Land and Water Boards of the Mackenzie Valley

LWB/GNWT

Guidelines for Effluent Mixing Zones

February 2023

Revision History Table

DATE	SECTION	Revision
February 2023	General	Separated from the LWB *Standard Process for Setting Effluent Quality Criteria*.
	General	Administrative updates: • Updated to reflect separation from the LWB *Standard Process for Setting Effluent Quality Criteria* • Updated terminology • Updated references to the LWB *Waste and Wastewater Management Policy* and other new and updated LWB guidance documents • Corrected typographical and grammatical errors
September 2017	New Guideline	Original release.

Table of Contents

List of Figures

Defined Terms and Acronyms

Term	Definition
AEMP	Aquatic Effects Monitoring Program
acute toxicity	A toxic effect (severe biological harm or death) produced in an organism by a substance or mixture of substances within a short exposure period (usually 96 hours or less).[1]
affected party	A party that is affected (or predicted to be affected) by a proposed or existing project, including an Indigenous government, an individual occupying land for traditional purposes, a private landowner, or a lease or interest holder (e.g., for a lodge).
applicant	A person who has filed an application with a LWB.
application	Any application for or in relation to a land use permit or water licence submitted in accordance with the *Mackenzie Valley Resource Management Act* (MVRMA), the *Waters Act*, or their regulations, and includes a request for a Board ruling, a plan approval, or any step required to advance a Board proceeding.
Boards (or LWBs)	The Land and Water Boards of the Mackenzie Valley, as mandated by the MVRMA. • Part 3 of the MVRMA establishes regional land and water boards with the power to regulate the use of land and water, and the deposit of waste, including the issuance of land use permits and water licences, so as to provide for the conservation, development, and utilization of land and water resources in a manner that will ensure the optimum benefit to the residents of the management area and of the Mackenzie Valley and to all Canadians. • Part 4 of the MVRMA establishes the Mackenzie Valley Land and Water Board (MVLWB). • Regional Land and Water Boards have been established in the Gwich'in, Sahtu, and Wek'èezhìı management areas and now form Regional Panels of the MVLWB.
CCME	Canadian Council of Ministers of the Environment
COPC	contaminant of potential concern
effluent	A wastewater discharge.
effluent quality criteria (EQC)	Numerical or narrative limits on the quality or quantity of effluent authorized for deposit to the receiving waters.
GLWB	Gwich'in Land and Water Board
GNWT	Government of the Northwest Territories
licensee	A person who holds a water licence issued by a LWB.

[1] Canadian Council of Ministers of the Environment. 1999. Glossary. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg

Term	Definition
Mackenzie Valley	The part of the Northwest Territories bounded on the south by the 60th parallel of latitude, on the west by the Yukon Territory, on the north by the Inuvialuit Settlement Region as defined in the Agreement given effect by the *Western Arctic (Inuvialuit) Claims Settlement Act,* and on the east by the Nunavut Settlement Area as defined in the Nunavut Land Claims Agreement Act, but does not include Wood Buffalo National Park.
MVLWB	Mackenzie Valley Land and Water Board
MVRMA	*Mackenzie Valley Resource Management Act*
NWT	Northwest Territories
outfall	The discharge point of an effluent into receiving waters.
project	Any undertaking[2] that requires a water licence.
receiving	The natural environment[3] that, receives any waste from a project.[4]
receiving waters	The waters[5] in the receiving environment that receive any direct or indirect deposit of waste from a project.
regulated mixing zone	The defined area contiguous with a point source effluent discharge site or a delimited non-point source effluent where the effluent mixes with ambient receiving waters and where concentrations of some substances may not comply with water quality objectives that have been established site-specifically for the receiving waters.
SLWB	Sahtu Land and Water Board
waste	As defined by Section 1 of the *Waters Act* and section 51 of the MVRMA.[6]

[2] "undertaking" is defined, in section 1 of the Waters Regulations and section 2 of the Mackenzie Valley Federal Areas Waters Regulations, as: an undertaking in respect of which water is to be used or waste is to be deposited, of a type set out in Schedule B, or Schedule II, respectively.

[3] "environment" is defined in section 2 of the MVRMA as: the components of the Earth and includes:
(a) land, water and air, including all layers of the atmosphere;
(b) all organic and inorganic matter and living organisms; and
(c) the interacting natural systems that include components referred to in paragraphs (a) and (b).

[4] The receiving environment is generally outside of the project boundary. Where a project is located in a previously disturbed area (i.e., the receiving environment is no longer considered 'natural'), the definition of 'receiving environment' may be modified to account for this.

[5] "waters" is defined in section 1 of *Waters Act* as: water under the administration and control of the Commissioner, whether in a liquid or frozen state, on or below the surface of land, and in section 51 of the MVRMA as: any inland waters, whether in a liquid or frozen state, on or below the surface of land.

[6] "Waste" is defined (in the *Waters Act*) as:

(a) a substance that, if added to water, would degrade or alter or form part of a process of degradation or alteration of the quality of the water to an extent that is detrimental to its use by people or by any animal, fish, or plant, or
(b) water that contains a substance in such a quantity or concentration, or that has been so treated, processed, or changed, by heat or other means, that it would, if added to any other water, degrade or alter or form part of a process of degradation or alteration of the quality of that water to the extent described in paragraph (a), and includes:
(c) a substance or water that, for the purposes of the *Canada Water Act*, is deemed to be Waste,
(d) a substance or class of substances prescribed by regulations made under subparagraph 63(1)(b)(i),

Term	Definition
watercourse	A natural watercourse, body of water or water supply, whether usually containing water or not, and includes, but is not limited to, groundwater, springs, swamps, and gulches.
water quality objective (WQO)	A numerical concentration or narrative statement that has been established to protect the receiving environment at a specified site.
wastewater	Any water that is generated by project activities or originates on-site, and which contains waste, and may include, but is not limited to, runoff, seepage, sewage, minewater, and effluent.
WLWB	Wek'èezhìı Land and Water Board

(e) water that contains any substance or class of substances in a quantity or concentration that is equal to or greater than a quantity or concentration prescribed in respect of that substance or class of substances by regulations made under subparagraph 63(1)(b)(ii), and

(f) water that has been subjected to a treatment, process or change prescribed by regulations made under subparagraph 63(1)(b)(iii).

1.0 Introduction

In the Mackenzie Valley, the use of water and the deposit of waste into water is regulated under the *Waters Act* and Waters Regulations, and the *Mackenzie Valley Resource Management Act* (MVRMA) and Mackenzie Valley Federal Areas Waters Regulations (MVFAWR). Responsibilities associated with the approval, issuance, administration, and enforcement of water licences are shared by the Land and Water Boards of the Mackenzie Valley (the LWBs or Boards), the Government of the Northwest Territories (GNWT), and Crown-Indigenous Relations and Northern Affairs Canada (CIRNAC). In recognition of their collective responsibility for water licensing, the LWBs and the GNWT have collaborated in the development of these *Guidelines for Effluent Mixing Zones* (the Guidelines).

