 Reservoir Control

Reservoir level control systems should use either loop-powered pressure transmitters or loop-powered ultrasonic transmitters. These devices can provide a remote level indication at the pump station and can provide operating levels for several pumps as well as high and low reservoir alarms. Any changes to operating levels can be made at the pump house. The high-level alarm should override individual pump controls to shut off all pumps. Each level transmitter in any reservoir, holding tank or wet well that receives pumped flows should be backed up by a mechanical float switch set at a High High Level just before the overflow level. This float switch should override any pump controls, shut off all pumps and trigger an alarm.

21.12 Monitoring

A Water Supplier must monitor its drinking water source, the water in its system and the water it provides for the parameters, and at the frequency, established by the Drinking Water Protection

Regulation (see DWPR Schedules A and B) and by its Operating Permit. In addition to these parameters, there are also recommended monitoring criteria for pathogen log reduction credit assignment based on the type of treatment processes used; refer to the *Guidelines for Pathogen Log Reduction Credit Assignment* for more details.

Refer to Chapter 22 – Water Quality Monitoring for further guidance on the water quality monitoring that should be undertaken by a Water Supplier to confirm the continued supply of potable water and that treatment units are performing as designed.

21.13 Distribution System Water Quality

Distribution system water quality can pose particular challenges for small water systems. Proper planning during design is integral, otherwise infrastructure upgrades are often required to mitigate water quality issues. The following Table 21-6 provides an overview of common water quality issues noted in distribution systems, possible causes and possible remediation actions.

Table 21-6 Adverse Water Quality Causes and Actions (sourced from Small System Operation and Maintenance Practices, FCM 2005)

Adverse Water Quality Result	Possible Causes	Possible Course of Action
Disinfection by-products (THMs or HAAs)	• Inadequate water treatment (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 DBP production. • Obtain assistance from 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).
Low disinfectant (Cl_2) 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.	• Check dosing system for leaks, pump problems, or other issues. • Check concentration of raw chemical for degradation. • Increase chlorine dosage. • Flush/swab distribution system. • Implement biofilm control program. • Properly operate storage facilities to ensure adequate turnover of water. • Properly operate and repair distribution systems.

Adverse Water Quality Result	Possible Causes	Possible Course of Action
	• Poor distribution system design. • Aging distribution system. • Pipe contamination due to poor transportation, handling, storage, and installation practices. • Degraded chemical from excessive storage times.	• Rehabilitate/replace watermains. • 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 distribution system). • Deliver pipes with end caps to reduce contamination during installation. • Consider design changes.
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. use a limestone contactor or add soda ash). • Consider alternate corrosion inhibitors (i.e. phosphates). • Flush distribution system regularly. • Educate public. • Rehabilitate/replace water services. • Use approved materials.
pH instability and scale formation	• Inadequate water treatment. • Excessive detention time in cement pipes. • Unstable water.	• Take daily water samples and test pH. • Control blending of water sources. • Properly operate distribution systems. • Consider design changes (i.e. pH adjustment, ion exchange). • Obtain expert assistance if the problem cannot be readily resolved.
By-products of linings and coatings	• Leaching of chemicals. • Unstable water.	• Use approved materials. • Properly cure linings and coatings.
***E. coli* or total coliform detection in treated water**	• Chlorination/disinfection system failure. • Wellhead contamination. • Distribution system contamination/backflow. • False positive sample.	• Perform all regulatory notifications/actions. • Check disinfection system. • Increase chlorine residual. • Flush system. • Retest using approved testing procedures. • Ensure water samplers are properly trained on collection methods. • Eliminate source of contamination. • Shut down source and use alternate/backup supply.

Adverse Water Quality Result	Possible Causes	Possible Course of Action
		• Ensure positive pressure in distribution system. • Identify and eliminate any potential back pressure sources. • Clean storage tanks at least every other year; more frequent cleaning may be required depending on water source and level of treatment.
Waterborne disease outbreak	• Inadequate water treatment. • 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 pressure in distribution systems (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.
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.
Taste and odour	• Poor raw water quality. • Inadequate water treatment. • High disinfectant concentrations. • Excessive detention time. • Blending of chlorinated and chloraminated water. • Stratification during ammonia addition for chloramination. • Internal corrosion of unlined mains.	• Upgrade treatment—select optimal process. • Maintain adequate disinfectant residual. • Flush/swab watermains. • Properly operate storage facilities. • Properly design and operate distribution systems. • Implement corrosion control treatment. • Rehabilitate/replace watermains. • Use approved materials that are suitable for Canadian climate (e.g. paint). • For chloramination, ensure ratio of chlorine to ammonia is maintained.

Adverse Water Quality Result	Possible Causes	Possible Course of Action
	• Leaching chemicals from watermain linings.	• Ensure linings are cured properly in new watermain construction. • Consider design changes. • Consider treatment changes (e.g. GAC).
Colour and appearance	• Inadequate water treatment. • Excessive detention time. • Internal corrosion of unlined mains. • Sediment in watermains.	• Control blending of water sources (i.e. conduct testing before mixing water from different sources). • Implement corrosion control treatment. • Rehabilitate/replace watermains. • Eliminate dead ends. • Flush/swab watermains.

22 Water Quality Monitoring

22.1 General

This chapter describes water quality monitoring that should be considered as part of water system design to confirm the continued supply of potable water and that treatment units are performing as designed, and provides design considerations to facilitate water quality monitoring.

Minimum monitoring requirements are prescribed in the *Drinking Water Protection Act* and the Drinking Water Protection Regulation. The Designer should be familiar with the operational requirements of the DWPA and DWPR. The water system design should enable the Water Supplier to effectively demonstrate compliance and meet good industry practice. Consideration should also be given to on-site record keeping (paper and/or digital).

The DWPA, Section 11, sets out the following monitoring requirements:

(1) In the case of a prescribed water supply system, the water supplier must:
  a. monitor its drinking water source, the water in its system and the water it provides for the parameters, and at the frequency, established by the regulations and by its operating permit,
  b. have the sampling required for that monitoring carried out in accordance with the regulations and the directions of the drinking water officer, and
  c. have the analyses required for that monitoring carried out in accordance with the regulations, through laboratories that meet the requirements established by the regulations and by individuals who are qualified in accordance with the regulations.

(2) The laboratory conducting monitoring analyses under this section must report the results in accordance with the regulations to the drinking water officer and, subject to the regulations, to the water supplier.

(3) A water supplier must ensure that a laboratory conducting monitoring analyses under this section is aware of the applicable standards and requirements established by the regulations and the operating permit for the water supply system.

Similarly, Section 8.0 of the DWPR sets out the following monitoring analysis requirements:

(1) A water supplier must transport water samples to a laboratory in accordance with the procedures established by a drinking water officer.

(2) For the purpose of section 11 (1) of the Act, a water supplier must monitor for total coliform bacteria and, effective April 1, 2006, *Escherichia coli*, at the frequencies set out in Schedule B of this regulation.

(3) Despite subsection (2), a drinking water officer may establish different sampling frequencies for a water supplier.

(4) A laboratory carrying out monitoring analyses for the parameters referred to in subsection (2) must be approved in writing by the Provincial Health Officer.

