Water Quality Based Effluent Limits Procedures Manual

Summary

This manual describes procedures for setting water quality based effluent limits for industrial and municipal discharges in Alberta.

The rationale for adopting the more stringent of water quality and technology limits is discussed. Background information is provided on how effluent limits are calculated from existing or desired long term effluent performance and how substance variability and sampling frequency are factored into the process. The basis for instream guidelines is reviewed within the context of acute and chronic values, duration and frequency of compliance. The concepts of design or worst case conditions and reasonable potential to exceed instream guidelines are introduced as are wasteload allocation principles and the subsequent development of end-of-pipe limits. The relative advantages and disadvantages of steady state and dynamic models for single and multiple discharge scenarios are reviewed. Examples of applying the methods described are provided throughout the text.

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1.0 Introduction

Overview

This manual provides procedures that departmental staff and the regulated community can follow to assess the need for, and to develop water quality based limits for discharges to Alberta streams.

Water quality protection is maximized through the application of three interrelated procedures which are outlined in this manual.

In the first procedure, an effluent discharge is evaluated to determine if there is potential to exceed an instream guideline for a particular substance. If no exceedance is predicted, the existing or proposed limits based on the pollution control and mitigative strategies for that plant are judged sufficient to protect the environment.

If however, an exceedance of the instream guideline is anticipated, the second procedure, wasteload allocation modelling is applied. Wasteload allocation modelling provides a means to analyze the effluent impact under a variety of conditions and generate an estimate of the maximum effluent load that can be allowed.

This leads to the final procedure, setting the actual end-of-pipe water quality based effluent limits. These limits account for normal operating variability and sampling frequency and provide a high level of environmental protection.

This three step process is relatively straightforward. However, complicating factors such as natural background substance levels, multiple discharges and mixing zone restrictions all need to be considered. The approach presented in this manual addresses the additional complexities introduced by these factors.

Simplified versus complex approaches

Various methods for calculating water quality based limits are presented in this manual. These range from simplified methods requiring limited data and computing resources to ones requiring more comprehensive data and computing intensive techniques. In many cases the simplified methods will yield more stringent results than the more sophisticated alternative. For example, the “steady state” methods employing “worst case” conditions **may** result in the development of a limit that would be more stringent than a limit derived through more sophisticated “dynamic” modelling. The more sophisticated methods are preferred because they are usually more accurate and will ensure the maintenance of instream guidelines at accepted compliance frequencies. However the data and resource requirements necessary to take advantage of the more sophisticated methods may not always be available. This manual discusses the sensitivities associated with the various approaches.

Basis for procedures

The United States Environmental Protection Agency's (US EPA) Technical Support Document for Water Quality Based Toxics Control, 1991 (TSD) is used as a primary reference for this manual. The techniques and approaches contained in the TSD, and as modified in this manual, are believed to represent the best model for regulating discharges and therefore, have been and will continue to be applied in the formulation of water quality based limits in Alberta. A number of other useful documents are also cited throughout the text.

Limitations of procedures

Non-point sources of pollution can significantly impact water quality. Procedures for managing non-point sources of pollution are not addressed in this manual. Similarly, although wasteload allocation approaches are just now beginning to emerge for sediment and benthic invertebrate protection, they are not considered sufficiently advanced to present as routine procedures in a manual of this nature.

Alternative approaches

The procedures in this manual enable protective, scientifically defensible water quality based limits to be developed. Alternative approaches for setting water quality based limits are acceptable provided they are protective and defensible. Ultimately, Alberta Environmental Protection reserves the authority to approve the use of alternative approaches.

Practical solutions

Situations may arise where following the procedures in this manual and/or the value of an instream guideline will produce water quality based effluent limits that may be unachievable, even with the use of advanced wastewater treatment. In these situations, interim limits may be assigned until new, economically achievable technology becomes available. On the other hand, there may arise situations where the application of limits may not make sense, or are difficult to justify. For example when natural background substance levels already exceed a guideline, or when upstream dischargers have already consumed available assimilative capacity. The solutions in these situations are unique and developing universal procedures to address them may not be feasible. This manual is not intended to restrict decision making under these circumstances.

Comment period and manual revision

This Manual represents existing departmental practice for setting water quality based limits and is considered to be a final document. However, we recognize that other information may exist that could have a bearing on the procedures advocated. Therefore, comment from the public and regulated community is invited until January 1, 1997.

Any comments, questions, or suggestions regarding the contents of this Manual may be directed to:

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1.1 Manual Organization

This manual documents and reviews procedures and provides rationale for setting water quality based effluent limits (WQBELs). For those already familiar with the procedures, it will be most convenient to simply refer to Appendix 1 for a tabulation of the parameters and conditions required to develop WQBELs. Sections 2 and 3 discuss the difference between technology based effluent limits and WQBELs and provide a review of the basic theory behind calculating both of these types of limits. Section 4 briefly summarizes the purpose and types of instream guidelines. Section 5 outlines procedures to determine effluent release impact and the modelling approaches to calculate the maximum supportable effluent load and end-of-pipe effluent limits. Section 6 contains rationale for design streamflows, whole effluent toxicity testing, mixing zone considerations and details several other considerations for carrying out modelling and setting limits. Glossary and References Sections are located at the end of the document as are numerous supporting Appendices.

1.2 Intended Audience

This manual is intended to be used by Alberta Environmental Protection staff in the formulation of WQBELs for approvals under the Environmental Protection and Enhancement Act and regulations. The manual is also intended to serve as a reference document for the regulated community and consultants who may be required to submit information and who will sometimes undertake the procedures contained in this manual. Although this is primarily a technical document, it is hoped that the fundamental concepts and approaches to setting water quality based effluent limits can be effectively conveyed to members of the general public.

1.3 Terminology Conventions

Terminology can have different meanings depending on the context within which it is used. The following commonly used terms and associated meanings are used in this manual (the Glossary should be consulted for more comprehensive and detailed explanations of terminology):

Term	Meaning
effluent, discharge, emission, release	*All of these terms refer to wastewater discharges from point sources entering a receiving stream.*
instream guideline, objective, criteria	*All of these terms refer to the instream substance value that must be maintained to support the designated use; classically, the terminology used depends on the jurisdiction, and the status of the value. This manual makes no distinction, it only relates methods for attaining compliance with these values..*
compliance, maintenance, attainment, or meeting an instream guideline	*When referring to instream guidelines, these terms address compliance with a guideline; compliance is not intended in a legalistic sense.*
receiving stream, river, stream, waterbody	*All refer to flowing surface waters.*
US EPA	*United States Environmental Protection Agency.*
TSD	*US EPA Technical Support Document for Water Quality Based Toxics Control (1991).*

2.0 Technology and Water Quality Based Limits

The purpose of establishing effluent limits is to ensure that appropriate pollution prevention and control technologies are adopted by the facility and that the receiving stream is protected. These pollution prevention and control technologies are considered through the implementation of technology limits.

Ambient constraints may, however, dictate the need for more stringent effluent limits, which in turn may require the facility to employ more sophisticated and expensive pollution prevention and control stategies. The limits thus derived are known as water quality based effluent limits. These WQBELs are developed if there is reasonable potential to adversely affect water quality.

To ensure limits are protective, regulators compare technology and WQBELs and adopt the more stringent of the two limits. The only exception is when, for existing facilities, a water quality based limit is not technically attainable. In such cases an advanced technology limit may be adopted as an interim effluent limit.

The following Sections briefly describe these limits.

2.1 Technology Based Limits

2.1.1 Industrial Technology Based Limits

Technology limits form the minimum effluent restrictions for industrial discharges. These limits are based on the application of appropriate pollution prevention and control strategies and consider the age and type of facility. These limits do not inherently consider ambient constraints, except to the extent that good technology limits will offer some level of protection by virtue of the use of modern technology.

There are two main types of technology limits, sector-specific and case-specific technology limits.

Sector-specific technology based limits

Sector-specific technology limits[1] form the minimum restrictions for industrial discharges. There are two types of sector-specific technology limits: sector-specific limits that have been developed in Alberta and sector-specific limits that are borrowed from other jurisdictions. Examples of the former are pH (6 to 9.5 pH units), fish toxicity (50% or greater survival of trout over 96 hours in undiluted effluent), AOX (1.4 to 1.5 kg AOX/t), among others (see Summary of Alberta Standards and Monitoring Requirements

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[1] Also known as categorical technology limits

document). Sector-specific technology limits are end-of-pipe limitations and do not describe specific technologies (except by way of describing the basis for the end-of-pipe limit).

The procedure that is followed when considering interjurisdictional sector-specific limits, has been to classify the industrial facility and then calculate the end-of-pipe limits, usually on the basis of production.

Sector-specific technology limits:

- are end-of-pipe limits; they do not describe specific technologies except by way of describing the basis for the end-of-pipe limit.
- represent some upper percentile of industry performance as a whole.
- are established by considering a wide enough industrial base that their imposition does not result in an economic advantage/disadvantage in the marketplace.
- recognize varying economic capabilities associated with the age and type of facility (e.g. subsectors within sectors).
- are periodically reviewed to keep pace with advancing technology.