As described in the LWB *Waste and Wastewater Management Policy* (the Policy), regulated mixing zones may be established on a case-by-case basis for licensed projects that discharge effluent into receiving waters such as rivers, streams, or lakes. Water licences for these types of projects typically include effluent quality criteria (EQC) conditions prescribing the maximum allowable concentrations or quantities of any contaminants of potential concern (COPC) in the effluent. Mixing zones, if established, aid in the derivation of EQC for individual water licences. These Guidelines are intended to support future decisions involving the use of mixing zones in the regulation of effluent.

1.1 Purpose

The overall purpose of these Guidelines is to improve the clarity and consistency of water licensing decisions related to effluent and the use of mixing zones. Specifically, these Guidelines:

- Provide a definition for regulated mixing zones that is applicable to water licensing in the Mackenzie Valley;
- Describe the relationship between mixing zones, effluent quality criteria, and water quality objectives;
- Describe the factors that may be considered by the LWBs when deciding whether to allocate a mixing zone;
- Describe criteria that will guide the decision to allocate a mixing zone;
- Describe, in general, the types of water licence requirements that are based on mixing zone determinations, and;
- Summarize the information that applicants should submit to support a proposed mixing zone.

These Guidelines are guided by the LWB *Waste and Wastewater Management Policy*, and supported by the LWB *Guidelines for Developing a Waste Management Plan* and *Standard Process for Setting Effluent Quality Criteria*.[7]

[7] All LWB guidance documents referenced in this Policy can be accessed on the Policies and Guidelines webpage on any of the LWB websites (www.glwb.com/www.mvlwb.com/www.slwb.com/www.wlwb.ca/).

1.2 Authority

The LWBs have the authority to develop and implement guidelines under sections 65, 102, and 106 of the MVRMA. In particular, section 106 of the MVRMA gives the MVLWB the responsibility to "issue directions on general policy matters or on matters concerning the use of land or waters or the deposit of waste that, in the Board's opinion, require consistent application throughout the Mackenzie Valley." The LWBs and the GNWT have developed these Guidelines in partnership, recognizing their collective responsibility with respect to the water licensing process.

1.3 How These Guidelines Were Developed

These Guidelines were developed as part of a continuing effort to improve and enhance water-related decision making as envisioned by the NWT Water Stewardship Strategy and Action Plan. They also support the implementation of the LWB *Waste and Wastewater Management Policy*. Note that the Guidelines are based on the principles and objectives of the Policy that are consistent with those of the NWT Water Stewardship Strategy; these include, for example, the principles of pollution prevention, sustainable development, and integrated management.

The initial draft of these Guidelines was prepared by an independent consultant based on an extensive review of approaches used in other jurisdictions in Canada and internationally. The draft Guidelines were edited jointly by staff from the LWBs and from the GNWT's Department of Environment and Natural Resources, before being subject to a public review process. The Guidelines have been in effect since September 2017, with administrative updates in February 2023.

1.4 Application

The Guidelines will be applied by the GNWT and LWBs in accordance with their respective mandates and responsibilities. The Guidelines will be applied by the following LWBs operating under the MVRMA:

- Mackenzie Valley Land and Water Board
- Gwich'in Land and Water Board
- Sahtu Land and Water Board
- Wek'èezhìı Land and Water Board

These Guidelines apply to all new water licence applications received after the effective date of the Guidelines. In the case of existing water licences, the Guidelines may be applied, at the discretion of the LWBs, to water licence renewal and amendment applications that include a proposal to amend any conditions that are related to a mixing zone determination.

Applicants for water licences that will require EQC for effluent(s) should consult these Guidelines to decide whether they would like to propose a regulated mixing zone for their project. Section 6 describes the kinds of information that an applicant should submit with any proposal for a mixing zone. In all cases, the LWBs will make decisions about the allocation of a regulated mixing zone based on the application and all other evidence presented during the regulatory process.

1.5 Monitoring and Performance Measurement for these Guidelines

The Guidelines will be reviewed periodically to determine whether revisions are necessary. Information gathered through the application of the Guidelines during regulatory proceedings and through the implementation of relevant licence conditions will guide the frequency and nature of revisions to the Guidelines. The LWBs and the GNWT will seek input on proposed revisions through public reviews and, in some cases, may establish working groups; however, the LWBs and the GNWT may also make administrative updates to the Guidelines from time to time as necessary.

2.0 Uses of a Mixing Zone in Regulating Deposit of Waste into Water

As set out in section 27 of the *Waters Act* and section 72.04 of the MVRMA, the LWBs may include, in any water licence, "the quantity, concentration and types of waste that may be deposited in any waters by the licensee" as well as the "conditions under which that waste may be deposited." The *Waste and Wastewater Management Policy*,[8] which was originally approved by the LWBs in 2011 as the *Water and Effluent Quality Management Policy,* describes the LWBs' approach to regulating, through water licence requirements, the deposit of waste to the receiving environment such that the following three objectives are met:

1. Water quality in the receiving environment is maintained at a level that allows for current and future water uses.
2. Waste is prevented and/or minimized.
3. The amount of waste to be disposed of or deposited to the receiving environment is minimized.

With respect to the first objective, the level of water quality that must be maintained to protect receiving waters is defined by water quality objectives (WQOs), which are established[9] for each specific receiving environment. The second and third objectives may be achieved through the implementation of waste management techniques such as source control, reuse, recycling, or treatment. The Policy describes several different types of water licence requirements (e.g., discharge criteria, management plans, monitoring, etc.) that are used to ensure, collectively, that each water licence meets the objectives above.

Once all reasonable measures have been taken to limit the amount of waste, the applicant may still need to propose deposit of some waste(s) to the receiving environment (directly or indirectly). In these cases, concerns may still exist about the quantity, concentration, and type of waste to be deposited, and the LWBs may set EQC and/or other discharge criteria in the water licence. EQC define the maximum allowable concentrations (e.g., mg/L), quantities (e.g., kg/year), or limits (e.g., pH range) of any contaminant or parameter of the waste which, in the LWBs' opinion, has the potential to adversely affect

[8] In cases of discrepancy between these Guidelines and the Policy, the Policy prevails.
[9] Note that section 5 of the Policy describes the kinds of information that the LWBs will consider when setting WQOs for each specific receiving environment.

water quality in the receiving environment.[10] The Policy requires that any EQC are set, at a minimum, to ensure that downstream WQOs are met in the receiving environment.

Although the Policy does not specify the location within the receiving waters where WQOs must be met, it does state that "on a case-by-case basis, the LWBs may decide to define a regulated mixing zone between the point of discharge and the point at which WQOs need to be met." Used in this way, defined 'mixing zones' become areas of the receiving waters that may have COPC concentrations that are greater than the respective WQOs. For this reason, there must be a careful consideration of 1) whether it is appropriate or necessary to allow a mixing zone at all for a specific project; and 2) what conditions must be met if a mixing zone is to ensure that the receiving waters are protected to a level that is acceptable to affected parties.