(5) If requested to do so by a drinking water officer, a laboratory must provide to the drinking water officer, the water supplier, or both, a report.
  a. listing all water samples sent by the water supplier to the laboratory, and
  b. describing, for all samples analyzed, the results of any monitoring analyses for total coliform bacteria and *Escherichia coli*.

Schedule B
Frequency of Monitoring Samples for Prescribed Water Supply Systems

Population Served by the Prescribed Water Supply System:	Number of Samples Per Month:
less than 5,000	4
5,000 to 90,000	1 per 1,000 of population
more than 90,000	90 plus 1 per 10,000 of population in excess of 90,000

On-going source water monitoring plays an important role in the multi-barrier approach to safe drinking water. Monitoring at the intake or raw water source allows plant operators to modify treatment if water quality fluctuates due to seasonal or unexpected changes, and to ensure that raw water remains within the design range for the treatment system. It also allows Water Suppliers to monitor their source water quality to assess if existing source water quality issues change or if new hazards emerge, and respond accordingly.

In addition to the bacteriological water quality monitoring requirements specified under Schedules A and B of the DWPR, additional monitoring or testing of source water may be required, as determined on a case-by-case basis. For example, depending on the source water and treatment, source water monitoring may be required for systems with filtration exemption or pathogen log reduction credits assigned for subsurface filtration. Refer to the following Ministry of Health guidance documents for additional information:

.1 *Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia*;
.2 *Drinking Water Treatment Objectives (Microbiological) for Ground Water Supplies in British Columbia*; and
.3 *Guidance Document for Determining Groundwater at Risk of Containing Pathogens (GARP)*.

22.2 Analytical Recommendations

All samples should be collected, preserved, stored, handled and analyzed in accordance with:

.1 The *Standard Methods for the Examination of Water and Wastewater*, published by the American Public Health Association, the American Waterworks Association and the Water Environment Federation (APHA/AWWA/WEF), as amended or replaced from time to time; or
.2 A method authorized in writing by the Drinking Water Officer.

Where on-line instruments are specified or allowed, such instruments should be kept maintained and calibrated in accordance with the manufacturer's recommendations.

22.2.1 Turbidity Analysis

The turbidity of filtered water is usually measured online or through grab samples in the field using the nephelometric method. Nephelometry determines turbidity using the intensity of scattered light measured by a detector that is at 90^{o} to the incident light source. Table 22-1 lists seven nephelometric methods for the measurement of turbidity in drinking water that have been developed by consensus standards organizations or are approved by recognized organizations. Designers should specify turbidimeters that conform to one of the methods discussed below when monitoring drinking water, selecting an option which is appropriate to the range of turbidity expected in source and treated water.

Table 22-1 Recognized Analytical Methods for Measuring Turbidity in Drinking Water (sourced from Guidelines for Canadian Drinking Water Quality: Guideline Technical Document – Turbidity)

Method	Reference	Description
APHA/AWWA/WEF Standard Method 2130B	APHA et al. (2012)	Tungsten lamp at 2200-3000 K and one or more perpendicular detectors (and filters) with spectral response peak of 400-600 nm; light path less than or equal to 10 cm. Applicable measurement range of 0 to greater than 1000 NTU.
USEPA Method 180.1 Rev. 2.0	USEPA (1993)	Tungsten lamp at 2200-3000 K and one or more perpendicular detectors (and filters) with spectral response peak of 400-600 nm; light path less than or equal to 10 cm. Applicable measurement range of 0-40 NTU.
ISO 7027	ISO (1999)	Tungsten lamp (and filters), diode or laser as radiation source at 860 nm (or 550 nm if sample is colourless) with a perpendicular detector and aperture angle of 20-30°. Two applicable measurement ranges are available, depending on the method selected. The diffuse radiation method has a range of 0-40 FNU. The attenuation of radiant flux has a range of 40-4000 FAU.
GLI Method 2	GLI International Inc. (1992)	Two perpendicular 860 nm light sources alternately pulse each 0.5 seconds, and two perpendicular detectors alternately measure "reference" and "active" signals. Applicable measurement range of 0-40 NTU. The method allows dilution for measurement of samples above 40 NTU.
Hach FilterTrak Method 10133 Rev. 2.0	Hach Company (2000)	Laser diode at 660 nm at 90° to detector/receiver (light path less than or equal to 10 cm), which may use photomultiplier tube and fibre optic cable. Applicable measurement range of 0-5000 mNTUs (0-5.0 NTU).

Method	Reference	Description
ASTM D6698-07	ASTM International (2007)	This method is for the online measurement of turbidity below 5 NTU in water. A variety of instrument technologies may be used in this method, including the design features listed in the methods above. Applicable measurement range of less than or equal to 0.02-5.0 NTU.
ASTM D6855-10	ASTM International (2010)	This method is for the static measurement of turbidity below 5 NTU in water. A variety of instrument technologies may be used in this method, including the design features listed in the methods above. Applicable measurement range of less than or equal to 0.02-5.0 NTU or FNU.

As the turbidity of a sample can change due to changes in temperature, particle flocculation and precipitation, samples should be analyzed immediately. It is recommended that samples be analyzed using on-site turbidimeters in the treatment plant or portable turbidimeters when conducting sampling in the field. It is not recommended to measure turbidity in an offsite laboratory.

22.3 Laboratory Testing Equipment

For facilities that have on-site laboratories, the following should be considered depending on the water quality parameters that are being treated at the water treatment plant:

.1 General considerations for the design of laboratory facilities are listed in Section 5.4 – Monitoring Equipment and Laboratory Facilities;

.2 Public water supplies which chlorinate should have test equipment for determining both free and total chlorine residual by methods in *Standard Methods for the Examination of Water and Wastewater;*

- Chlorine residual test equipment should be provided and should be capable of measuring residuals to the nearest 0.1 mg/L. All systems should use the DPD colourimetric method or amperometric titration. It is recommended that systems using the DPD method have a digital readout and self-contained light source;

.3 Surface water supplies should provide equipment/facilities for microbiological testing of water from both the treatment plant and the distribution system; however, these samples are for operational monitoring, not to meet regulatory monitoring requirements. Depending on the regulatory sampling schedule, deviations from this recommendation may be allowed;

.4 Surface water and GARP supplies, as well any source water with a filtration exemption, should have a nephelometric turbidimeter meeting the requirements of Table 22-1;

.5 Each surface water treatment plant using flocculation and sedimentation, including those with lime softening, should have a pH meter, jar testing equipment, and titration equipment for both hardness and alkalinity;

.6 Each ion exchange softening plant and lime softening plant treating only groundwater should have a pH meter and titration equipment for both hardness and alkalinity;

.7 Each iron and/or manganese removal plant should have test equipment capable of accurately measuring iron to a minimum of 0.1 mg/L, and/or test equipment capable of accurately measuring manganese to a minimum of 0.05 mg/L;
.8 If fluoridation or fluoride removal treatment is implemented, equipment should be provided for measuring the quantity of fluoride in the water;
.9 WTPs which feed polyphosphates and/or orthophosphates should have test equipment capable of accurately measuring phosphates from 0.1 to 20 mg/L;
.10 Where the process treatment involves reduction of raw water colour, equipment should be provided to determine both true and apparent colour in the raw water and treated water quality ranges;
.11 Where UV treatment is used, a UVT spectrophotometer (capable of measuring transmission of 254 nm wavelength light through a path length of 1 cm of water) with an accuracy within +/- 2% should be provided. Refer to the Ministry of Health's *Guidelines for Ultraviolet Disinfection of Drinking Water* for more detailed information; and
.12 Jar testing equipment should be provided to evaluate modifications to coagulation/flocculation/clarification treatment processes and chemical dosages at the bench scale. If DAF is used at the WTP, specialized jar testing equipment for bench-scale DAF should be obtained. The Designer should provide the initial jar test settings that reflect plant operations as part of the design process. This should include the mixing speed, mixing times, and chemical injection sequences.