If it is found that the facility cannot be adequately classified within an existing sector, case-specific technology limits must be developed.

Case-specific technology based limits

Case-specific technology limits are a classification of technology limits. These limits are used when sector-specific technology limits do not exist and where they are determined to be more stringent than the limits that ambient constraints would require.

The issues considered in formulating case specific limits are similar to those associated with sector-specific limits, except the procedure is normally applied to a single facility.

The development of case-specific technology limits is necessary under the following circumstances:

- Sector-specific technology limits are not available for the facility.
- The facility has sector-specific technology limits but emits substances that are not covered by these limits.
- Sector-specific technology limits may exist, but the industrial processes have changed or are of a different nature and the substances produced are no longer accurately described by the existing limits.
- Either sector-specific technology or water quality based limits must ultimately be applied but the facility must meet them over some time frame. Case specific limits[2] may then be applied on a scheduled basis.

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[2] The limits assigned under this scenario may also be referred to as “interim” sector-specific technology or water quality based limits.

2.1.2 Municipal Technology Based Limits

For municipal discharges, the technology based approach generally establishes a minimum required treatment level. This level is based on the premise that this technology level must be technically proven, and that this technology is affordable for the municipality. In Alberta, this treatment level is termed “Best Practicable Technology” (BPT) and is categorized by its ability to remove certain conventional pollutants that include such parameters as carbonaceous biochemical oxygen demand (CBOD), total suspended solids (TSS), fecal coliform, pH, oil and grease, and non-conventional pollutants such as phosphorus and ammonia.

2.2 Water Quality Based Limits

Water quality based limits are often developed under the assumption of worst case conditions. Alternatively, more sophisticated modelling approaches may be employed that more precisely reflect the desired frequency of compliance of the discharged substance with instream guidelines.

Some components of the water quality based procedure for setting effluent limits are:

Mixing zones

Water quality based limits may also provide for limited zones for dilution of the effluent plume where substances may exceed instream guidelines. These “mixing zones” are established in a manner which restricts the duration of exposure to organisms passing through the effluent plume and protects basin uses.

Chemical Specific and whole effluent toxicity

Limits that are based on meeting instream guidelines are either developed through "*chemical specific*" or "*whole effluent toxicity*" approaches. The *chemical specific* approach involves restricting individual substance concentrations to meet associated instream guidelines, while the *whole effluent* approach involves restricting the toxicity of an entire effluent to the extent that no toxicity will occur instream. The *whole effluent* approach considers the aggregate effect of a complex mixture of substances. *Chemical specific* and *whole effluent* limits can be calculated based on projected stream and effluent flows and substance concentrations.

Biological component

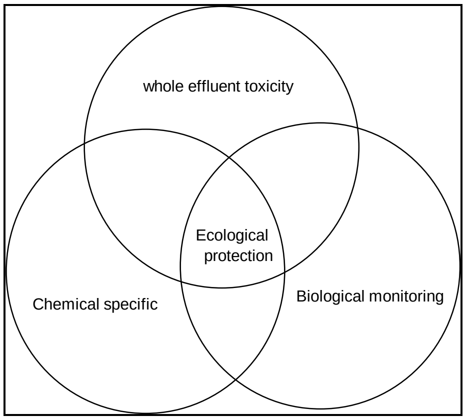
A third component to water quality based limits is the "*biological*" approach. The *biological* approach is more commonly associated with actual monitoring of the receiving stream to gauge and confirm the appropriateness of the existing limits. For example, benthic invertebrate monitoring upstream and downstream of the effluent discharge is done to assess the extent and acceptability of impact. Should that impact be judged unacceptable, in spite of instream guidelines otherwise being achieved, the effluent limits would have to be tightened.

The Triad Approach to Water Quality Protection

Considering the chemical-specific, whole effluent toxicity and biological approaches in the formulation of WQBELs is known as the triad approach. As Figure 1 illustrates, the use of all three components should maximize certainty that the environment is protected.

The biological component includes but is not limited to the assessment of benthic invertebrate impact, sediment contaminant levels, and fish tissue analysis. Any instream impact based on these assessments represents an integrated, long term impact of an existing discharge(s), and/or natural background conditions. The biological approach represents well developed scientific techniques, but guidelines for translating acceptable instream levels to allowable end-of-pipe limits are not well established. The EPA has issued some guidance on this approach (Biological Criteria, 1990).

Figure 1 Conceptual triad approach



Ecological protection

All three of the triad components are addressed before ecological protection is considered to be maximized. If two of the elements are satisfied but a third indicates an impact, the effluent may need to be further curtailed. The reasoning follows that each of the triad components is revealing something different; they are not necessarily correlated. For example, a prediction of chronic toxicity based on the whole effluent approach may be valid in spite of the presence of a thriving benthic community. A chronic toxicity prediction could have been based on worst case conditions which may not have occurred during a benthic survey. Or the chronic toxicity prediction could have been based on a fish toxicity test and the benthic fauna quantified during the survey may not have been affected under this scenario.

Equally valid arguments can be made for the presence of benthic impact in the absence of predicted impact, or chemical specific versus whole effluent toxicity responses. The analyst should become familiar with the strengths and weaknesses of the various approaches.

This manual addresses only chemical specific and the whole effluent approaches.

3.0 Effluent Limits

End-of-pipe (EOP) effluent limits will normally be composed of an average monthly limit (AML) and a maximum daily limit (MDL). In the case of sector-specific technology limits, the AML and MDL are already specified. They need only be recalculated to account for representative production levels at the facility in question.

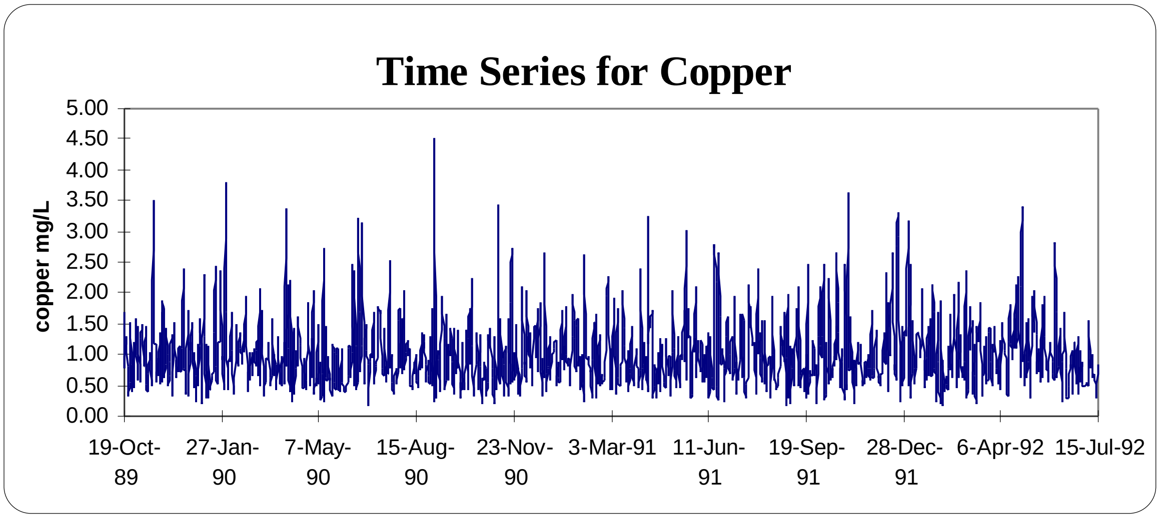
In this Section the statistics associated with setting an effluent limit based on an existing or desired long term average (LTA) are discussed. These considerations are independent of whether the limit is technology or water quality based.

3.1 Statistics and Distributions

Establishing rational end-of-pipe limits requires quantifying sources of variability and applying statistical procedures.