2.1 Definition of a Regulated Mixing Zone

For many projects, wastewater generated at different areas of the site (e.g., groundwater, sewage, site run-off, process water, etc.) is collected, stored, and sometimes treated prior to being discharged to a watercourse from a single point source or outfall using a pipe or a diffuser, for example. In general, mixing zones are only relevant to point-source effluent; however, in some cases, the Board may define a mixing zone for delimited non-point source effluent (i.e., where the applicant can delineate the spatial boundaries of the effluent from the waste source to the receiving waters).

For the purposes of the Policy and these Guidelines, a regulated mixing zone is defined as:

> The defined area contiguous with a point-source effluent discharge site or a delimited non-point source effluent where the effluent mixes with ambient water and where concentrations of some substances may not comply with water quality objectives that have been established site-specifically for the receiving environment.

This definition is based on that from the Canadian Council of Ministers of the Environment (CCME)[11] with changes to the language as necessary to be consistent with the Policy. Note that regulated mixing zones can be defined for continuous, temporary, or seasonal discharges of effluent.

2.2 Considerations for Allocating a Regulated Mixing Zone

The decision of whether to allocate a mixing zone for an individual project will be made by the Board based on all evidence presented in each specific regulatory process. Since decisions are always tied to the specific evidence before the Board, it is not possible to make definitive rules a priori of when a mixing zone will or will not be allowed. In some cases, it may not be necessary to allocate a mixing zone at all. For example, if the Board has decided to set EQC equal to or less than the WQOs set for the receiving

[10] When EQC are determined to be needed, the EQC will always be set out in conditions in the main body of the licence.
[11] Page 13 of CCME, 2008 (see References)

environment (e.g., in situations where there is a requirement for maximum protection of water quality), allocating a mixing zone would serve no useful purpose.

In cases where the Board decides to allocate a mixing zone, it is with the understanding, as stated[12] by the CCME, that "it is often possible to allow somewhat elevated concentrations of COPCs to occur within relatively small areas of a receiving water body, without significantly affecting the integrity of the water body as a whole." Generally, the use of a mixing zone in water licensing acknowledges that:

- concentrations of COPCs in effluent may be higher than the WQOs set for the receiving environment;
- because of the processes of dilution and assimilation, the end-of-pipe COPC concentrations in the effluent do not necessarily represent the final COPC concentrations in the receiving waters; and,
- exceeding WQOs in a relatively small area of a watercourse is not likely to impair water uses in the receiving environment if the criteria stated in section 3 of these Guidelines are met.

To avoid or prevent any unacceptable impacts on the receiving environment, most jurisdictions that allow mixing zones require that certain principles or criteria be met. As part of preparing the Guidelines, criteria from the CCME and other jurisdictions in Canada and internationally were evaluated[13] for use in the Mackenzie Valley; section 3 of the Guidelines lists the criteria that will be applied by the LWBs when allocating regulated mixing zones. Some of the key principles that apply to decisions regarding mixing zones include:

- In no case should a mixing zone impair the uses of a watercourse.
- Mixing zones are not to be used as an alternative to reasonable and practical treatment of effluent or effluent streams.
- Although exceedances of WQOs may be allowed within a defined mixing zone, the water quality within or discharged into it should never be acutely toxic to aquatic life.
- The size of the mixing zone should be minimized to the extent practical.
- Mixing zone sizes may vary from one watercourse to another.
- The allocation of a mixing zone may vary from one substance to another. While mixing zones may be appropriate for substances that degrade or can be assimilated into the receiving waters without long term effects, substances that are toxic, persistent, and bioaccumulative (e.g., chlorinated dioxins and furans, PCBs, mercury, toxaphene) are not generally allowed in a mixing zone (i.e., EQC would be set equal to WQOs for those substances).

[12] Section 6.2 of CCME, 2003 (see References)
[13] See References for a full list of documents consulted in preparing these Guidelines.

2.3 Summary of How Regulated Mixing Zones will be Established and Used in the Water Licensing Process

Applicants who wish the Board to consider allocating a mixing zone for their project should propose a mixing zone, including rationale, in their water licence application. To support the proposed mixing zone, the applicant must submit the information that is detailed in section 6.

As stated in the Policy, the Board will consider allocating a mixing zone for a project on a case-by-case basis, based on the evidence provided in any given regulatory process. In addition to meeting the definition of a regulated mixing zone in these Guidelines, the mixing zone should be regulated to ensure that the criteria described in section 3 will be met.

When allowed, the main use of a regulated mixing zone in the water licensing process is to define the point at which WQOs must be met downstream of an effluent discharge point or outfall. As described in section 5.1, defining the point at which numeric WQOs must be met serves the very practical purpose of allowing the calculation of numeric EQC, as either concentrations or loadings (i.e., quantity), that meet the requirements of the Policy. Other ways in which a regulated mixing zone may affect the water licence requirements are discussed in section 5.

3.0 Decision Criteria for Allocating Regulated Mixing Zones

As discussed further in section 4, the dimensions allocated to a mixing zone will vary on a case-by-case basis depending on factors including characteristics of the effluent (e.g., quality, flow, outfall design) and the receiving waters (e.g., quality, uses, aquatic life). The criteria listed below will be used to guide the establishment of a regulated mixing zone with the goal of minimizing effects to a watercourse. These criteria are consistent with the LWBs' Policy objectives and based on criteria established for mixing zones in other provincial jurisdictions.[14] Conformance of proposed mixing zones to the criteria below will be determined by the Board based on the evidence presented for a specific water licence application.

1. The dimensions of the mixing zone must be as small as practicable.
2. The mixing zone must not be of such size or shape as to cause or contribute to the impairment of existing or future water uses in the receiving environment.
3. Mixing zones must not be used as an alternative to reasonable and practical pollution prevention practices, including wastewater treatment.
4. The mixing zone should not impinge on or contact critical fish or wildlife habitats (e.g., spawning or rearing areas for fish, habitats for migratory waterfowl).
5. Mixing zones must not be established such that drinking water intakes are contained therein or otherwise negatively affected. Ideally, mixing zones should always be located as far away (i.e., downstream) as practical from drinking water intakes.
6. Conditions within the mixing zone should not cause acute toxicity to aquatic organisms.

[14] See the following References for criteria established in other jurisdictions: Alberta, 1995; British Columbia, 2014; CCME, 2008; Manitoba, 2011; Ontario, 1994; Saskatchewan, 2015.

7. Mixing zones must not be established for substances that are persistent, toxic, and bio-accumulative.[15]
8. The mixing zone must allow an adequate zone of passage for the movement or drift of all stages of aquatic life. The mixing zone should not interfere with migratory routes including migration into tributaries; specific portions of a cross-section of flow or volume may be allocated by the Board for the purpose of migration.
9. Water in the mixing zone should be free from nutrients in concentrations that create nuisance growths of aquatic weeds or algae or that results in an unacceptable degree of eutrophication of the receiving water.
10. Mixing zones should not unduly attract aquatic life or wildlife, thereby causing increased exposure to substances of potential concern.
11. Accumulation of toxic substances in sediment to toxic levels should not occur in the mixing zone.
12. Mixing zones should not contain substances that render the mixing zone aesthetically unacceptable, including, for example, materials which form objectionable deposits (e.g., scums, oil, or floating debris) or substances producing objectionable colour, odour, taste, or turbidity.
13. The mixing zone must be able to maintain its assimilative capacity (e.g., loading).