Additionally, the following general equipment should be considered for the laboratory:

.1 Spectrophotometer;
.2 Glassware appropriate for preparing reagents and analysis (e.g. pipettes, beakers, volumetric flasks graduated cylinders, Erlenmeyer flasks);
.3 Deionized water source;
.4 Thermometer;
.5 Fume hood if required for specific reagents or water quality testing specific to the facility; and
.6 Analytical balance to 0.1 mg accuracy.

22.4 Treatment System Monitoring

Water treatment facilities should be designed to provide equipment for monitoring, notification and recording that demonstrates the treatment processes are operating reliably, meeting performance objectives, and comply with the treatment requirements set out in the drinking water system's Operating Permit. Treatment system monitoring may consist of a combination of grab sampling, online analyzers, and local and remote condition alarming/notification. Equipment and system monitoring are a key component of the multi-barrier approach to ensure the supply of clean, safe and reliable drinking water and provide an effective tool for early identification of potential treatment process or equipment performance issues.

The scope of the monitoring should be developed based on recommendations from the Drinking Water Officer, the size and complexity of the treatment processes, remoteness and operational response times, skill level of operations staff, level of equipment and system redundancy, and the Water Supplier's standard practice. Consideration should also be given to meeting warranty requirements and monitoring the performance of new equipment.

For source/raw water quality monitoring, additional discussion can be found in Section 6.1.3 – Source Water Quality.

Refer to Chapter 20 – Instrumentation and Controls for details on the requirements of specific monitoring equipment, especially to Section 20.3 – Instrumentation for instrumentation selection and design.

22.4.1 Water Quality Parameters

Generally, any parameters that are targeted in the treatment process should be monitored. Table 22-2 identifies recommended water quality monitoring parameters for source water/raw water and various treatment processes.

Table 22-2 Monitoring Parameter for Specific Treatment Systems

Process	Recommended Water Quality Monitoring Parameters
Source Water/Raw Water	• The specific parameters to test and frequency of sampling should be selected on a source-by-source basis and should consider the source water type, proximity to potential contaminant sources, current and anticipated land use in the source area, and effects of changing climate conditions. Table 6-1 (see Section 6.1.3 – Source Water Quality) lists recommended parameters for raw water assessment which may be carried through to regular monitoring.
Coagulation/Flocculation	• pH • Streaming current • Zeta potential • Alkalinity
Sedimentation	• Effluent turbidity
Solids Contact Clarifiers	• Turbidity • pH following clarification
Proprietary Clarifiers	• Instrumentation for proprietary clarifiers including ballasted flocculation and dissolved air flotation should be provided per manufacturer recommendations and should include effluent turbidity
pH Adjustment	• pH
Rapid Media Filtration	• Filter effluent particle counts • pH • Turbidity of the influent, effluent and filter-to-waste per filter
Membrane Filtration	• Instrumentation should be provided per manufacturer recommendations. • Turbidity, integrity test (and optionally, particle count) on each individual filter train effluent

Process	Recommended Water Quality Monitoring Parameters
Slow Sand Filtration	• Turbidity
Cartridge Filtration	• Turbidity
Clearwell	• Free chlorine residual • Fluoride residual (if fluoridation is practiced) • pH • Turbidity
Contact Time	At locations where contact time needs to be calculated: • Free chlorine residual • pH • Turbidity • Water temperature
Treated Water	• Free chlorine residual • Colour • Fluoride residual (if system fluoridates) • Monochloramine (if system uses chloramination) • pH • Water temperature • Turbidity
UV Systems	Refer to the *Guidelines for Ultraviolet Disinfection of Drinking Water* • UVT (if required for dosing strategy) • Water temperature (inside vessel)
Residuals Treatment	• Turbidity • TSS • pH
Filter Backwash Recycled Water	• pH • Turbidity

22.4.2 Sample Taps

Designers should provide sample taps before treatment to assess the source water quality, and after treatment but before entering the distribution system. Designers should provide additional sample taps at intermittent points in more complex treatment plants to help in process control, verify on-line analyzers, and assess specific treatment processes.

Designers should locate source sample taps upstream far enough to avoid influence from downstream chemical injection. Designers should locate sample taps for treated and partially treated water after added chemicals mix completely. Because turbulent flow conditions can dislodge pipe scale or entrain air, avoid sample taps in turbulent flow locations, such as near valves, elbows, tees and flanges. Also, avoid tapping the bottom or top of the pipe, which can introduce sediment or air. Sample probes or quills are recommended to collect samples from the centre of the pipe.

Sample taps should be smooth nosed without any internal or external threads to reduce the risk of microbial contamination or aeration of the sample. Aeration can change the pH or result in loss of chlorine residual so that the sample is not representative of the water in the pipe.

22.5 Distribution System Water Quality Monitoring

Water Suppliers should monitor and report on distribution water quality and designs should incorporate means to readily monitor water quality. The DWO should be consulted to confirm the location, frequency, and parameters that need to be sampled.

The key parameters that are commonly considered to be indicators of water quality in terms of public health are:

.1 Chlorine residual (free and total);
.2 *E. coli* (as an indicator of fecal contamination);
.3 Total coliform; and
.4 Disinfection by-products (such as THMs, HAAs, etc.).

Useful parameters from an operational perspective include:

.1 Ammonia, nitrate, nitrite (if chloramination is used);
.2 Turbidity;
.3 Flow; and
.4 Pressure.

For monitoring of lead, refer to the *Guidelines on Evaluating and Mitigating Lead in Drinking Water Supplies, Schools, Daycares and Other Buildings,* by Ministry of Health for guidance on sampling objectives and protocols and Chapter 12 – Internal Corrosion Control. Other routine sampling and monitoring parameters can include the following:

.1 pH;
.2 Temperature;
.3 Alkalinity;
.4 Conductivity;
.5 Colour;
.6 Taste and odour parameters as required;
.7 Iron and manganese, as required;
.8 Soluble metal stemming from pipe material (e.g. lead, iron, copper);
.9 Corrosion inhibitors (if used); and
.10 Fluoride (if used).

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Drinking Water Officers' Guide: Appendices

Version 1.2 / First Published 2014

Ministry of Health

BRITISH COLUMBIA

NOTE: Some of these appendices are under development and all of the forms listed in the appendices are samples. As local health authorities may use and/or require alternate versions of these forms, you should contact your local health authority for the version of the form you need.

Contents

Sample Drinking Water Officer Delegation

Drinking Water Officer Delegation

WHEREAS:

A. Section 3(4) of the *Drinking Water Protection Act* S.B.C. 2001, C. 9 ("the Act") authorizes a Drinking Water Officer, subject to the regulations to delegate to any person a power or duty of a Drinking Water Officer,

B. I am a Drinking Water Officer under section 3 of the Act, and

C. I consider it to be necessary and appropriate for the better administration of the Act to delegate my authority under the Act.