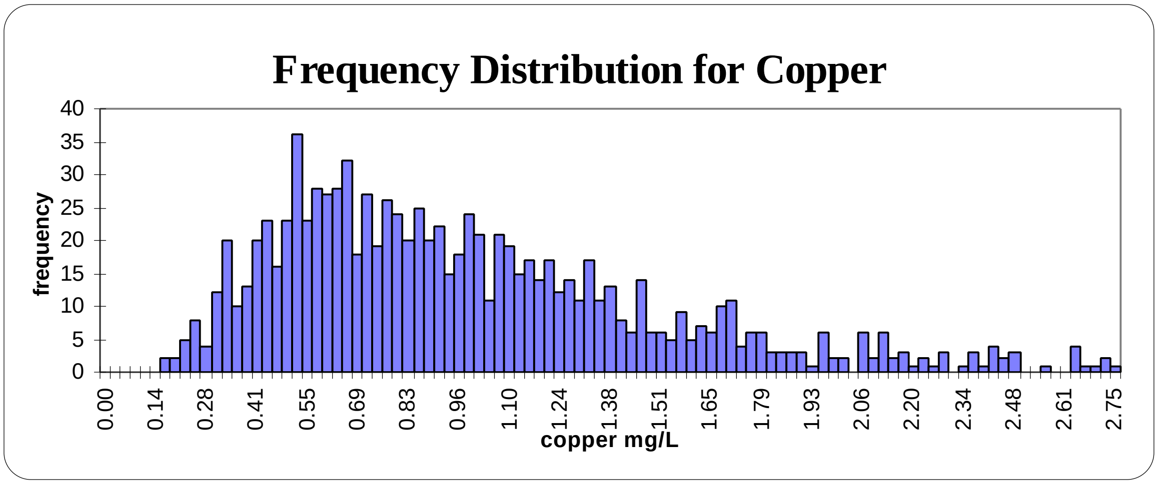
Effluent flow rates and substance concentrations vary for a number of reasons, including changes in operational control, changes in production cycles for industries, variations in treatment systems performance due to influent changes, nutrient, and/or aeration changes, as well as changes in climate. Very few effluents remain absolutely constant in quantity or quality. If the concentration of a substance is plotted against time, the daily concentration variations can be seen.

Figure 2. Time series for copper



This variation can be described by constructing frequency-concentration plots of the same data.

Figure 3. Frequency distribution for copper



The shape of the frequency-concentration plot describes the type of statistical distribution. The types of statistical distributions include normal (bell shaped), lognormal (positively skewed), or other variations on the lognormal distribution. Most substances in a treated effluent follow a lognormal distribution. **This distribution should be used as a conservative default assumption when estimating percentiles, unless there is supportable evidence to the contrary.**

Treated effluent data usually follow a lognormal distribution because the data are non-negative and treatment efficiency at the low end of the concentration scale is limited, while effluent concentrations may vary widely at the high end of the scale, reflecting varying degrees of treatment system performance. These factors combine to produce the characteristically positively skewed appearance of the lognormal curve when data are plotted in a frequency histogram. The distributional fit of the data varies from application to application, but not enough to alter the conclusion that effluent substance discharges are generally lognormally distributed.

The recommendation of the use of the lognormal distribution for daily substance measurements is based on practical rather than theoretical consideration. Instream water quality data are also often lognormally distributed.

Effluent data from a facility should be described using standard descriptive statistics, such as the mean or long term average (LTA) of the substance. The coefficient of variation (CV) is a standard statistical measure of the relative variations of a distribution or set of data, defined as the ratio of the standard deviation to the mean. Using a statistical model, such as the lognormal distribution, an entire distribution of values can be projected from limited data, and limits can be set at a specified probability of occurrence (e.g., the 99th percentile).

For technology-based requirements, the limits are based on proper operation of a treatment system. For water quality based requirements, the limits are based on maintaining effluent quality at a level that will support the wasteload allocation, the value required to comply with instream guidelines. The wasteload allocation in turn defines the desired level of treatment plant performance or target long term average effluent quality. The average monthly and daily maximum limits are derived from the LTA as a function of the shape of the distribution.

A number of excellent statistical discussions and texts are available for the application of WQBELs setting. See Appendix 6 for a listing.

3.2 Percentiles

The derivation of end-of-pipe limits requires the application of percentiles. Percentiles are statistical point estimates of a distribution.

The statistical equation for determining percentiles is as follows:

$$X_{\text{percentile}} = \text{mean} + z(s) \qquad \textit{Equation (1)}$$

where: s = standard deviation

z = z score for the normal distribution

The probability levels used for deriving approval limits have been used historically in connection with the development of sector-specific technology limits and have reportedly been upheld in legal challenges to these limits (as cited in TSD). It is important to note that these percentiles are statistical probabilities used as the basis for developing limits. The goal in establishing these levels is to allow the regulator to distinguish between adequately operated wastewater treatment plants with normal variability from poorly operated treatment facilities. **The use of these percentiles does not imply that the approval holder is being granted some allowable frequency of non-compliance with end-of-pipe limits.**

3.3 Maximum Daily Limit

A maximum daily limit represents the absolute maximum allowable load or concentration of a substance that a facility may release into a receiving stream in one day. This limit may be based on water quality constraints, or sector-specific or case specific technology considerations. The value is typically represented by the 99th percentile of existing or required performance. The general equation for normal distributions is:

$$MDL = LTA + z(s) \qquad \textit{Equation (2)}$$

where:
MDL = Maximum Daily Limit
LTA = Long Term Average (mean)
s = standard deviation
z = z score for the normal distribution= 2.236 for 99th percentile

The above equation can be used for the calculation of maximum daily limits except lognormal distribution assumptions are usually employed and thus the functional equation becomes:

$$\mathrm{MDL} = \mathrm{LTA} \bullet e^{[zs - 0.5s^2]} \qquad \textit{Equation (3)}$$

where:
MDL = Maximum Daily Limit
LTA = Long Term Average (mean)
$s^2 = \ln(\mathrm{CV}^2 + 1)$
z = z score for the normal distribution = 2.236 for 99th percentile

The above equations are used primarily for determining limits from wasteload allocation values. Although they can be used for determining percentile values on actual performance data, the equations presented in the Technology Based Limits Procedures Manual (draft) are more convenient to use.

3.4 Average Monthly Limit

Because it is difficult and sometimes impossible to continuously monitor the effluent to ensure compliance with the MDL, the concept of average monthly limits is employed. The AML represents the maximum averaged load or concentration of a substance that a facility may release into a receiving stream over some specified time period. Typically this value represents the 95th percentile of existing or required performance. The value of the AML is also dependent on how often the effluent is monitored.

The value of an average of a number of samples is related to the number of samples taken and the variability of the data. The more samples taken, the closer the result should be to the population (or true) mean. Similarly, the lower the variability of the data for a given sample size, the closer the result should be to the long term mean. These relationships are used to develop an average monthly limit.

It is important to account for these relationships because it is impossible to monitor most substances continuously. What values are occurring between those times that samples are taken is predicted by understanding the shape of the population distribution.

The general equation for determining average monthly limit percentiles is:

$$AML = LTA + z\left(\frac{s^2}{n}\right)^{\frac{1}{2}} \qquad \textit{Equation (4)}$$

where: AML = Average Monthly Limit
LTA = Long Term Average (mean)
n=number of samples per month
s = standard deviation
z = z score for the normal distribution, z=1.64 for 95th percentile

The above equation can be used for the calculation of average monthly limits except lognormal distribution assumptions are usually followed and thus the functional equation becomes:

$$\mathrm{AML} = \mathrm{LTA} \bullet e^{[z s_n - 0.5 s_n^2]} \qquad \textit{Equation (5)}$$

where AML = Average Monthly Limit
LTA = Long Term Average (mean)
$s_n^2 = \ln(\mathrm{CV}^2 / n + 1)$
n = number of samples per month
z = z score for the normal distribution = 1.64 for 95th percentile

Note, the above equations are used primarily for translating wasteload allocation values into daily and monthly effluent limits that would appear in the facilities operating approval. Although they can be used for determining percentile values on actual performance data, the equations presented in the Technology Based Limits Procedures Manual (draft) are more convenient to use.

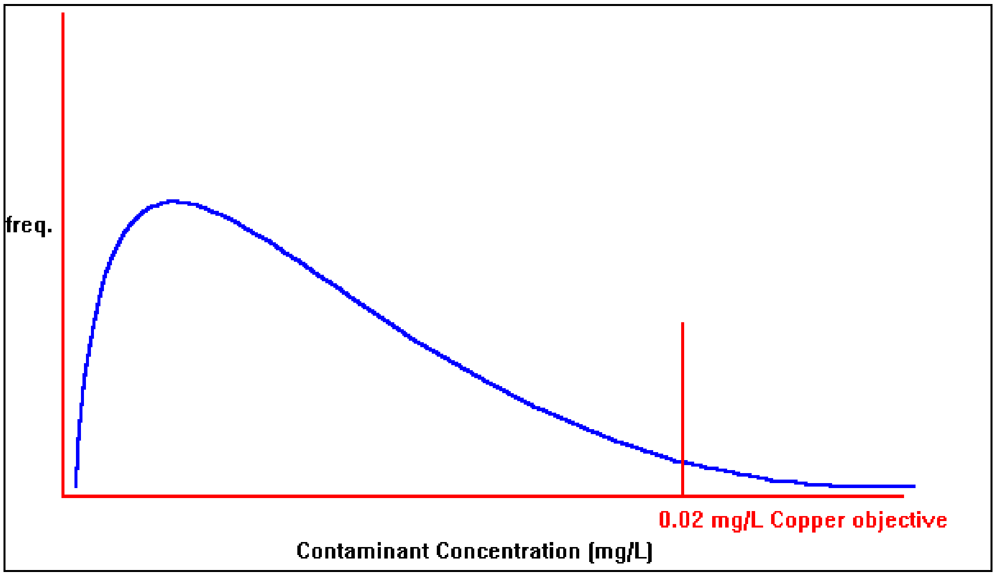
4.0 Guidelines - Frequency, Magnitude and Duration

Water quality based limits are related to the streamflows available for dilution, mixing zone restrictions, background concentrations of substances and the variability associated with the substance discharge. These limits are also related to the numerical values of instream guidelines. Those guidelines may be based on acute, chronic, or human health assumptions; they may be applied with associated averaging periods and they may have specific frequency of compliance requirements. The following subsections discuss the factors related to instream guidelines.