4.0 Regulated Mixing Zone Dimensions

The dimensions of a regulated mixing zone will be set by the Board based on the considerations described in the Guidelines and on the evidence presented in the regulatory process. In section 4.1 below, the Guidelines discuss the general processes of effluent mixing in the receiving waters and how those natural processes relate to the definition of a regulated mixing zone. Section 4.2 describes some of the potential spatial or fraction of flow methods that may be used to set regulated mixing zone dimensions.

4.1 Relationship Between a Regulated Mixing Zone and the Physical Process of Mixing

When effluent is discharged into a watercourse such as a river or lake, it does not, under most circumstances, completely and instantaneously mix with the receiving water. Instead, what forms is an effluent plume starting at the discharge point as effluent begins to mix with the receiving waters. The mixing zone is a transitional area within a watercourse in which an effluent is gradually assimilated into the receiving water. At some point downstream of the discharge point, the physical process of mixing will be complete. This 'physical' mixing zone is defined as the area up to the point where there is virtually no measurable difference between unaffected receiving water and receiving water mixed with the effluent. At this point, the effluent is considered fully mixed with the receiving water.

The size of the physical mixing zone varies over time with factors such as: effluent flow rate, design of the outfall, ambient watercourse properties (e.g., depth, velocity, density, etc.), season and concentrations of water quality parameters in both the effluent and the receiving waters. Because of its inherent variability over time, the physical mixing zone is not useful for regulatory purposes. As well, the physical process of

[15] For example, see list of chemicals on the United States Environmental Protection Agency's Toxics Release Inventory at: https://www3.epa.gov/enviro/triexplorer/list-chemical-pbt.htm

mixing may extend for very long distances from the discharge point; setting regulated mixing zone dimensions equal to the physical mixing zone could therefore result in unacceptably large areas in the watercourse that have COPC concentrations in excess of WQOs.

For the purpose of water licensing, only a portion of the physical mixing zone will be allocated for use in setting EQC. Unlike a physical mixing zone, which varies over time due to the factors described above, the spatial boundaries of a regulated mixing zone can be defined within a watercourse using finite dimensions such as length, width, or radius (Figure 1). At the edge of the regulated mixing zone, sufficient mixing will have occurred that measured water quality will achieve the expected WQOs. Other jurisdictions in Canada also regulate effluent using only a specific portion of the physical mixing zone, calling this area the 'allocated mixing zone,' 'limited use zone,' 'initial dilution zone,' or simply the 'mixing zone.' For consistency, the term 'mixing zone' is used in this document to refer to the regulated mixing zone.

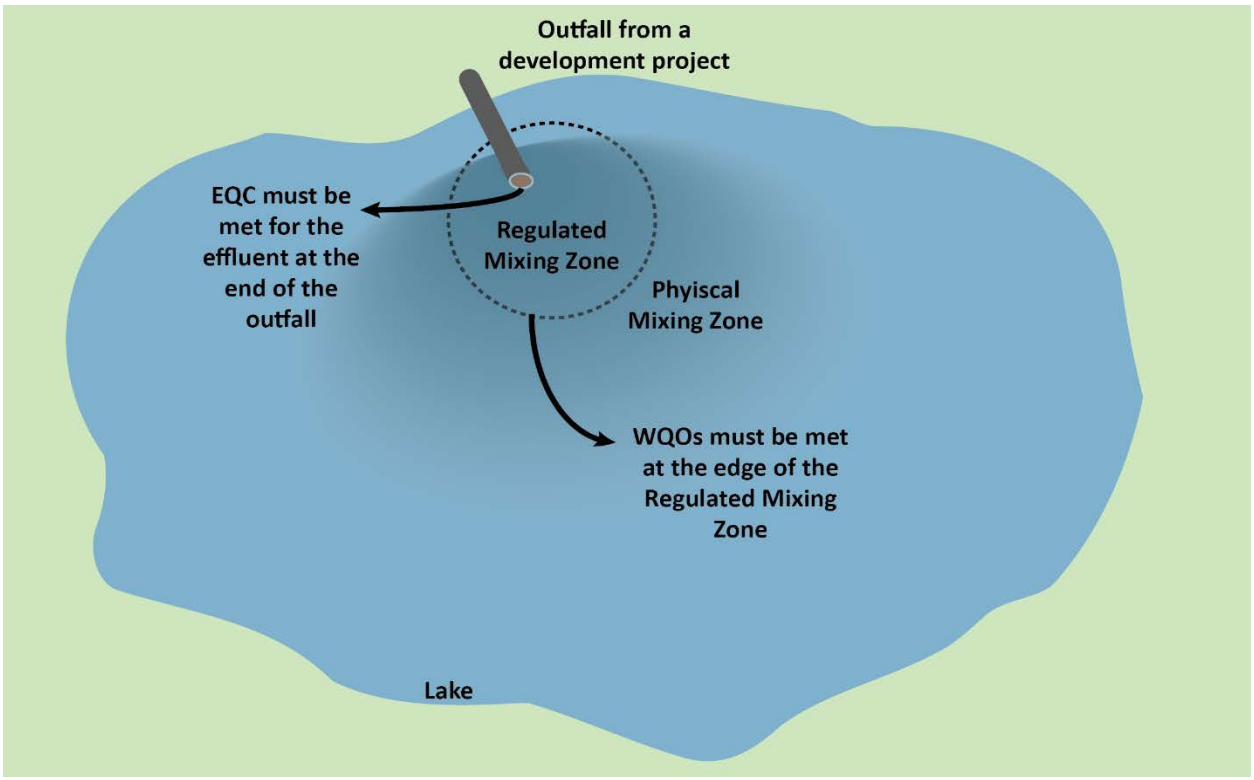

Figure 1a: Difference Between a Physical Mixing Zone and a Regulated Mixing Zone in a Lake