THEREFORE:

1. I, **[NAME OF DRINKING WATER OFFICER]**, Drinking Water Officer, hereby delegate to **[NAME OF DELEGATE]**, all of my powers and duties under the *Drinking Water Protection Act* and Drinking Water Protection Regulation, except,

   (a) The power to delegate under section 3(4) of the Act,

   (b) [OTHERS?]

2. This delegation does not purport to exhaust or limit my authority as Drinking Water Officer to exercise my powers or duties in respect of any matter where I consider that appropriate.

3. This delegation revokes all previous delegations.

4. This delegation may be revoked or modified by me at any time.

Dated at **[CITY/TOWN],** this __ day of _________, 20__.

____

[NAME OF DRINKING WATER OFFICER]
Drinking Water Officer

Emergency Response and Contingency Plan Template

This template is designed to be a starting point to aid you in preparing your own plan. Please modify to suit the needs of your water supply system (e.g., add or delete emergency contacts as you see fit). For resources and information, see Emergency Response and Contingency Planning for Small Water Systems and the Guide to Emergency Response and Contingency Plans for Water Supply Systems from the Ministry of Health.

Name of Water Supply System:

Mailing Address:

Phone Number(s):

Date Prepared:

Emergency Contact Information:

Name	Phone Number(s)	Email	Fax
Operator (primary):	Primary: Secondary:		
Operator:	Primary: Secondary:		
Owner (responsible):	Primary: Secondary:		
Other owner(s):	Primary: Secondary: Primary: Secondary:		
Health Authority Contacts			
Drinking water officer / Environmental health officer:	Office: Secondary:		
Public health engineer:	Office:		

Name	Phone Number(s)	Email	Fax
	Secondary:		
Medical health officer:	Office: Secondary:		
After-hour health authority emergency contact:			
Government Agencies			
Local Government Emergency Program Coordinator (Municipality):			
Local Government Emergency Program Coordinator (Regional District):			
Emergency Management BC; Emergency Coordination Centre:	1-800-663-3456		
Ministry of Environment & Climate Change Strategy:			
Ministry of Water, Land and Resource Stewardship:			
Ministry of Transportation & Infrastructure:			

Name	Phone Number(s)	Email	Fax
Media			
Laboratories			
Bacteriological: Address:			
Chemical: Address:			
Emergency Departments			
Police/RCMP:			
Fire Department:			
Ambulance:			
Hospital:			
Health Centre:			

Name	Phone Number(s)	Email	Fax
Repair Services			
Utility:			
Electrician:			
Plumber:			
Bulk water hauler/ alternate water supplier:			
Excavator:			
Water Well Drilling Contractor:			
Pump Installer:			
Computer Support:			

Name	Phone Number(s)	Email	Fax
Equipment Supplier(s)			
Water Treatment Supplier:			
Other Local Water Supply System(s)			

In the case of emergency contacts, provide as many forms of communication to each contact as possible (including: primary, secondary and after-hours phone numbers). The Emergency Contact Information must be reviewed on annually to ensure the contact information is up to date. Forward any changes to your local drinking water officer or delegate.

Date Reviewed	Completed by	Forwarded to Drinking Water Officer

Template for Planned Responses

Fill in the following blank template with your planned responses to possible emergencies you listed under "other." Make more copies of this page as necessary. For sample planned responses and more information on Emergency Response and Contingency Plans, see the Emergency Response and Contingency Planning for Small Water Systems document on the Ministry of Health's website.

EMERGENCY:

ACTIONS

CONTACTS

EMERGENCY:

ACTIONS

CONTACTS

Sample Operating Permit Cover Letter

Dear _________________:

Please find enclosed an operating permit issued under section 8 of the *Drinking Water Protection Act* (the "Act"). This permit is effective [**specify start date and end date, if any]**.

Please note this operating permit is issued on terms and conditions, and that, according to section 8(1)(b) of the Act, the water supply system must be operated in accordance with these terms and conditions. **[If the Terms and Conditions are not all set out on the permit but instead reference other documents, including this letter, that should be highlighted here]**

Please also note that water suppliers have various responsibilities under the Act and the Drinking Water Protection Regulation (The "Regulation"), beyond those set out as terms and conditions of the operating permit. It is your responsibility to familiarize yourself with the Act and Regulation. See section 2.2 of Part A of the *Drinking Water Officers' Guide* for a summary of responsibilities and references to some of the relevant provisions of the Act and Regulation. This is intended for basic information purposes only and it is important that you read the Act and Regulation in their entirety.

If you have any questions about this operating permit, please do not hesitate to contact me.

Yours truly,

[ISSUING OFFICIAL NAME]
[TITLE]

Sample Standard Form Operating Permit

Permit to Operate

A Drinking Water System with ___ to ___ connections

[CHOOSE EITHER 2 to 14, 15 to 300, or 301 to 10,000 CONNECTIONS]

Purveyor:
Facility Name:
Facility Number:
Facility Address:

Conditions of Permit

______________________ Effective Date

______________________ Public Health Inspector

This permit must be displayed
in a conspicuous place and is nontransferable.

Place
Decal
Here

Permit to Operate

This permit must be displayed
in a conspicuous place and is nontransferable.

Place
Decal
Here

Drinking Water Source-to-Tap Screening Tool

In 2004, the Province developed the Drinking Water Source-to-Tap Screening Tool as a method for assessing risk in drinking water supply systems. You can find the Drinking Water Source-to-Tap Screening Tool at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators.

This self-screening tool is the easiest to use of the assessment tools produced by the Ministry of Health, but it is also the tool that produces the least amount of detail. It should be completed by the water supplier (voluntarily or as required by the local DWO) and submitted to the DWO. If significant risks are identified, the DWO can determine if a water supplier needs to undertake a more comprehensive source-to-tap assessment to further analyze and mitigate the risks.

The tool includes 97 questions designed to inventory and assess the:

- administration, management and operation of the water supply system
- water source
- water treatment system
- water storage system
- distribution system
- tap water quality

Water Supply System Assessment

The Water System Assessment User's Guide, and associated assessment forms, is a source-to-tap assessment designed to be completed by the water supply operator or the DWO. It was developed in 2012 to fill a gap between the Drinking Water Source-to-Tap Screening Tool and the Comprehensive Drinking Water Source-to-Tap Assessment (below). The intention is to offer an alternative that will allow for developing an action plan to reduce risks to and in a water supply system, without the added cost and time commitment of a comprehensive assessment. You can find the Water System Assessment User's Guide at http://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators.

The full assessment is designed to enable quick and efficient data collection, and completed in about one day. It consists of the following assessment forms:

- **Hazard Assessment**: The questions in this form take you step by step through your water supply system. They are designed to cover the water supply system from the water source through to the customer's taps.
- **Risk Rating**: This form breaks the potential problems (hazards) down to try to identify how serious they are (risk).
- **Risk Grouping**: This form orders the hazards into similar groupings to help you see areas that need the most work. This will add perspective to help you deal with the risks to your system.
- **Action Plan**: This will be a short report to develop timelines and prioritize system improvements.

These assessment forms are available in Microsoft Excel or hard copy, and both will yield the same results. If you are able to use the computer version, though, you will have access to extra features such as information brought forward to the next form and automatic calculations.