4.1 Frequency of Exceedance

Any instream guideline may eventually be exceeded due to background fluctuations or due to point source loading variability or a combination of the two. This is due to the stochastic nature of point source flows, effluent substance concentrations, streamflows, and background substance concentrations. If the frequency distribution of a substance is represented relative to its guideline (Figure 4), it can be seen that higher concentrations exceed the guideline less frequently. Statistically, it would be impossible to shift the distribution far enough to the left so that there would never be an exceedance of that guideline.

Figure 4 Hypothetical frequency distribution of copper concentration



Therefore it is evident that some frequency of exceedance must be specified. The criteria for the selection of a specific frequency of exceedance is that the frequency of exceedance chosen will allow rapid recovery of an ecosystem. The default allowable frequency of exceedance for acute and chronic criteria is once in three years. This is considered to be the threshold frequency at which organisms can recover from modest assaults. However the TSD (1991) discusses considerations that would allow varying that frequency of exceedance to as little as once every 25 years, depending on such things as current health of the river and protection of long lived fish. Although once in three years will be protective for most ecosystems, any frequency used should be based on defensible principles.

4.2 Types of guidelines

Guidelines are typically developed to protect uses. This manual focuses mainly on protection of aquatic life (PAL) guidelines since these guidelines most often result in the most stringent wasteload allocations. “Other” guidelines (aesthetic, human health, etc.) are discussed towards the end of the Section.

4.2.1 Protection of Aquatic Life Guidelines

The EPA expressed their protection of aquatic life criteria in terms of acute and chronic averaging periods. This format recognizes that high concentrations of chemicals can cause rapid toxic effects to organisms, while much lower concentrations can be tolerated for greater time periods. This enables a regulatory agency (through the setting of limits) to achieve a balance between over- and under-protectiveness.

Acute guidelines

Acute toxicity is fast acting, hence the amount of time over which an organism can be exposed must be limited. US EPA Gold Book acute criteria are designed to be applied as one hour averaged periods. However, as a practical reality, it is generally understood that a one day averaging period will suffice, unless the effluent substance is highly variable. Most effluent data is available as one day averaged data.

Chronic guidelines

Chronic toxicity is toxicity which occurs over a long period of time or after multiple exposures. It has been recognized that chronic guidelines can be exceeded (up to the acute guideline value) for short periods without stressing organisms, provided that on average the chronic guideline is maintained. Because chronic toxicity tests used to derive instream guidelines are typically 20 to 30 day tests at steady state concentrations of a substance, some averaging period less than this is selected to appropriately restrict higher short term exceedances and yet not be so short as to defeat the concept of the averaging period. The 4 day averaging period is used as a default value.

Examples

Some guidelines, such as the acute criteria for ammonia, should not be exceeded on average for more than one hour to prevent acute impacts (longer averaging periods (e.g., one day) may be justified based on the effluent and stream background variability). On the other hand the chronic criteria for ammonia may be considered to be as long as a 30 day averaging period, provided the effluent ammonia is not too variable (Water Quality Standards Handbook (1994), Ambient Water Quality Criteria for Ammonia. (1984).

Mixing zones

In addition to meeting the desired frequency of compliance with the instream guideline, which may be approximated through the use of worst case conditions, or through more sophisticated means as described in the next Section, guidelines may also have to be met before the effluent plume has completely mixed with the receiving stream. This is done to ensure that high concentrations of substances in the plume, which may exceed the instream guideline, do not extend for long distances and potentially affect organisms and other stream uses. The common approach taken to ensure that uses are protected is through the fraction of a streamflow (the design or worst case streamflow), or through the specification of an areal or spatial restriction. Guidelines then have to be met after dilution with that fraction of flow or at the edge of this spatial boundary. These mixing zone considerations are more fully discussed in Section 6.

4.2.2 Other guidelines

Nutrient guidelines and aesthetic (colour, staining, etc) guidelines will normally be applied as 4 to 30 day chronic values without mixing zone restrictions according to Appendix 1 design conditions. US EPA Gold Book Human health carcinogen and non-carcinogen criteria should be screened at the design conditions also specified in Appendix 1.

4.3 Example Guidelines

The following Table 1 is extracted from a portion of the Appendix 8 listing of guidelines which represents a compilation of Alberta, Canada and US EPA Gold Book instream guidelines. The column headings in combination with Appendix 1 indicate how these guidelines are to be treated with respect to averaging periods. For example chronic guidelines should be considered as 4 day average values, acute guidelines as 1 hour to 1 day averaged values.

Table 1. Example instream guidelines (all values in mg/L)

Substance[3]	Acute[4]	Chronic[5]	HHC[6]	HHNC[7]	Source
acenaphthene	1.7	0.52			USEPA
acrylonitrile			0.000059		USEPA
aldrin	3		0.00000013		USEPA
aldrin dieldrin		0.000004			CCME
anthracene			9.6		USEPA
antimony				0.014	USEPA
arsenic	0.36	0.19		0.000018	USEPA
arsenic		0.01			ASWQO
arsenic total		0.05			CCME
asbestos			7000000		USEPA
atrazine		0.002			CCME
barium				1	USEPA
barium		1			ASWQO
benzene			0.0012		USEPA
benzene		0.3			CCME
benzidine	2.5		0.00000012		USEPA
benzo a anthracene			0.0000028		USEPA
benzo a pyrene			0.0000028		USEPA
benzo k fluoranthene			0.0000028		USEPA
3 4 benzofluoranthene			0.0000028		USEPA
beryllium	0.13	0.0053			USEPA
beryllium		0.0001			CCME

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[3] all Table values are for freshwater only
[4] one hour to one day averaging period
[5] 4 day default averaging period
[6] human health carcinogen
[7] human health non-carcinogen

5.0 Reasonable Potential to Exceed and Wasteload Allocation Procedures

Section organization

The concepts preceding this Section have provided a basis for the procedures presented here. This Section is organized according to how a water quality based limit is developed:[8]

1. an effluent is first screened to determine whether there are substances that could cause an instream guideline to be exceeded (reasonable potential to exceed);
2. a wasteload allocation is performed if potential to exceed is demonstrated; and
3. end-of-pipe limits are subsequently calculated to support that wasteload allocation.

Proceeding through these steps requires an understanding of worst case conditions and steady state or dynamic modelling techniques.

Worst case conditions

The function of water quality based limits is to ensure protection of water quality primarily through the maintenance of instream guidelines. Regulators have traditionally subscribed to a concept called "worst case" or "design" conditions. These represent restrictive conditions under which guidelines must be met, such as 7Q10 streamflow, a projection of background stream substance concentrations and simultaneous high effluent discharge of the substances in question. The calculation of potential to comply with guidelines or the formulation of limits under these conditions are done at "steady state".

Steady state example

For example, assume a substance concentration of 10 mg/L, at an effluent flow rate of 1 m^3/s, discharging into a stream with a 7Q10 flow rate of 100 m^3/s (assume no background substance concentration or mixing zone restriction). This would result in an instream substance concentration of 0.1 mg/L. This value could then be compared to the relevant instream guideline to determine if the guideline would be met under these worst case/design conditions.

Worst case conditions used as surrogate

It is recognized that the probability of these events occurring simultaneously is not directly resolvable. **In fact the previously described "design" conditions are used as a surrogate means to achieve some desired frequency of compliance of the instream guideline.** More sophisticated models can sometimes be employed to precisely resolve

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[8] These procedures (dependent on instream guidelines) are not intended to preclude the application or consideration of other factors that may be deemed necessary to ensure water quality protection. These other factors may include but not be limited to a consideration of benthic integrity and fish health.

and control that acceptable frequency of compliance. This approach frees the analyst from choosing point estimates of design conditions and provides more accurate results by considering the probabilities of all possible outcomes.

Dynamic example

For example, continuing with the above calculation, consider that the identical calculation was carried out for each day of effluent and streamflow for approximately 14 years and that 5000 results were produced. If a frequency distribution was constructed with this data, a range of probabilities would be evident with decreasing probabilities trailing off to the right. If the instream guideline was to be complied with at a one in three year frequency, the analyst would pick off the substance concentration associated with that probability (eg., [1 - 1/(3 X 365)] = 99.91). That number would then be compared to the instream guideline to assess frequency of compliance.