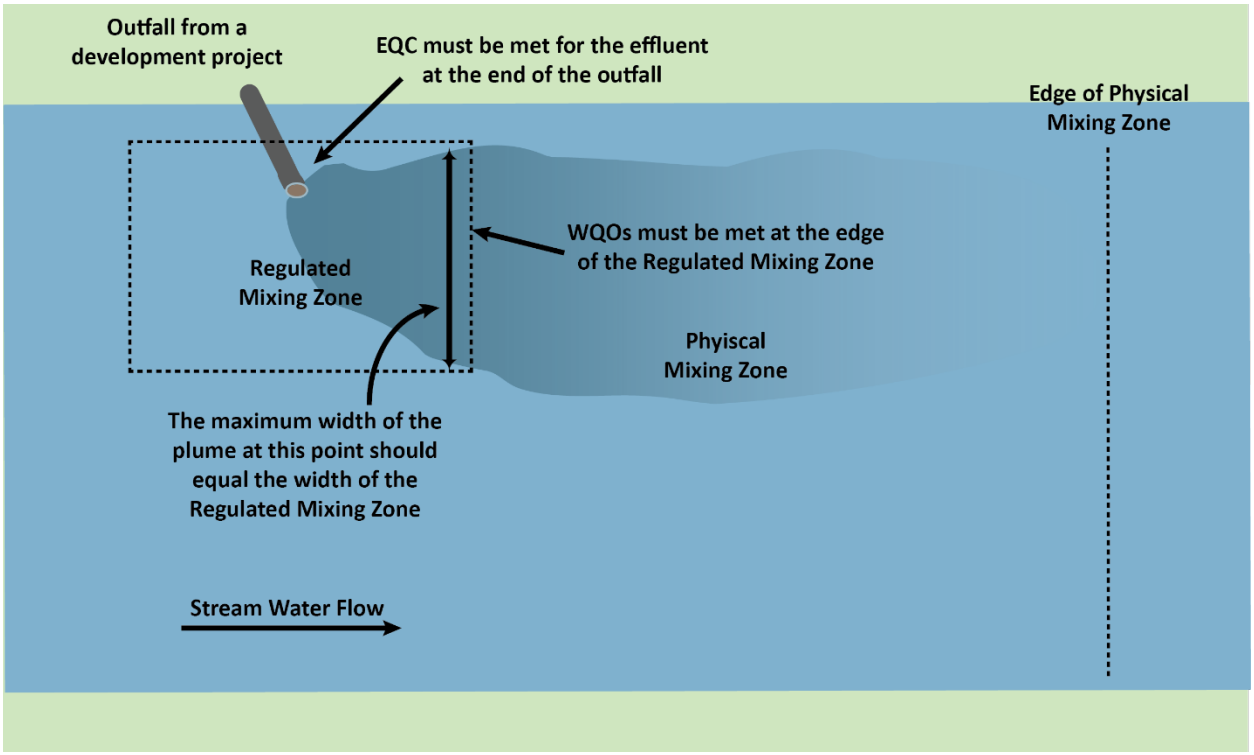

Figure 1b: Difference Between a Physical Mixing Zone and a Regulated Mixing Zone in a Stream

4.2 Considerations for Defining the Dimensions of a Regulated Mixing Zone

As stated in section 3, the dimensions of a regulated mixing zone are meant to be as small as practicable; in other words, the mixing zone size should be large enough to allow for initial dilution and mixing of the effluent but small enough to avoid causing adverse effects to the receiving watercourse. Since decisions about the size of the mixing zone must be made before a project begins discharging effluent, initial conclusions about the extent to which a proposed mixing zone may meet the criteria listed in section 3 can only be based on predictions or modelling information provided by the applicant. In recognition of the inherent uncertainty in modelling, some Canadian jurisdictions[16] have defined maximum mixing zone sizes based on a fraction of streamflow or fixed spatial restrictions (see Appendix 1 for examples). In those cases, restrictions are set very conservatively to ensure that criteria such as the ones listed in section 3 are met under all circumstances.

In the Mackenzie Valley, the LWBs consider the following restrictions as a useful starting point[17] for defining the dimensions of a regulated mixing zone:

- For lakes – regulated mixing zones should have a maximum radius of 100 m or 25% of the width of the lake (whichever is smaller), not exceed 10% of the available volume for mixing, and not extend closer to shore than the mean low water mark. See Figure 2a for a visual representation.
- For streams and rivers – regulated mixing zones should have a rectangular shape where the width is the dimension perpendicular to the path of the stream and the length is parallel to the path of the stream. The width of the mixing zone should not exceed the lesser of 100 m and 25% of the width of the stream. The length of the mixing zone may be defined from a point 100 m upstream of the discharge and a point which is the lesser of 100 m downstream and a distance downstream at which the width of the effluent plume equals the maximum allowable width of the mixing zone. See Figure 2b for a visual representation.

[16] For example: Saskatchewan (2015), Manitoba (2011), British Columbia (2004), and Alberta (1995).
[17] Note that the final dimensions of a regulated mixing zone may be set larger or smaller than what is listed here based on the evidence provided during individual water licensing processes.