The Water System Assessment User's Guide explains how to use the forms and provides helpful tips to get you started. It includes suggestions and examples to help you understand where problems may arise. The appendices provide guidance to answering questions in the hazard assessment, as well as information about useful resources.

Comprehensive Drinking Water Source-to-Tap Assessment Guideline

The Comprehensive Drinking Water Source-to-Tap Assessment Guideline is a tool to help water suppliers develop a more comprehensive understanding of the risks to drinking water safety and availability of their system. This is the most comprehensive and time-consuming assessment tool produced by the Ministry of Health and should only be completed with the assistance of a qualified professional.

This guideline can be applied as a voluntary measure by water suppliers wanting to understand risks to drinking water safety in their systems, but it may not be the most cost-effective approach for assessing a small water system. A DWO can order this assessment if significant risks to a water supply system are identified through the Drinking Water Source-to-Tap Screening Tool or by some other means. This order can include completing the entire assessment, or taking a more targeted approach and using only the modules that will address the risks identified through the screening tool.

The professionals conducting the assessments, DWOs and water suppliers are the intended audiences for this guideline. It provides a structured, consistent approach to evaluating risks to drinking water. The purpose is to help water supply systems learn how to operate more effectively, as well as ensuring the best possible water quality and assured quantity.

The guideline consists of an introduction, which should be reviewed in detail for information on the assessment process prior to commencing and eight modules. The complete document can be accessed at https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-quality/drinking-water-quality/resources-for-water-system-operators#source-to-tap-assessment.

Sample Letter Ordering Assessment Under Section 19

[DATE]

Dear ______________

Further to our recent discussions, I am writing pursuant to section 19 of the *Drinking Water Protection Act* (the "Act") to order you to complete a water source and system assessment. You may find a copy of the Act on the government website at http://www.bclaws.ca/civix/document/id/complete/statreg/01009_01, or if you do not have access to the internet, please call me and I can provide you with a copy.

It is my view that I have reason to believe that an assessment is necessary to properly identify and assess threats to drinking water in relation to the water supply system because:

[INSERT REASONS]

Section 20 of the Act provides that I may provide directions respecting the process, preparation, form, content, area of coverage, and time for completing an assessment. In this regard, I am directing that you complete an assessment in accordance with

[CHOOSE ONE OF: The enclosed Screening Tools Assessment document[1]
The Enclosed Water Supply System Assessment document
The enclosed Comprehensive Risk Assessment Document
Set out some other process]

With respect to timing, I am directing that the assessment be completed, and a copy of the assessment results provided to me, by **[DATE]**. I should also note that section 21(2) of the Act requires that an assessment be made public in accordance with section 15. In this regard, I require you to make the assessment public, after it has been provided to me, through the following means:

[SPECIFY]

If you have any questions or comments respecting this order, please do not hesitate to call or write me by **[14 days from date of letter]**. This order will not become effective until **[21 days from the date of letter]** and if, upon considering any further questions or

[1] In any case where this tool is selected, the letter should note that this is an initial tool that is less time-consuming and resource intensive to implement than the Comprehensive Risk Assessment Tool, and that the drinking water officer reserves the right to direct that the Comprehensive Risk Assessment Tool, or some other additional process, be completed if the Screening Tool identifies concerns that warrant a more thorough assessment.

comments by you, I consider it appropriate to rescind or modify this order, I will advise you before **[21 days from the date of this letter]**.

Yours truly,
[NAME]
Drinking Water Officer

Sample Order Respecting Public Notice

[DATE]

[Person to whom order is directed]
[Address]

Dear _____________:

Re: Order to Provide Public Notice

This letter constitutes an Order under section 14 of the *Drinking Water Protection Act*, S.B.C. 2001, C. 9 (the "Act"), which states:

> The drinking water officer may request or order a water supplier to give public notice in a manner approved by the drinking water officer, or in accordance with the directions of the drinking water officer, if
>
> (a) the drinking water officer has received a report under section 12 [notice if immediate reporting standard not met],
>
> (b) the drinking water officer has received a report under section 13 [water supplier must report threats], or
>
> (c) the drinking water officer considers that there is, was or may be a threat to the drinking water provided by a water supply system.

Action required

The action that I am requiring you to take is as follows:

- Issue a **[Choose one of: Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** in the form and including the information specified on the attached form; and
- Publicize the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** through the following means:

[CHOOSE, ADD, DELETE, AMEND AS APPROPRIATE]

- Immediately telephone all users of the water system and notify them of all the contents of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** and advise them how they can obtain a written copy of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** if they wish to do so.
- Notify each user of the system by providing a copy of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** in person, or in the event they are not home by leaving a copy of the Notice in their mailbox.
- Post a copy of this Order and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** at the following locations and check those locations every ____ days to confirm that the posting remains, or re-post as necessary.
- Advise the following local media of the existence of the Order and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]**.
- Advise the **[LOCAL GOVERNMENT]** of the existence of the Order and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]**.
- Document all steps taken to provide notice as outlined above.

Reasons for this Order

I have determined that this Order is necessary under section 14 for the following reasons:

- **[Specify whether the Order is based upon section 14(1)(a), (b) or (c)]**
- **[Summarize relevant facts and the reasons for the decision to issue this Order, e.g. monitoring results, other events etc.]**

Authority to issue this Order

I have issued this Order under my authority as a Drinking Water Officer under section 3 of the Act.

[OR]

I have issued this Order as a person who has been delegated the powers and duties of a Drinking Water Officer, under section 3(4) of the Act.

Duration of this Order

This Order remains in effect unless and until you are notified in writing by me or another Drinking Water Officer that the Order is amended or rescinded.

No right of appeal

There is no ability to appeal this Order, or to request a review or reconsideration under the *Drinking Water Protection Act*. If you have information that you believe may be relevant to my decision whether or when to rescind this Order, I invite you to provide it to me, but I wish to emphasize that the Order remains in effect unless and until it is modified or rescinded by me or another Drinking Water Officer, in writing.

Consequences of failure to comply

It is an offence under the *Drinking Water Protection Act* to fail to comply with an Order under section 14. Penalties upon conviction for an offence may be up to $200,000 per day and up to 12 months imprisonment.

Please do not hesitate to contact me if you have any questions respecting this Order.

Yours truly,

[NAME]
[TITLE]

Attachment

Sample Request Respecting Public Notice

[DATE]

[Person to whom order is directed]
[Address]

Dear ______________:

Re: Request to Provide Public Notice

As you may be aware, section 14 of the *Drinking Water Protection Act*, S.B.C. 2001, C. 9 (the "Act") provides that a Drinking Water Officer may

> …request or order a water supplier to give public notice in a manner approved by the drinking water officer, or in accordance with the directions of the drinking water officer, if
>
> (d) the drinking water officer has received a report under section 12 [notice if immediate reporting standard not met],
>
> (e) the drinking water officer has received a report under section 13 [water supplier must report threats], or
>
> (f) the drinking water officer considers that there is, was or may be a threat to the drinking water provided by a water supply system.

Pursuant to this section, I am requesting that you:

- Issue a **[Choose one of: Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** in the form and including the information specified on the attached form; and
- Publicize the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** through the following means:

[CHOOSE, ADD, DELETE, AMEND AS APPROPRIATE]

- Immediately telephone all users of the water system and notify them of all the contents of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** and advise them how they can obtain a written copy of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** if they wish to do so.