Steady state versus dynamic

In situations where data or resources are inadequate to carry out this type of "dynamic modelling", or where routine screening for compliance of a substance is required, steady state modelling is the preferred method. Although the comparison is dependent on the design conditions chosen and the frequency of compliance sought, empirical evidence suggests that on average, the steady state method will yield roughly equivalent results to the dynamic method (TSD, 1991). Provided the recommended steady state design conditions are carefully selected, the level of protection afforded through this approach is considered acceptable.

Although the methods described in this manual focus primarily on the description and use of worst case conditions in steady state modelling, it is the frequency of compliance with the instream guideline that is the underlying objective being addressed.

5.1 Reasonable Potential to Exceed

A fundamental consideration for determining whether a facility will require a water quality based limit relates to addressing the question of whether there is "reasonable potential to exceed" an instream guideline. If "reasonable potential to exceed" is demonstrated, then some strategy of reducing that potential is pursued, typically the assignment of limits. Since "reasonable potential to exceed" is used as a benchmark for determining the need for a water quality based limit, the conditions chosen, and the amount and quality of data used in the calculations are critical factors.

Mass balance dilution model

The determination of "reasonable potential to exceed" involves employing the mass balance dilution model at worst case conditions on the substances that might be expected to be found in the effluent and for which instream guidelines exist:

$$C = (QeCe + QsCs) / (Qe + Qs) \qquad \textit{Equation (6)}$$

where
Qe = volume of effluent discharge
Qs = volume of receiving stream available for mixing
Ce = concentration of a substance in the effluent
Cs = upstream concentration of substance
C = resultant instream concentration of substance after mixing

Instream concentration (C) not to exceed instream guideline

The maximum value of C should not exceed the instream guideline value. If it does, reasonable potential to exceed is considered to have been demonstrated.

Conditions under which to conduct screening

The conditions under which to conduct reasonable potential to exceed screening follow in the next subsections. These conditions include the specification of which guidelines, design streamflows, and mixing zone restrictions to employ. The latter two conditions are only briefly described in this Section. More details on streamflows and mixing zones follow in the next Section. Reasonable potential multipliers which are used to deal with uncertainty associated with small data sets are discussed in this Section. Finally, an example of conducting a reasonable potential to exceed screening is provided.

5.1.1 Sequence of Guidelines to Use for Screening

The department has guidelines for some of the substances that have potential to cause water quality impacts. The interim ASWQG are currently being revised. There are also US EPA and Canadian Water Quality Guidelines (CWQG) that may be referenced. A protocol for selecting which guidelines to use is outlined in Table 2.

Table 2 Recommended sequence of guidelines use

Sequence	Guideline
1.	*ASWQG, treated as chronic, 4-day averaged guidelines. USEPA Gold Book values for acute and human health guidelines for the same substances.*
2.	*If ASWQG for the substance in question does not exist, use CWQG, treated as chronic, 4-day averaged guidelines. USEPA Gold Book values for acute and human health guidelines for the same substances.*
3.	*If ASWQO or CWQG for the substance in question do not exist, USEPA Gold Book acute, chronic, and human health guidelines should be used with the appropriate design averaging periods.*

5.1.2 Streamflows and Mixing Zone Restrictions for Screening

The following subsections discuss the streamflows that are normally employed for reasonable potential to exceed screenings and wasteload allocation calculations. These flows usually represent worst case conditions. However, as a caveat, higher streamflows may in some cases be more appropriate. For example, metals or nutrient background concentrations may be highest during high spring or summer flows. On the other hand, the lower flow periods with lower background substance concentrations may ultimately prove to be the worst case condition since the proportional substance contribution from the discharge may be highest during that period. In these situations it would be most prudent to screen under a variety of conditions to determine which is the most limiting season and streamflow.

Streamflows (hydrological)

The streamflows to be used depend on the guideline being screened. Acute guidelines should normally be screened using the 1Q10 flow, while chronic, ASWQG and CWQG guidelines should normally be screened against the 7Q10. US EPA human health guidelines are screened using the 30Q5 and the harmonic mean flows for non-carcinogen and carcinogen guidelines respectively. The above XQY flows are known as hydrological design flows.

Streamflows (biological)

Biological flows may also be used. Acute US EPA guidelines should be screened using the 1 day in 3 year biological flow, while US EPA chronic and human health non-carcinogen guidelines, ASWQG and CWQG guidelines would be screened against the 4 day in 3 year biological flow. US EPA human health carcinogen guidelines are screened using the harmonic mean flow as before. More detail and the rationale for biological and hydrological streamflows are presented in Section 6.

Spatial restrictions or fraction of streamflows

Another design condition is the further restriction of the streamflow available for the dilution calculation through a fraction of flow or spatial mixing zone approach (generally for protection of aquatic life guidelines). These are physical/spatial areas in the stream within which instream guidelines may be exceeded, but are minimized to the extent that beneficial uses are protected. Mixing zones are sized so as to limit acute lethality to organisms passing through the plume and so that the waterbody as a whole is protected. In some cases further refinement of the data after the initial screening will cause a modification of the mixing zone size. Refer to the Mixing Zone subsection in Section 6.

Modified mass-balance equation

To use the fraction of flow method, the mass balance *Equation 6* is modified according to the following equation:

$$C = \left(QeCe + ff(Qs)Cs\right) / \left(Qe + ff(Qs)\right) \qquad \textit{equation (7)}$$

where:
Qe = volume of effluent discharge
Qs = volume of receiving stream available for mixing
Ce = concentration of a substance in the effluent
Cs = upstream concentration of substance
C = resultant instream concentration of substance after mixing
and:
ff = fraction of flow

Near-instantaneous mixing

Mixing zone restrictions are inappropriate in some situations, particularly where multiport diffusers are installed and span a significant portion of the stream width. In these situations, near-instantaneous mixing may be achieved and compliance with guidelines is assessed at full dilution of the stream (at specified design flows). In the case where near-instantaneous mixing is achieved through multiport diffusers, no mixing zone restriction need be considered in screening (for chronic guidelines), provided rule of thumb restrictions are complied with. Near-instantaneous mixing is defined as no measurable difference in the concentration of a substance across a transect of the stream (eg., does not vary by more than 10%) two stream widths from the outfall. More details can be found in the Mixing Zone Section.

Inconclusive result

If there are poor or incomplete effluent data, background data or unreliable dilution estimates, the result may be considered inconclusive. When this outcome occurs, more monitoring of the substance in question should be undertaken.

Alternative ways to screen

There are two ways to determine reasonable potential to exceed. The most common one is to obtain a statistical estimate of the substance in question (the 99th percentile effluent concentration) and calculate the potential for it to exceed the relevant instream guideline under specified conditions.

It is just as valid to calculate the wasteload allocation required to support the instream guideline and then compare this result to the effluent concentration of the substance (the 99th percentile effluent concentration). The latter approach could be used to query an existing or proposed discharger where effluent data are not available or must be generated.

5.1.3 Summary of Conditions for Screening

Table 3 indicates the flow and mixing zone restrictions to use during the reasonable potential to exceed procedure. These same conditions are used for developing the wasteload allocation which is essentially the backcalculation of allowable loadings required to support the instream guidelines.

Table 3 Conditions to use for reasonable potential to exceed screening

Parameter	**Conditions for Reasonable Potential Screening**	
	streamflow	**mixing zone restriction**
acute guidelines **(USEPA)**	*1Q10 (or 1 day in 3 year biological flow)*[bf]	*end-of-pipe, or with adequate justification, 30 metres surrounding outfall*[sz] *(at design streamflow), or 5% fraction of design streamflow.*[9]
chronic guidelines **(ASWQG, CWQG, USEPA)**	*7Q10 (or 4 day in 3 year biological flow)*[bf]	*comply with rule of thumb*[rt] *restrictions to the extent resolvable, or with adequate justification, the more stringent of 10 times stream width for length and 1/2 stream width*[sz]*, (both determined at 7Q10), and 10% fraction of design streamflow*[10]
human health non-carcinogen **(USEPA)**	*30Q5 (or 4 day in 3 year biological flow)*[bf]	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*
human health carcinogen **(USEPA)**	*harmonic mean flow*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*

[bf] If the biological flow is calculated, it should be used instead of the hydrologic flow.

[sz] If the calculated spatial zone results in a more stringent WLA than the fraction of flow, then the spatial restriction should be employed.

[9] An LC50 >100% at EOP (using rainbow trout and/or *Daphnia magna*) will in most cases be required.

[rt] See Mixing Zone Section or Appendix 1 for a description of rule of thumb restrictions

[10] In the case where near-instantaneous mixing is achieved through multiport diffusers, no mixing zone restriction need be considered (for chronic guidelines), provided rule of thumb principles are complied with. Near-instantaneous mixing is defined as no measurable difference in the concentration of a substance across a lateral transect of the stream (eg., does not vary by more than 10%) for a distance equal to two stream widths downstream of the outfall.

5.1.4 Steps for Determining Reasonable Potential to Exceed

The following steps detail the sequence of activities and calculations required to determine reasonable potential to exceed an instream guideline.