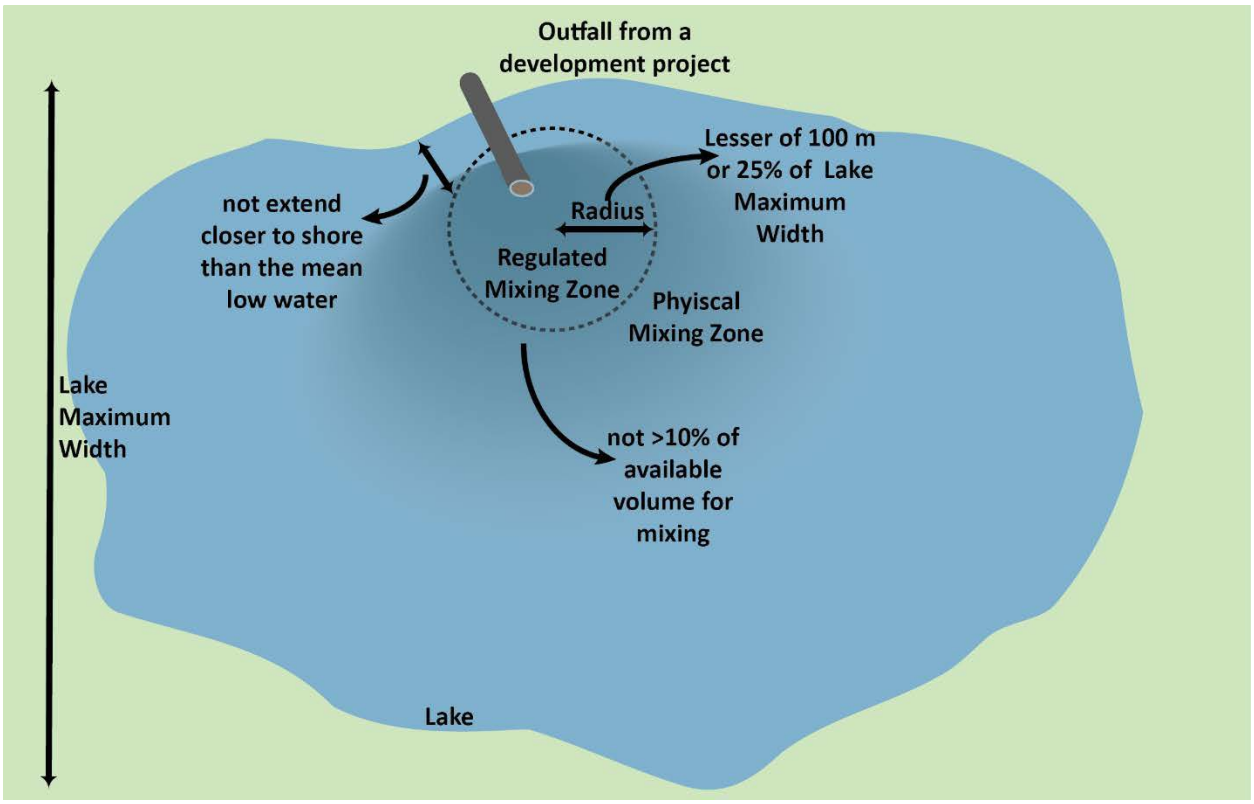

Figure 2a: Dimensions of a Regulated Mixing Zone for Lakes

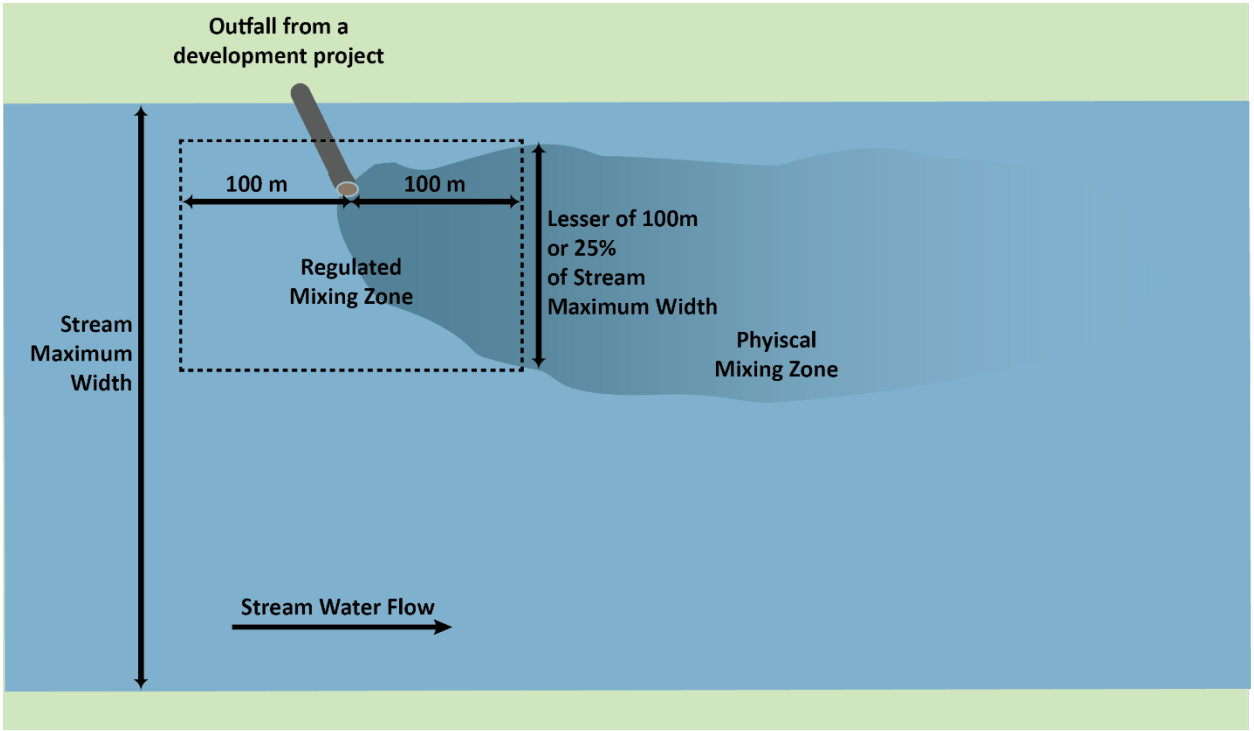

Figure 2b: Dimensions of a Regulated Mixing Zone for Streams or Rivers

Notwithstanding the information above, the exact dimensions of a regulated mixing zone will be determined by the LWBs on a case-by-case basis and the sizes may vary depending on the characteristics of the receiving watercourse and the effluent associated with each individual project. In making final determinations, the LWBs will require the information described in section 6 as well as evidence that the criteria listed in section 3 have been addressed to the extent practicable.

5.0 Water Licence Requirements Related to Mixing Zones

This section provides information about the types of requirements that are often incorporated into water licences for projects that have established mixing zones. Specific requirements for individual water licences will be decided by the LWBs on a case-by-case basis.

5.1 Effluent Quality Criteria

Where a mixing zone is allocated, EQC represent the maximum concentration and load of a substance in the effluent that will meet WQOs at the edge of the regulated mixing zone. To calculate EQC, the following information is needed:

- The WQOs that must be met in the receiving watercourse(s). Note that section 5.1 of the Policy describes the kinds of information that the LWBs will consider when establishing WQOs site-specifically for a receiving environment.
- The characteristics of effluent mixing (both vertically and horizontally), assimilation, and dilution within the regulated mixing zone. Conservative conditions such as periods of low water volume or flow in the mixing zone are generally used to back-calculate EQC that will meet WQOs in the receiving watercourse(s) at all times.
- The background or baseline[18] concentrations of substances in the receiving environment. Substances that are considered COPC in the effluent are often already present in lower concentrations in the receiving waters. Natural background or baseline concentrations of substances in the receiving watercourse must be added to the loads of substances coming from the effluent to ensure that, collectively, substance concentrations do not exceed the WQOs at the edge of the regulated mixing zone.

Details of the information needed to set EQC are available in the LWB *Standard Process for Setting Effluent Quality Criteria*.

The characteristics of the mixing zone, and hence the method of EQC calculation, may be quite different for rivers/streams and lakes. In both cases, the initial dilution is based on the inflow of water into the mixing zone; but, while inflow for rivers/streams is continuous, inflows for lakes may be intermittent or consist only of run-off in the case of headwater lakes. Because of the lower inflow rates, the calculation

[18]In this context, 'background' water quality refers to the natural, pre-disturbance concentrations of substances in the water. 'Baseline' water quality refers to the concentrations of substances in the water prior to the current project; this case acknowledges that there may have already been anthropogenic activity in the area so that water is not at background levels anymore.

of EQC for lakes must consider the accumulation of substances over time in addition to the instantaneous mixing and dilution of substances from the effluent in the receiving waters. Watercourse flow and assimilation characteristics are generally based on a combination of baseline monitoring and modelling; therefore, EQC for new water licences are often set conservatively, and a water licence may require monitoring or a Plume Delineation Study to validate or adjust the assumptions made about initial mixing of effluent in the receiving waters.

5.2 Plume Delineation Studies

Effluents from licenced projects generally differ from receiving waters in terms of quality (i.e., substance concentrations) and density. As discussed in section 4.1, effluents do not generally mix instantaneously with the receiving waters after discharge. The zone of incompletely mixed effluent and receiving water forms a plume extending downstream or away from the discharge point. Depending on the flow characteristics of the receiving watercourse, the plume may, for example, extend downstream along the watercourse's edge or sink to the bottom of the watercourse for varying distances as substances gradually mix and assimilate into the water. The behavior of effluent plumes within receiving watercourses may be estimated or modeled as described in section 6; however, to confirm any assumptions made about effluent mixing, the LWBs may also set a water licence requirement for a Plume Delineation Study.