- Notify each user of the system by providing a copy of the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** in person, or in the event they are not home by leaving a copy of the Notice in their mailbox.

- Post a copy of this Request and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]** at the following locations and check those locations every ____ days to confirm that the posting remains, or re-post as necessary.

- Advise the following local media of the existence of the Request and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]**.

- Advise the **[LOCAL GOVERNMENT]** of the existence of the Request and the **[Water Quality Advisory / Boil Water Notice / Do Not Use Water Notice]**.

- Document all steps taken to provide notice as outlined above.

<u>Reasons for this Request</u>

I am making this request for the following reasons:

- **[Specify whether the Request is based upon section 14(1)(a), (b) or (c)]**

- **[Summarize relevant facts and the reasons for the decision to issue this Request e.g. monitoring results, other events etc.]**

<u>Duration of this Request</u>

This Request remains in effect unless and until you are advised by me or another Drinking Water Officer that the Request is amended or rescinded.

Please do not hesitate to contact me if you have any questions respecting this Request.

Yours truly,

[NAME]
[TITLE]
Attachment

Sample Boil Water Notice

BOIL WATER NOTICE

Issued pursuant to **[an Order OR a Request]** of a Drinking Water Officer under section 14 of the *Drinking Water Protection Act*

WATER SUPPLY SYSTEM COVERED BY THIS NOTICE

This Boil Water Notice applies to the following water supply system:

[DESCRIPTION OF SYSTEM], Operating permit number ________

and should be followed by all persons using water from the system.

REASON FOR THIS NOTICE

This Notice is being issued because:

[Include:

- **A description of the drinking water threat that occurred, including the potential health effects**
- **The population at risk**
- **What the water system is doing to correct the problem]**

RECOMMENDATIONS

The Drinking Water Officer, in consultation with the Medical Health Officer, recommends the following steps be taken to minimize the risks associated with this water system.

[Set out proposed steps including length of boiling required, use of alternate water supplies, avoiding consumption by vulnerable groups etc.]

OBLIGATION OF OWNERS OF PUBLIC PREMISES

Owners of public premises served by this water system must:

(a) notify the public that the water is not potable water by posting a sign at every sink or drinking water fountain accessible to the public;
(b) if normal business practices provide an opportunity, verbally advise any person who may use the domestic water system for a domestic purpose that the water is not potable water.

(See Drinking Water Protection Regulation, section 10)

DURATION OF THIS NOTICE

This Notice remains in effect unless and until another public notice is issued upon the **[Request OR Order]** of a Drinking Water Officer advising that the Notice has been amended or may be rescinded.

WHAT IS A "BOIL WATER NOTICE"

A Boil Water Notice is one of three types of public notices commonly used by Drinking Water Officers. The decision whether to request or order issuance one of these notices rests with the discretion of a Drinking Water Officer, but in general, they are used in the following circumstances:

Water Quality Advisory	Used in situations in which the public health threat posed by the water supply system is modest, and actions can be taken to reduce the risks through means other than requiring a Boil Water Notice or Do Not Use Water Notice.

Boil Water Notice	Used in situations in which the public health threat posed by the water supply system is significant and the nature of the threat is one that can be effectively addressed through boiling of the water.
Do Not Use Water Notice	Used in situations where a significant public health threat exists in relation to the water supply system, and the threat cannot be adequately addressed through a Water Quality Advisory or Boil Water Notice.

The Drinking Water Officer reserves the right however to Request or Order another form of public notice in relation to this water supply system, if they determine that necessary in future. If that were to occur, a subsequent public notice would be issued.

QUESTIONS

If you have any questions concerning this notice, please contact:

___________, Owner or Operator of the water supply system at **[TELEPHONE]**

[OR]

[SELECT ONE OR MORE OF THE FOLLOWING, AS APPROPRIATE FOR THE CIRCUMSTANCES AND THE OFFICE / HEALTH AUTHORITY IN QUESTION]

___________, Drinking Water Officer, at **[TELEPHONE]**

___________, Medical Health Officer, at **[TELEPHONE]**

___________, Environmental Health Officer, at **[TELEPHONE]**

___________, Public Health Inspector, at **[TELEPHONE]**

___________, Public Health Engineer, at **[TELEPHONE]**

Sample Do Not Use Water Notice

DO NOT USE WATER NOTICE

Issued pursuant to **[an Order OR a Request]** of a Drinking Water Officer under section 14 of the *Drinking Water Protection Act*

WATER SUPPLY SYSTEM COVERED BY THIS NOTICE

This Do Not Use Water Notice applies to the following water supply system:

[DESCRIPTION OF SYSTEM], Operating permit number _______

and should be followed by all persons using water from the system.

REASON FOR THIS NOTICE

This Notice is being issued because:

[Include:

- **A description of the drinking water threat that occurred, including the potential health effects**
- **The population at risk**
- **What the water system is doing to correct the problem]**

RECOMMENDATIONS

The Drinking Water Officer, in consultation with the Medical Health Officer, recommends that the water from this water supply system not be used for domestic purposes—i.e., it should not be used for drinking, cooking, bathing **[ADD / EDIT AS NECESSARY]**—until further notice.

[Specify alternate sources of water that may be used]

OBLIGATION OF OWNERS OF PUBLIC PREMISES

Owners of public premises served by this water system must:

(c) notify the public that the water is not potable water by posting a sign at every sink or drinking water fountain accessible to the public;
(d) if normal business practices provide an opportunity, verbally advise any person who may use the domestic water system for a domestic purpose that the water is not potable water.

(See Drinking Water Protection Regulation, section 10)

DURATION OF THIS NOTICE

This Notice remains in effect unless and until another public notice is issued upon the **[Request OR Order]** of a Drinking Water Officer advising that the Notice has been amended or may be rescinded.

WHAT IS A "DO NOT USE WATER NOTICE"

A Do Not Use Water Notice is one of three types of public notices commonly used by Drinking Water Officers. The decision whether to request or order issuance one of these notices rests with the discretion of a Drinking Water Officer, but in general, they are used in the following circumstances:

Water Quality Advisory Used in situations in which the public health threat posed by the water supply system is modest, and actions can be taken to reduce the risks through means

	other than requiring a Boil Water Notice or Do Not Use Water Notice.
Boil Water Notice	Used in situations in which the public health threat posed by the water supply system is significant and the nature of the threat is one that can be effectively addressed through boiling of the water.
Do Not Use Water Notice	Used in situations where a significant public health threat exists in relation to the water supply system, and the threat cannot be adequately addressed through a Water Quality Advisory or Boil Water Notice.

The Drinking Water Officer reserves the right however to Request or Order another form of public notice in relation to this water supply system, if they determine that necessary in future. If that were to occur, a subsequent public notice would be issued.

QUESTIONS

If you have any questions concerning this notice, please contact:

___________, Owner or Operator of the water supply system at **[TELEPHONE]**

[OR]

[SELECT ONE OR MORE OF THE FOLLOWING, AS APPROPRIATE FOR THE CIRCUMSTANCES AND THE OFFICE / HEALTH AUTHORITY IN QUESTION]

___________, Drinking Water Officer, at **[TELEPHONE]**

___________, Medical Health Officer, at **[TELEPHONE]**

___________, Environmental Health Officer, at **[TELEPHONE]**

___________, Public Health Inspector, at **[TELEPHONE]**

___________, Public Health Engineer, at **[TELEPHONE]**

Sample Hazard Abatement and Prevention Order

[DATE]

[person to whom the hazard abatement order is issued – see Section 25(2)]
[Address]

Dear ____________________:

Re: Hazard Abatement or Prevention Order

This letter constitutes an Order under section 25 of the *Drinking Water Protection Act* (the "Act"). For your ease of reference, I enclose a copy of the Act.