Table 4 Steps for determining reasonable potential to exceed

Step 1 Identify substances	*Examine the effluent monitoring record and delineate those substances for which instream guidelines exist (ASWQG, CWGQ, USEPA).*
Step 2 Calculate effluent statistics	*Calculate the mean, standard deviation, and 99th percentile statistics on the effluent substances using lognormal (or deltalognormal) distribution assumptions and construct time series graphs to enable the examination of trends and data editing. If the number of data points is limited (less than 10) then the reasonable potential multiplier method should be used (see next Section for explanation of reasonable potential multiplier).*
Step 3 Calculate stream flow statistics	*Generate or obtain streamflow statistics for 1Q10 (for acute), 7Q10 (for chronic), 30Q5 (human health non-carcinogen) and HMF (human health carcinogen). Alternatively, use biological flows.*
Step 4 Estimate upstream substance concentrations	*Examine NAQUADAT/ENVIRODAT or other data sources for background concentrations. Typically use the average seasonal low flow values to represent background concentrations (except use the 85th percentile for ammonia and pH).*
Step 5 Mass balance dilution equation	*Use the mass balance equation to generate an instream concentration for each substance (use fraction of the design flows - typically use 5% for acute and 10% for chronic) and 99th percentile effluent substance concentration. Alternatively, use spatial mixing zone restrictions.*
Step 6 Compare result with instream guideline value	*Compare the generated values with the corresponding instream guidelines. If any are exceeded, either refine the data used if necessary, proceed with deriving a wasteload allocation and setting an end-of-pipe limit, or pursue an alternate mitigative strategy.*

5.1.5 Example of Reasonable Potential to Exceed Approach

A reasonable potential to exceed assessment for copper discharges from a facility is to be undertaken. The information has been summarized as follows:

Table 5 Example parameters for reasonable potential to exceed exercise

Parameter	Notation	Value	
upstream copper concentration	Cs	0.001 mg/L	
mean effluent flow	Qe	$0.7\ m^3/s$	
99th percentile for effluent copper	Ce	3.0 mg/L	
copper effluent CV	CV	0.6	
stream hardness	as $CaCO_3$	200 mg/L as $CaCO_3$	
instream guideline type		***acute***	***chronic***
streamflow	Qs	$1Q10 = 50\ m^3/s$	$7Q10 = 55\ m^3/s$
fraction of streamflow	ff	5%	10%
instream guideline value	C	0.034 mg/L	0.021 mg/L

Mass balance dilution equation:

$$C = \left(QeCe + ff(Qs)Cs\right) / \left(Qe + ff(Qs)\right) \qquad \text{Equation (7)}$$

Therefore:

for acute: C=(0.7*3.0+0.05*50*0.001)/(0.7+0.05*50) = 0.657
for chronic: C=(0.7*3.0+0.1*55*0.001)/(0.7+0.1*55) = 0.340

since: 0.657 mg/L >0.034 mg/L (acute)
and: 0.340 mg/L >0.021 mg/L (chronic)

Reasonable potential to exceed has been demonstrated for acute and chronic guidelines.

5.2 Using Reasonable Potential Multipliers

Reasonable potential multipliers are used to compensate for small data sets. The estimated maximum substance concentration is calculated as the upper bound (typically 99th percentile) of the expected lognormal distribution of effluent concentrations at a high confidence level (typically 95 percent). The projected substance concentration after consideration of dilution can then be compared to an appropriate instream guideline to determine the potential for exceeding that guideline under worst case conditions. See Appendix 7 for additional details.

Alternate method

The TSD provides documentation of the EPA's assumptions in determining the multipliers to derive the 99th percentile effluent concentration based on a limited sample size. An alternate method for estimating quartiles from limited data sets with an assumed lognormal distribution is presented in Gilbert (1987). This method produces an estimate of an upper percentile value that is a maximum likelihood estimator which is proportional to the geometric mean. The details of this method are given in Gilbert (1987). Either method is acceptable.

Look-up Tables in Appendix 7

Appendix 7 contains lookup Tables of reasonable potential multiplying factors at the 99th and 95th percentile level and 95th and 99th percent confidence level. **It is recommended that the 99th percentile level and 95th percent confidence level be used as a default.**

Use multipliers for data sets less than 10

The reasonable potential multiplier approach should be used for data sets less than 10. A CV of 0.6 should also be used (unless there is evidence to suggest that it should be higher).

Refine data

If potential is demonstrated, the next step may be to check or refine the data, or require the generation of more data on behalf of the facility to see if the potential persists.

There may be upper bounds to the concentration of a substance in a wastewater discharge depending on the source. For example if the influent value for a substance will never exceed a certain value due to natural constraints, it would be impossible to see values higher than this in the effluent.

Single and multiple discharge situations

The use of reasonable potential multipliers in multiple discharge situations on individual effluents can quickly lead to higher probabilities of occurrence than otherwise desired. Ideally, in these situations the analyst will conduct probability or basin wide dynamic modelling to more realistically calculate reasonable potential scenarios. Nevertheless, small data sets still need to be manipulated and the basic theory of the reasonable potential multiplier is still valid. In the final analysis, best professional judgment must be employed by analysts who understand the relationships and the sensitivity of the various assumptions employed.

5.2.1 Example of Reasonable Potential Multiplier Approach

It has been determined that there are 4 reliable effluent values for copper with which to conduct a reasonable potential to exceed calculation. The values are:

0.43 mg/L
0.59 mg/L
0.21 mg/L
0.64 mg/L

The analyst wants to be 99 percent confident that the effluent value used will represent the 99th percentile. A CV of 0.6 is assumed. From the Table below, the multiplier of 4.7 is obtained and multiplied by 0.64, the highest effluent value in the data set, to yield 3.0 mg/L.

The effect of larger sample sizes can be compared by adding 6 more values (assuming none of them exceed the existing highest value of 0.64 mg/L). A sample size of 10 gives a multiplier of 3.0, yielding an estimated 99th percentile of 1.92. Using a lower confidence level of say, 95 percent (Appendix 7) gives an estimate of 1.09.

Table 6 Reasonable potential multiplying factors: 99% desired percentile and 99% desired confidence level

number of samples	Coefficient of Variation									
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
1	1.6	2.5	3.9	6.0	9.0	13.2	18.9	26.4	36.0	48.1
2	1.4	2.0	2.9	4.0	5.5	7.4	9.8	12.6	16.1	20.2
3	1.4	1.9	2.5	3.3	4.4	5.6	7.1	8.9	11.0	13.4
4	1.3	1.7	2.3	2.9	3.8	4.7	5.9	7.2	8.7	10.3
5	1.3	1.7	2.1	2.7	3.4	4.2	5.1	6.2	7.3	8.6
6	1.3	1.6	2.0	2.5	3.1	3.8	4.6	5.5	6.4	7.5
7	1.3	1.6	2.0	2.4	2.9	3.5	4.2	5.0	5.8	6.7
8	1.2	1.5	1.9	2.3	2.8	3.3	3.9	4.6	5.3	6.1
9	1.2	1.5	1.8	2.2	2.7	3.2	3.7	4.3	4.9	5.6
10	1.2	1.5	1.8	2.2	2.6	3.0	3.5	4.1	4.6	5.3

5.3 Wasteload Allocation

Wasteload allocation refers to that amount of a stream's total permissible substance load that is allocated to one or more existing or future point source discharges The total allowable substance load is determined by calculating the amount of substance that can be discharged while maintaining instream guidelines under worst case conditions.

This subsection describes how to derive the wasteload allocation and subsequently, how to develop end-of-pipe limits from the wasteload allocation. The approach to developing a WLA is fundamentally similar to reasonable potential screening discussed in previous subsections except the calculations are essentially performed in reverse.

5.3.1 Calculating the Wasteload Allocation

By making C equal to $SWQG$ and WLA equal to Ce, the mass balance equation (*Equation 7*) presented earlier can be rearranged to solve for the wasteload allocation, the maximum substance concentration that can be allowed at end-of-pipe under specified conditions:

$$WLA = \left[SWQG \times \left(Qe + (Qs \times ff) \right) - (Qs \times ff) \times Cs \right] / Qe \qquad \textit{Equation (8)}$$

where:

WLA = wasteload allocation (the effluent concentration of substance)
$SWQG$ = surface water quality guideline
Qe = effluent flow
Qs = instream flow
Cs = upstream substance concentration
ff = fraction of flow

Single and multiple discharges

In the single discharge format, calculation of the wasteload allocation is fairly straightforward. Multiple discharge scenarios may introduce significant complexity. When using steady state approaches, the decisions relate to understanding how to represent the probabilities of simultaneous events without being over or under protective. For example it would not normally be appropriate to consider 10 facilities discharging at their maximum loading in concert with extreme low flow events. The chances of that happening would be well beyond the target frequency of exceedance associated with the instream guideline being considered (i.e., the wasteload allocation would be overly stringent). Dynamic continuous or probability modelling (see Glossary for definition) may provide a solution, but requires significant data inputs, experienced modelling analysts, and time. Multiple discharge scenarios also require assumptions regarding total number of future facilities.