If required, a Plume Delineation Study is typically done within a year of the beginning of discharge. The Study is usually conducted by analyzing samples of water taken at different locations around the discharge point and extending into the receiving watercourse in a grid-like pattern. Samples are taken at different depths in the water column and the study may be done both under open water and under-ice conditions as mixing differs greatly in different seasons. The results of the Study will be compared to mixing zone predictions to ensure that the assumptions upon which the EQC were set are accurate. If the results of the Study indicate that the initial modelling assumptions are inaccurate it may be necessary to adjust water licence conditions (potentially including the EQC) through a water licence amendment process.

5.3 Monitoring Requirements

Monitoring to assess attainment of WQOs is an essential component of the overall environmental management process. As described above, EQC are set to ensure that WQOs are met at the edge of the mixing zone. To check the accuracy of EQC calculations, water licences typically require the licensee to monitor water quality at stations located at the edge of the mixing zone. The monitoring stations will be located based on the predicted plume characteristics, for example:

- Within a lake, the effluent plume may diffuse out in a circular pattern around the discharge point; in that case, the mixing zone may be defined by the radius of the circle and monitoring stations will be set at several points along the perimeter.
- Within a river or stream, the mixing zone may be defined as a rectangle with monitoring locations set at the downstream edge and at a distance across the width of the river.

- In all cases, if the effluent plume is predicted to float upwards or sink towards the bottom of the watercourse, the licensee may be required to take samples at one or more depths to ensure that the maximum concentration of the plume at the edge of the mixing zone is captured.

Typically, water quality monitoring at the edge of the mixing zone is required monthly so that mixing assumptions can be verified under all seasonal conditions. The location, frequency, and suite of analytical parameters for monitoring the edge of the mixing zone is generally prescribed within the Surveillance Network Program of a water licence. An analysis of the monitoring data, including a comparison to mixing predictions, may be required within a Plume Delineation Study Report and/or an Aquatic Effects Monitoring Program Annual Report, depending on the project. If monitoring results indicate that WQOs are being exceeded at the edge of the mixing zone, it may be necessary to amend the EQC prescribed in the water licence.

Note that requirements for monitoring around a mixing zone will vary between water licences. Issues related to the safety of sampling in the receiving environment, such as high flows or thin ice for example, and schedule of discharge (i.e., continuous or seasonal), will also be considered when setting monitoring requirements for a mixing zone.

6.0 Information Required to Define a Mixing Zone

Applicants who wish the Board to allocate a mixing zone for their project should propose a mixing zone, including rationale, in their water licence application. It is not possible to provide a single definitive list of information requirements for mixing zone applications for all the different kinds of projects and receiving environments in the Mackenzie Valley; therefore, this section only provides an outline of the types of information that applicants should include in their applications. Applicants are expected to provide any information that is necessary to support their application for a mixing zone based on best professional judgement. Prior to submission, applicants are encouraged to contact LWB staff to discuss information requirements for their specific applications.

To support the proposed mixing zone, the applicant must submit, at a minimum, the following information:

1. A description of why a mixing zone is necessary for the project. For example, if after the implementation of pollution prevention measures and/or wastewater treatment, the applicant predicts that concentrations of some substances in the effluent will be higher than the corresponding WQO.
2. Proposed dimensions for the mixing zone with supporting rationale and information as further described below.
3. A description of how conditions in the proposed mixing zone addresses each of the criteria outlined in section 3 of the Guidelines. Note that the evidence submitted by the applicant in this regard is especially important if the dimensions of the proposed mixing zone are greater than those discussed in section 4.2.

4. If applicable, any relevant information provided during an environmental assessment/impact review process with respect to the proposed mixing zone.

Regulated mixing zones are associated with setting EQC for a project. Therefore, the information required to support a proposed mixing zone necessarily overlaps with the information needed by the LWBs to set EQC. The information requirements for setting EQC are available in the LWB *Standard Process for Setting Effluent Quality Criteria*; an overview of the types of information that may support a proposal for a regulated mixing zone includes:

- Receiving watercourse characteristics
    - Include any information about the receiving waters that may be relevant to mixing processes within the water. Examples include, but are not limited to: the type of watercourse (e.g., lake, river, stream), the volume of the receiving watercourse available for assimilation or dilution, background or baseline receiving water quality, and a description of physical/hydraulic processes that affect mixing within the receiving watercourse(s) (e.g., ice formation, channel characteristics, depth, turnover rates, precipitation/evaporation rates, flow characteristics, or any other metric that may affect mixing).
- Water Quality Objectives
    - Applicants should propose, with rationale, site-specific WQOs for the receiving environment that will need to be met at the edge of the proposed mixing zone. Section 5.1 of the Policy describes the kinds of information upon which site-specific WQOs may be based. Appropriate WQOs will ultimately be established by the Board as described in the Policy or by regulations established under the *Waters Act* or the MVRMA.
- Effluent and discharge characteristics
    - For example: flow rate, concentration of COPCs in the effluent, comparison of predicted or actual COPC concentrations in effluent to relevant toxicity guideline values or site-specific WQOs, results from toxicity testing of effluent, physical and aquatic receptors of COPCs in the receiving waters, design and expected performance of the outfall, diffuser type, and expected buoyancy of the effluent relative to the receiving water.
    - Predicted quantity of effluent and a description of whether discharge will occur on a continuous, temporary, or seasonal basis.
    - Applicants should propose EQC as described in the LWB *Standard Process for Setting Effluent Quality Criteria*, and final EQC determinations will be made by the Board in accordance with the Policy.

- Contaminant characteristics
    - Mixing processes can differ for different contaminants (e.g., some substances may decay over time, others can bioaccumulate, and others may be conservative, like ions); therefore, any information relevant to the relative mixing characteristics of COPCs in the effluent should be presented.

In all cases, the applicant should provide the information necessary to demonstrate how WQOs will be met at the edge of the proposed mixing zone under a range of expected, best-case, and worst-case conditions[19] for mixing and dilution. For relatively simple situations, simple mass-balance dilution models can be applied to predict contaminant concentrations in the mixing zone. More detailed modeling may be required for situations with complex effluents, varying effluent flows, and/or for receiving waters in which the characteristics of mixing vary substantially with season or over time. In these cases, several commercially available computer software packages are used to assess and predict physical, chemical, and biological conditions in mixing zones. The US EPA recommends the use of the following models:

1. Visual Plumes (VS) – MS Windows-based, simulates single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges (http://www.epa.gov/ceampubl/swater/vplume/VP-Manual.pdf).
2. RSB and UM models with PLUMES model interface and manager – for plumes discharged to marine and fresh water including buoyant and dense plumes, single source and multiple diffuser outfall configurations (http://www.epa.gov/waterscience/standards/mixingzone/files/RSB_UMPLUMES.pdf).
3. Cornell Mixing Zone Expert System (CORMIX) – hydrodynamic simulations suitable for complex discharge situations, such as discharges into flowing watercourses (lakes, rivers, estuaries, and coastal waters) beyond predictive capabilities of other initial mixing models for multiport diffusers (http://www.epa.gov/waterscience/models/cormix.html).