Action required

The action that I am ordering you to take is as follows:

[SPECIFY, HAVING REGARD TO RANGE OF POWERS SET OUT IN SECTION 25(3)]

Reasons for this Order

I am issuing this Order because I have reason to believe that **[a health hazard exists AND / OR there is a significant risk of an imminent drinking water health hazard]**. I have formed this belief in the circumstances of this case for the following reasons:

[SPECIFY]

Authority to issue this Order

I have issued this Order under my authority as a Drinking Water Officer under section 4 of the Act.

[OR]

I have issued this Order as a person who has been delegated the powers and duties of a Drinking Water Officer, under section 4(3) of the Act.

Duration of this Order

This Order remains in effect unless and until you are notified in writing by me or another Drinking Water Officer that the Order is amended or rescinded.

Right for review or reconsideration

You may request that I reconsider this decision if you believe that there is sufficient new evidence for this purpose. You may also request that this decision be reviewed by the Provincial Health Officer or a Medical Health Officer nominated by him.

If you wish to make a request for reconsideration or review, please review section 39.1 of the *Drinking Water Protection Act*. I can also provide you with forms if you wish, but there is no requirement to use a specific form.

Please note however that a request for reconsideration or review does not put the Order into abeyance while any such request is considered. If you believe that the Order should be deferred while a review or reconsideration is requested, please advise me accordingly and I will consider whether to amend the Order accordingly. Unless I do so, the Order remains in force during any period of review or reconsideration.

Consequences of failure to comply

It is an offence under the *Drinking Water Protection Act* to fail to comply with an Order under section 25. Penalties upon conviction for an offence may be up to $200,000 per day and up to 12 months imprisonment. In addition, if you fail to comply with the Order, a Drinking Water Officer may take or authorize actions to be taken as necessary, at your expense (see sections 27 and 28).

Please do not hesitate to contact me if you have any questions respecting this Order.

Yours truly,

[NAME]
[TITLE]

Enclosure

[cc: registered owner of land in cases where order is directed against a person who is not the owner, as per section 25(4)]

Sample Letter Advising that Action May be Taken and Costs Recovered Under Section 27

[DATE]

[person to whom hazard abatement or contravention order was issued]
[Address]

Dear _________________________:

Re: Notice under section 27 of the *Drinking Water Protection Act*

On [**DATE]** a **[hazard prevention OR contravention]** Order was issued to you under section **[25 OR 26]** of the *Drinking Water Protection Act*. To date, it appears that you have failed to take the following actions required by that Order:

[SPECIFY]

I am writing to direct, pursuant to section 27, that if you fail to take the outstanding action necessary to comply with the Order by **[DATE]**, the action may be taken by the Health Authority or a person authorized by it, at your expense, and without further notice to you.

Please note that under section 27(3) and (4) of the Act, cost recovery can be pursued by way of a claim for debt in court, or by adding the costs and expenses to property taxes under section 27(4). For your ease of reference, I enclose a copy of the Act.

If you have any questions concerning this letter, please contact me at **[TELEPHONE]**.

Yours truly,

[NAME]
[TITLE]

Enclosure

[cc: registered owner of land in cases where order is directed against a person who is not the owner, as per section 26(4) and 25(4)]

Sample Contravention Order

[DATE]

[Name of person in contravention]
[Address]

Dear ______________________:

This letter constitutes a Contravention Order under section 26 of the *Drinking Water Protection Act*, S.B.C. 2001, C. 9 (copy enclosed). It is issued on the basis that I have reason to believe you are in contravention of the following sections of the Act:

[SPECIFY SECTIONS]

Reasons for this Order

I am issuing this Order because I have reason to believe you are in contravention for the following reasons:

[SPECIFY REASONS]

Action required

The action that I am ordering you to take is as follows:

[SPECIFY, HAVING REGARD TO RANGE OF POWERS SET OUT IN SECTION 26(3), AND INCLUDE TIMEFRAMES]

Right for review or reconsideration

You may request that I reconsider this decision if you believe that there is sufficient new evidence for this purpose. You may also request that this decision be reviewed by the Provincial Health Officer or a Medical Health Officer nominated by him.

If you wish to make a request for reconsideration or review, please review section 39.1 of the *Drinking Water Protection Act*. I can also provide you with forms if you wish, but there is no requirement to use a specific form.

Please note however that a request for reconsideration or review does not put the Order into abeyance while any such request is considered. If you believe that the Order should be deferred while a review or reconsideration is requested, please advise me accordingly and I will consider whether to amend the Order accordingly. Unless I do so, the Order remains in force during any period of review or reconsideration.

Authority to issue this Order

I have issued this Order under my authority as a Drinking Water Officer under section 4 of the Act.

[OR]

I have issued this Order as a person who has been delegated the powers and duties of a Drinking Water Officer, under section 4(3) of the Act.

Consequences of failure to comply

It is an offence under the *Drinking Water Protection Act* to fail to comply with an Order under section 25. Penalties upon conviction for an offence may be up to $200,000 per day and up to 12 months imprisonment. In addition, if you fail to comply with the Order, a Drinking Water Officer may take or authorize actions to be taken as necessary, at your expense (see sections 27 and 28).

Yours truly,

[NAME]
[TITLE]

Enclosure

Sample Letter Requesting Information about "Owners" of a System

---

[DATE]

[Recipient]
[Address]

Dear ___________________:

I am writing to advise that I am presently reviewing **[concerns OR outstanding issues**] respecting the water supply system located at _____________, which serves **[DESCRIBE]**.

In the course of doing so, it is appropriate that I consider which party or parties may fall within the definition of "owner" of the water supply system as that term is defined in section 1 of the *Drinking Water Protection Act*. Specifically, section 1 states:

> "owner" in relation to a water supply system includes
>
> (a) a person who is
> (i) responsible for the ongoing operation of the water supply system, or
> (ii) in charge of managing that operation, and
>
> (b) If
> (i) parts of the water supply system are owned by different persons, or
> (ii) all or part of the system is jointly owned by different persons,
>
> all of those persons;

If you have any information as to the names and addresses of parties that may potentially fall within the definition of "owner" I would appreciate if you could contact me at **[TELEPHONE]**.

Yours truly,

[NAME]
[TITLE]

Sample Letter Advising a Person They May be Considered an "Owner" of a System

---

[DATE]

[Recipient]
[Address]

Dear ______:

I am writing to advise that I am presently reviewing **[concerns OR outstanding issues**] respecting the water supply system located at ____, which serves **[DESCRIBE]**.

In the course of doing so, it is appropriate that I consider which party or parties may fall within the definition of "owner" of the water supply system as that term is defined in section 1 of the *Drinking Water Protection Act*. Specifically, section 1 states:

> "owner" in relation to a water supply system includes
>
> (c) a person who is
> (i) responsible for the ongoing operation of the water supply system, or
> (ii) in charge of managing that operation, and
>
> (d) If
> (i) parts of the water supply system are owned by different persons, or
> (ii) all or part of the system is jointly owned by different persons,
>
> all of those persons;

It appears to me that you may fall within the definition of being an "owner" on the basis that **[EXPLAIN]**. However, before I reach any conclusion in this regard, I wish to provide you with an opportunity to make your views known to me, and to provide any information you consider relevant.