5.3.2 Calculating Limits from the Wasteload Allocation

The wasteload allocation is used to calculate the end-of-pipe limits using the following relationships:

$$LTA = WLA - z(s) \qquad \text{Equation (9)}$$

where:

LTA = long term average (mean)
WLA = wasteload allocation
s = standard deviation
z = z score for the normal distribution, z=1.64 for 95th percentile

As before:

$$MDL = LTA + z(s)^{*} \qquad \text{Equation (2)}$$

$$AML = LTA + z\left(\frac{s^2}{n}\right)^{\frac{1}{2}} \qquad \text{Equation (4)}$$

where:

AML = average monthly limit
MDL = maximum daily limit
n = number of samples per month

However these equations are normalized by using the CV (standard deviation divided by the mean) instead of the standard deviation, and as before, lognormal assumptions are assumed. Therefore the functional equations become:

Table 7 Limits setting equations to use for wasteload allocation

Long Term Average (LTA) (acute n=1, chronic n=4)	**Average Monthly Limit (AML) (1<n<30)**	**Maximum Daily Limit (MDL)**
$\mathrm{LTA} = \mathrm{WLA} \bullet e^{[0.5 s_n^2 - Z s_n]}$ **where:** $s_n^2 = \ln((CV^2/n)+1)$ z= 2.236 (99th percentile)	$\mathrm{AML} = \mathrm{LTA} \bullet e^{[z s_n - 0.5 s_n^2]}$ **where:** $s_n^2 = \ln((CV^2/n)+1)$ z = 1.642 (95th percentile)	$\mathrm{MDL} = \mathrm{LTA} \bullet e^{[z s - 0.5 s^2]}$ **where:** $s^2 = \ln(CV^2+1)$ z= 2.236 (99th percentile)

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[*] Substitution of the right hand side of the LTA equation for LTA yields MDL = WLA. This relationship holds for acute guidelines, but not for averaged chronic guidelines as explained below.

LTA determination

The above LTA equation has been modified to account for guidelines which are to be complied with over an averaged period. As discussed in Section 4, this concept recognizes that high concentrations of substances can cause rapid toxic effects to organisms, while much lower concentrations can be tolerated for greater time periods. The acute guidelines are normally averaged over 1 day. The chronic guideline values are typically averaged over a period of 4 days, although shorter or longer periods may be justifiable depending on the stream ecosystem and current health.

This value of 4, or whatever the associated guideline averaging period, should not be confused with the value of "n" in the AML equation, which refers to the number of samples of the effluent to be taken to determine compliance with the limits.

Determining the more stringent of acute and chronic WLA's

If a guideline has both acute and chronic averaging periods associated with it, then the LTA must be calculated for each WLA separately before it can be understood which will yield the most stringent result. Different wasteload allocations will be calculated for acute and chronic guidelines due to different values (the chronic guideline will always be more stringent), different design conditions such as streamflows (eg., 1Q10 for acute, and 7Q10 for chronic), and different mixing zone boundaries (acute may be end-of-pipe or some small instream zone (e.g., 5% fraction of flow), while chronic may have some larger allowable zone restrictions (e.g., 10% fraction of flow)). The calculated wasteload allocations cannot be used to determine which will yield the more stringent result because the LTA's and subsequent end-of-pipe limits are based on the associated guideline averaging periods and inherent effluent variability characteristics.

Two-value steady state approach defined

If the final end-of-pipe limits are calculated based on both acute and chronic values, the procedure is referred to as the two-value steady state approach. The approach ensures that the limits are toxicologically protective and generally more accurate than those derived using simpler formats. The approach attempts to ensure that a maximum frequency of exceedance (of the instream guideline) of less than once in three years is maintained (provided that the 1Q10 flow for acute objectives and the 7Q10 flow for chronic objectives is used).

Summary of conditions to employ for wasteload allocations and limits setting

The following Table 8 (repeated in Appendix 1) documents the various conditions that are used to calculate a wasteload allocation and subsequently develop WQBELs.

Table 8 Design conditions to use for wasteload allocations and limits setting

Parameter	**Water Quality Based Effluent Limits Design Conditions**		
	streamflow	**averaging period**	**mixing zone restriction**
acute guidelines **(USEPA)**	*1Q10 (or 1 day in 3 year biological flow)*[bf]	*1 hour to 1 day averaging period*	*end-of-pipe, or with adequate justification, 30 metres surrounding outfall*[sz] *(at design streamflow), or 5% fraction of design streamflow*[11]*, provided rule of thumb*[rt] *restrictions are complied with to the extent resolvable*
chronic guidelines **(ASWQG, CWQG, USEPA)**	*7Q10 (or 4 day in 3 year biological flow)*[bf]	*1 day to 30 days averaging period (default 4 days)*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable, or with adequate justification, the more stringent of 10 times stream width for length and 1/2 stream width*[sz]*, (both determined at 7Q10), and 10% fraction of design streamflow*[12]
human health non-carcinogen **(USEPA)**	*30Q5 (or 4 day in 3 year biological flow)*[bf]	*4 day to 30 day averaging period (default 4 days)*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*
human health carcinogen **(USEPA)**	*harmonic mean flow*	*NA*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*
reasonable potential screening	$C = \left(QeCe + ff\,(Qs)Cs\right) / \left(Qe + ff\,(Qs)\right)$ *ff = fraction of flow, Qe = effluent flow, Qs = streamflow, Cs = upstream substance concentration*		
wasteload allocation (WLA)	$WLA = \left[SWQG \times \left(Qe + (Qs \times ff)\right) - (Qs \times ff) \times Cs\right] / Qe$ *SWQG = surface water quality guideline, ff = fraction of flow, Qe = effluent flow Qs = streamflow, Cs = upstream substance concentration*		
long term average (LTA)	$LTA = WLA \bullet e^{[0.5 s_n^2 - Z s_n]}$ $s_n^2 = \ln((CV^2 / n) + 1)$[cv], *z=2.236, default averaging periods: acute n=1, chronic n=4*		
average monthly limit (AML)	$AML = LTA \bullet e^{[z s_n - 0.5 s_n^2]}$ $s_n^2 = \ln((CV^2 / n) + 1)$[cv], *z=1.642, number of samples per month (4<n<30)*		
maximum daily limit (MDL)	$MDL = LTA \bullet e^{[z s - 0.5 s^2]}$ $s^2 = \ln(CV^2 + 1)$[cv], z = 2.236		

[bf] If biological flow is calculated, it should be used instead of hydrologic flow.

[sz] If the spatial zone calculated results in a more stringent WLA than the fraction of flow, then the spatial restriction should be employed.

[11] An LC50 >100% at EOP (using rainbow trout and/or *Daphnia magna*) will in most cases be required.

[rt] See Mixing Zone section for description of rule of thumb crestrictions

[12] In the case where near-instantaneous mixing is achieved through multiport diffusers, no mixing zone restriction need be considered (for chronic guidelines), provided rule of thumb principles are complied with. Near-instantaneous mixing is defined as no measurable difference in the concentration of a substance across a lateral transect of the stream (eg., does not vary by more than 10%) two stream widths downstream of the outfall.

[cv] Use CV of 0.6 for data sets less than 10 (unless evidence suggests a higher value). Use calculated CV for data sets greater than 10 .

5.3.3 Example of Wasteload Allocation and End-of-Pipe Limits

The following example illustrates the two-value steady state approach for a fictitious facility. It is assumed that the analyst has already determined that there is reasonable potential to exceed the instream copper guideline as in the previous example. The Gold Book criteria for copper (updated according to the National Toxics Rule December 22, 1992) has been used because it has both acute and chronic values associated with it. As with most Gold Book and CWQG guidelines for metals, the value is hardness dependent.

The US EPA Gold Book copper criterion equations are:

$$\text{acute criterion} = e^{\{0.9422[\ln(\text{hardness})]-1.464\}}$$

$$\text{chronic criterion} = e^{\{0.8545[\ln(\text{hardness})]-1.465\}}$$

It is also assumed that the typical default values for calculation of the LTA, AML and MDL are used (i.e., 99th, 95th, and 99th percentiles respectively).