Inputs to the models should consider the range of expected, best-case, and worst-case conditions for effluent discharge and mixing to demonstrate that WQOs will be met in the mixing zone under all potential conditions of effluent quality/quantity as well as seasonal flows within the receiving waters. For example, it is common practice to use low flow statistics[20] such as the 7Q20 or 7Q10 flows for rivers to simulate worst-case conditions with respect to dilution and mixing in rivers. The climate in the Mackenzie Valley will also alter assimilation and may alter mixing under prolonged ice cover. Assimilation of contaminants over time and the effect of prolonged low water yields must also be considered for lakes.

[19] Conditions that might affect the final concentration of COPCs at the edge of the mixing zone include, for example, the predicted ranges of effluent quality and quantity, the range of hydrological conditions (i.e., low water or high water years) that might affect dilution, or the range of potential wind conditions that could affect mixing.
[20] The 7Q20 or 7Q10 values are equal to the seven-day, consecutive low flow with a twenty or ten-year return frequency, respectively.

7.0 References

Alberta, 1995:

Water Quality Based Effluent Limits Procedures Manual, December 1995, Alberta Environmental Protection Branch, Government of Alberta.

Australia, 2010:

Guidance for the Determination and Assessment of Mixing Zones. Publication 1344, June 2010, Environmental Protection Agency, Victoria, Australia.

British Columbia, 2004:

Environmental Management Act, Municipal Wastewater Regulation, B.C. Reg. 87/2012 [includes amendments up to B.C. Reg. 41/2016, February 29, 2016] Part 6 – Specific Requirements for Discharge to Water.

British Columbia, 2014:

Technical Guidance 1 – Environmental Management Act Applications: Terms of Reference for Environmental Impact Assessment and Technical Assessment Reports, Version 1.0, December 2014, British Columbia Ministry of Environment.

CCME, 2003:

Canadian Water Quality Guidelines for the Protection of Aquatic Life: Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives, 2003, Canadian Council of Ministers for the Environment, Winnipeg, MB.

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Technical Supplement 2: Canada-wide Strategy for the Management of Municipal Wastewater Effluent, Environmental Risk Management Framework and Guidance, June 2008, Canadian Council of Ministers for the Environment, Winnipeg, MB.

European Union, 2010a:

Technical Guidelines for the Identification of Mixing Zones pursuant to Art. 4(4) of the Directive 2008/105/EC. Report prepared by the European Commission, December 2010.

European Union, 2010b:

Technical Background Document on Identification of Mixing Zones. Report prepared by the European Commission, December 2010.

Manitoba, 2011:

Manitoba Water Quality Standards, Objectives, and Guidelines, Manitoba Water Stewardship Report 2011-01, 2011, Water Stewardship Division, Government of Manitoba.

Ontario, 1994:

Deriving Receiving-Water Based, Point-Source Effluent Requirements for Ontario Waters. Procedure B-1-5, PUBS #3302, 1994, Ontario Ministry of Environment and Energy, Government of Ontario

Saskatchewan, 2015:

Surface Water Quality Objectives, Interim Edition, EPB 356, June 2015, Water Security Division, Government of Saskatchewan

US EPA, 1991:

Technical Support Document for Water Quality-Based Toxics Control. EPA 505-290-1 U.S. Environmental Protection Agency, Office of Water, Washington, DC.

US EPA, 2006:

Compilation of EPA Mixing Zone Documents.
http://water.epa.gov/scitech/swguidance/standards/mixingzones/index.cfm

APPENDIX 1: Examples of How Mixing Zone Dimensions Are Defined in Other Canadian Jurisdictions

Although the Guidelines are clear that the final dimensions of a regulated mixing zone will be determined by the LWBs on a case-by-case basis, section 4.2 describes mixing zone dimensions that the LWBs consider a useful starting point for applicants who wish to propose a mixing zone in their water licence applications. The dimensions listed in section 4.2 are based on guidance from other Canadian jurisdictions as listed below. Information sources are listed in the References section of the Guidelines.

1. From Section 3.2 of Saskatchewan, 2015:

    - "the limited use zone in streams and rivers should be apportioned no more than 25 percent of the cross-sectional area or volume of flow, nor more than one-third of the river width at any transect in the receiving water during all flow regimes which equal or exceed the 7Q10 flow for the area. Surface water quality objectives applicable to the area must be achieved at all points along a transect at a distance downstream of the effluent outfall to be determined on a case-by-case basis."
    - "in lakes and other surface impoundments, surface water quality objectives applicable to that waterbody must be achieved at all points beyond a radius of 100 metres from the effluent outfall. The volume of limited use zones in lakes should not exceed 10 percent of that part of the receiving waters available for mixing."

2. From page 13 of Manitoba, 2011:

    - "The mixing zone should be designed to allow an adequate zone of passage for the movement or drift of all stages of aquatic life: (i) For those materials that elicit an avoidance response from aquatic life, the mixing zone should contain no more than 25 % of the cross-sectional area or volume of flow at any transect in the receiving water. Should a proportion of the stream width greater than 25 % be selected for these materials, the mixing zone could act like a physical barrier and could effectively preclude the passage of aquatic life."
    - "In lakes and other surface impoundments, the volume of mixing zones should not exceed 10 % of the volume of those portions of the receiving waters available for mixing or 100 m in radius, whichever is less."

3. From Part 6, Items 92-93 of the British Columbia Municipal Wastewater Regulations (British Columbia, 2004):

    - **"92** (1) For calculating the initial dilution zone for marine waters or a lake, both of the following, measured from the point of discharge and from mean low water, apply:

        a) the height is the distance from the bed to the water surface;
        b) the radius is the lesser of

            i. 100 m, and

ii. 25% of the width of the body of water.

(2) For discharge from an outfall diffuser, the radius referred to in subsection (1) (b) (i) must be measured from the first and last diffuser ports.

(3) In embayed marine waters and lakes, the initial dilution zone must not extend closer to shore than mean low water.

(4) In open marine waters, the edge of the initial dilution zone must be located outside of the shallow water zone in which surf will form along the shore."

- **"93** (1) For calculating the initial dilution zone for a stream, river or estuary, all of the following, measured from the point of discharge and from mean low water, apply:

  a) the height is the distance from the bed to the water surface;
  b) the width, perpendicular to the path of the stream, is the lesser of

     i. 100 m, and
     ii. 25% of the width of the stream or estuary;

  c) the length, parallel to the path of the stream, is the distance between a point 100 m upstream and a point that is the lesser of

     i. 100 m downstream, and
     ii. a distance downstream at which the width of the municipal effluent plume equals the width determined under paragraph (b)."

4. From Table 12, Section 6, page 8 of Alberta, 1995:

   a) "Chronic guidelines are preferably met before 10 times the stream width for a length restriction and ½ the streamwidth laterally (streamwidth calculated at design flow), or using 10% of the 7Q10."