Please provide any response you may have by **[DATE]**. In considering any response, I would encourage you to review the various provisions of the Act that relate to the rights and responsibilities of owners, including the various requests and orders that can be made by a Drinking Water Officer in relation to an owner. For your ease of reference I enclose a copy of the Act.

Please note that if I do not receive a response from you by **[DATE]** I will consider you to be an "owner" of the system, as defined in the *Drinking Water Protection Act*, and may take further action I consider appropriate. This could include orders directed against you, or other steps that may result in financial liability by you.

Please do not hesitate to call me at **[TELEPHONE]** if you have any questions regarding this letter.

Yours truly,

[NAME]
[TITLE]

Enclosure

Sample Water System Hazard Rating Assessment Tool

The following water system assessment tool was developed by a Health Authority. It is a simple tool that aids a drinking water officer in determining the hazard rating associated with an individual water supply system by providing a basic hazard rating depending on the level of risk of various components and factors of the water supply system. The drinking water officer has discretion to use whatever information available and deemed relevant to make a determination related to risk ratings. The final decision concerning the overall risk of the water supply system is at the discretion of the drinking water officer.

How to Use: Go through each category and choose the component/factor that best reflects the individual water supply system. Circle or make note of the corresponding risk rating number for the given component/factor. Once complete, add up the risk rating numbers to determine the corresponding hazard rating for the system as a whole: high, medium or low (see *Hazard Rating Upper Limits* in the grey table).

Item	Risk Rating
Number Of Connections	
More than 300 connections	5
15 to 300 connections	4
Less than 15 connections	3
Population Served	
> 10 000	10
> 1 000	8
> 100	5
> 10	3
High Risk Populations	
List of High Risk Populations	Hospitals
	Child Care
	Adult Care
	Camps/Campsite
	Schools
	Restaurants
Amount for Each Population	1

Item	Risk Rating
Water Source	
Surface Water	10
Combined	8
Shallow Well	7
Deep Well	3

Item	Risk Rating
Surface Water Treatment	
Not Disinfected	15
Disinfected	10
Disinfected, Residual	8
Disinfected, Parasite Reduction	6
Disinfected, Parasite Reduction, Residual	2
Shallow Well Water Treatment	
Not Disinfected	12
Disinfected	10
Disinfected, Residual	8
Disinfected, Parasite Reduction	6
Disinfected, Parasite Reduction, Residual	2
Deep Well Water Treatment	
Untreated	5
Treated	1
1. Bacteriological History	
Current Permanent Boil Advisory	15
Current Periodic Boil Advisory	12
Past Boil Advisories or Periodic Unsatisfactory Results	9
Meets Guidelines	1

Item	Risk Rating
2. Chemical History	
Insufficient Chemical Analysis History	5
Chemical Contamination Identified - No Treatment	5
Chemical Contamination Identified - Appropriate Treatment	3
Meets Guidelines	1
3. Emergency Plan	
Not Submitted	10
Incomplete Plan	5
Complete Plan	1
4. Maintenance	
Insufficient Information	15
Poor Attention	12
Moderate Attention	4
Excellent Attention	1
5. Staff Training	
Insufficient Information	10
No Training	10
Some Training	5
Completed Certificate Program	1

Add up the risk rating numbers to determine the corresponding hazard rating: high, medium or low

Hazard Rating Upper Limits	
Total Possible:	101
High	101
Moderate	65
Low	45

Sample Request for Reconsideration Form

REQUEST FOR RECONSIDERATION OF A DECISION OF A DRINKING WATER OFFICER

Pursuant to section 39.1 of the *Drinking Water Protection Act*, I request reconsideration of the following decision of a Drinking Water Officer:

____

____

____

____

(Please attach a copy of the decision letter or order issued by the Drinking Water Officer)

I consider this decision is subject to reconsideration under section 39.1 on the basis that it is a decision under:

- ☐ section 19 [drinking water officer authority in relation to assessments]
- ☐ section 25 [hazard abatement and prevention orders]
- ☐ section 26 [orders respecting contraventions]
- ☐ section 31(4) [request respecting plan initiation]
- ☐ it was a decision that resulted from a reconsideration of one of the above

I make this request on the basis of the following new evidence:
(attach documents as necessary)

____

____

____

____

I consider this new evidence to justify a reconsideration and different decision because:

____

____

____

____

Name and contact information for person making the request:

Name: ____

Address: ____

Telephone: ____

______________ ____________________

Date **Signature**

When completed, please send this form to [CONTACT NAME OR TITLE], at:

[ADDRESS]
[FAX NUMBER]

Sample Notice to Third Parties on Request for Review

[DATE]

[Person requesting the review]:
[Address]

Dear _______________:

I have reviewed your request for review of the ________ decision of **[NAME]**, **[TITLE]** under section 39.1 of the *Drinking Water Protection Act*.

Before reaching a decision on this matter, I have determined, pursuant to section 39.1(c), that it is appropriate for you to give notice of this request to the following person(s):

[SPECIFY, INCLUDING ADDRESSES]

In this regard, I am directing you to provide the above named persons(s) with the following information, at the address(es) noted above:

- A copy of this letter
- A copy of your request for review form (including all attachments)
- **[OTHER]**

This notice must be provided by **[DATE]**.

I will give the above noted person until **[DATE PLUS 10 DAYS OR AS OTHERWISE DETERMINED]** to make any submission they consider appropriate. They must also provide a copy of any such submission to you.

If you have any response to such submissions, you must provide that to me by **[DATE PLUS 15 DAYS OR AS OTHERWISE DETERMINED]**, with a copy to the other party(ies).

Yours truly,

[NAME]
[TITLE]

Office of the Provincial Health Officer

REQUEST FOR REVIEW OF A DRINKING WATER OFFICER DECISION

(Please note that reviews are conducted on the material that was before the Drinking Water Officer when the decision was made. New evidence cannot be submitted or considered on a review. If you have new evidence that you consider relevant, you may wish to ask the Drinking Water Officer to reconsider his/her decision. An alternate form is available for such requests.)

Pursuant to section 39.1 of the *Drinking Water Protection Act*, I request a review of the following decision of a Drinking Water Officer: *(Please attach copy of decision letter/order issued by Drinking Water Officer)*

I consider this decision is to be subject to review under section 39.1, on the basis that it is a decision that was made under:

- ☐ section 19 [drinking water officer authority in relation to assessments]
- ☐ section 25 [hazard abatement and prevention orders]
- ☐ section 26 [orders respecting contraventions]
- ☐ section 31(4) [request respecting plan initiation]
- ☐ it was a decision that resulted from a reconsideration of one of the above

I believe that the decision should be reversed or varied for the following reasons:

(Please attach additional pages if necessary)

Contact information for person making the request:

Name:

Address:

City: **Postal Code:**

Phone:

Print and mail completed form to:

Office of the Provincial Health Officer
PO Box 9648, STN PROV GOVT
1515 Blanshard St., 4^{th} Floor
Victoria BC V8W 9P4

Signature: ______________________ Date: ______________________