Table 9 Example parameters

Parameter	Notation	Value	
upstream copper concentration	*Cs*	*0.001 mg/L*	
mean effluent flow	*Qe*	*0.7* m^3/s	
99th percentile for copper in effluent	*Ce*	*3.0 mg/L*	
copper CV in effluent	CV	*0.6*	
stream hardness		*200 mg/L as* $CaCO_3$	
intended number of effluent samples per month	n	*4*	
instream guideline type		***acute***	***chronic***
streamflow	*Qs*	*1Q10 = 50* m^3/s	*7Q10 = 55* m^3/s
fraction of streamflow	*ff*	*5%*	*10%*
instream guideline value	*SWQO*	*0.034 mg/L*	*0.021 mg/L*

The following observations are made in the above Table:

- The background value must be supportable - in practice background values for metals at the detection limit are very difficult to interpret. The issue of the bioavailable versus total metals concentration is complex and hotly debated. Various newly accepted tools are available such as the water effects ratio (WER) (see subsection so entitled later in Section 6), that enable a more accurate simulation of conditions.
- The example assumes that the highest background value for copper has occurred during low flow conditions, which is not always the case. Similar trends may exist for nutrients. These factors must be considered before conclusions can be reached regarding reasonable potential to exceed and wasteload allocations.
- The 99th percentile of effluent copper must be supportable - often the reasonable potential multiplier approach can be taken to account for limited data. This can significantly increase the value used depending on the CV assumed (usually 0.6) and the number of data points.

- The stream hardness affects the guideline. The lower the hardness, the more stringent the copper guideline.
- The fraction of flow approach is taken here; the analyst may instead elect to employ spatial dimensions for screening. The more stringent result is a function of stream dynamics.

The wasteload allocation is calculated by using the following dilution equation:

$$WLA = \left[SWQG \times \left(Qe + (Qs \times ff) \right) - (Qs \times ff) \times Cs \right] / Qe \qquad \text{Equation (8)}$$

WLA For acute:	WLA For chronic:
[0.034 x (0.7 + (50 x 0.05)) - (50 x 0.05) x 0.001]/0.7 = **0.152 mg/L**	[0.021 x (0.7 + (55 x 0.1)) - (55 x 0.1)x 0.001]/0.7 = **0.178 mg/L**

These WLA values represent the maximum levels that could be discharged (the WLA). The LTA’s must be calculated from the WLA's to determine whether the acute or chronic level is most stringent:

LTA for Acute	LTA for chronic:
$\mathrm{LTA} = \mathrm{WLA} \bullet e^{[0.5s^2 - Zs]}$ where: $s^2 = \ln(\mathrm{CV}^2 + 1)$ **LTA = 0.049 mg/L**	$\mathrm{LTA} = \mathrm{WLA} \bullet e^{[0.5s_4^2 - Zs_4]}$ where: $s_4^2 = \ln((\mathrm{CV}^2 / 4) + 1)$ **LTA = 0.094 mg/L**

Where it can be seen that the acute value is more stringent than the chronic value. Now proceed to calculate the end-of-pipe limits:

AML	MDL
$\mathrm{AML} = \mathrm{LTA} \bullet e^{[zs_n - 0.5s_n^2]}$ where: $s_n^2 = \ln((\mathrm{CV}^2 / n) + 1)$ **AML = 0.076 mg/L (4.58 kg/d);**	$\mathrm{MDL} = \mathrm{LTA} \bullet e^{[zs - 0.5s^2]}$ where: $s^2 = \ln(\mathrm{CV}^2 + 1)$ **MDL = 0.152 mg/L (9.18 kg/d)**

The discharger would be required to reduce the copper concentration in the effluent from the present 3.0 mg/L to 0.152 mg/L on a maximum daily basis.

6.0 Special Considerations

6.1 Rationale for Stream Design Flows

The concept of using worst case conditions including stream design flows as a surrogate to achieving a desired frequency of compliance with instream guidelines was discussed earlier. In this Section background for stream design flows is provided.

When following the steady state modelling approach to wasteload allocation and limits setting, there are two ways to calculate the design flow, the biological and hydrological methods.

The 7Q10 design flow has traditionally been used in Alberta and many other jurisdictions for assessment of water quality. The US EPA (1986) reported that about half of the states were using 7Q10 as the design flow at the time that report was published. Other jurisdictions use different return periods, but the values tend to be similar.

The hydrologic method, which uses distribution statistics like the log Pearson Type III method for deriving 7Q10 type flows, is the most common method. The biological flow more accurately reflects the duration and frequency of compliance attributes of any instream guideline. An instream guideline specification will typically be a 4-day averaging period with a one in three year return period. A biological flow can be developed which exactly mimics that return frequency by using each day in the streamflow record.

The hydrologic method relies on a numeric distribution and uses only one data point for every year of record. Because data typically does not fit the distribution exactly (especially at the very low flows), there can be considerable error associated with this “force fitting” of the data to a distribution. The biologically based flow method does not require the flow data to follow any numeric distribution. An empirical analysis is performed on the flow record to determine what X-day flow has occurred on the average every Y-years. The biologically-based method uses all the data and performs an analysis of all flows and their long term trends through time. For example, for a 12 year data set, many of the hydrologic methods would make a determination using only 12 data points. In contrast, the biologically-based method would use over 4000 data points for that same period to determine critical low flows.

A greater number of data points makes the biologically based method more statistically robust. The hydrologic method only accounts for one flow excursion value per year even if there were multiple low flow excursions of the same magnitude within the year. The biologically based method considers all low flow excursions for the full period of record. The US EPA (1986) Technical Guidance Manual for Performing Waste Load Allocation: Book VI; Design Conditions: Chapter 1, Stream Design Flow for Steady State Modeling; Office of Water, should be consulted for a further review of the subject.

The biological flow method is considered to be more accurate than the hydrologic 7Q10 method and hence is the preferred approach. However, this is a new approach and unpracticed in Alberta so the hydrological approach will continue to be used. Where the biological flow method is followed, the results should be used instead of the hydrologic design values.

6.2 Whole Effluent Toxicity

There is little difference in the use of whole effluent toxicity test results and the chemical specific approach to screening assessments and limits setting.

The WET approach considers the combined effect of a mixture of substances and is particularly necessary because guidelines for all substances have not been developed, nor is there an adequate understanding of the toxicity caused by the interaction of different substances.

The approach involves the use of toxicity bioassays to measure the toxicity of an effluent. These tests can measure the degree of response of exposed aquatic test organisms to a specific substance, to an effluent, or to a receiving stream sample. There are two main types of toxicity tests: acute and chronic or sublethal tests.

Acute whole effluent toxicity test

An acute test is usually conducted over a period of 48 (fathead minnow) to 96 hours (rainbow trout), and the endpoint is usually mortality. This endpoint is commonly expressed as the lowest concentration of a substance or effluent that is lethal to 50% of the exposed test organisms (LC_{50}).

Chronic whole effluent toxicity test

A chronic or sublethal test is usually conducted over a period of 4 days (eg., *Selenastrum capricornutum* to 7 days (*Ceriodaphnia dubia and fathead minnow*) and the endpoint measured is latent mortality and sublethal effects, for example changes in reproduction and growth. The endpoints are often expressed as the no observable effects concentration (NOEC) and the lowest observable effects concentration (LOEC). The NOEC is the highest concentration of a substance or effluent at which no adverse effects are observed on the aquatic test organisms. The LOEC is the lowest concentration of substance that causes observable adverse effects in the exposed test organisms. An inhibition concentration of 25% (IC_{25}) is considered empirically equivalent to an NOEC endpoint.

Whole effluent toxicity - toxic units

To express guidelines and facilitate modelling, toxicity is expressed in toxicity units (TU). A TU is essentially the inverse of the sample endpoint and is calculated by dividing the endpoint concentration into 100 to obtain toxic units. For example, if a chronic test result is a NOEC of 25% effluent, that result can be expressed as 100/25 or 4 chronic toxic units (4 TUc); if an acute test is a LC_{50} of 50%, that result can also be expressed as 100/50 or 2 acute toxic units (2 TUa).

Acute and chronic whole effluent toxicity - toxic units

It is important to distinguish TUa from TUc. The difference between TUa and TUc can be likened to the difference between miles and kilometers. In order to compare a TUa and TUc, an acute-to-chronic ratio (ACR) needs to be computed. The ACR is a conversion factor that changes TUa into equivalent TUc. The ACR = LC_{50}/NOEC. If data are insufficient to calculate an ACR, a default value of ACR=10 is recommended.

Acute and chronic whole effluent toxicity - instream guidelines

The instream guidelines for acute and chronic whole effluent toxicity against which to compare effluent toxicity test results are 0.3 TUa and 1.0 TUc, respectively. In essence, the acute guideline represents a factor of three dilution of an LC_{50} = 100% endpoint, while the chronic endpoint is equivalent to the NOEC (alternatively the IC_{25}).

Use of multiple species testing

The use of multiple species in the assessment of whole effluent toxicity is essential for complex effluents and in situations where a substance has no instream guideline. The sensitivity of a single species may not adequately represent the overall sensitivity of the indigenous biota. The preferred approach is to represent each phyla in the bioassays, a plant (*Selenastrum capricornutum*), a vertebrate (eg., fathead minnow and rainbow trout), and an invertebrate (*Daphnia magna* and *Ceriodaphnia dubia*). These species are sensitive representatives of their respective phyla and a consideration of the range of their responses will ensure protection of most aquatic ecosystems. Bioassay protocol for each of the above named tests are provided and supported by Environment Canada. The use of non-standard indigenous species testing in routine effluent limits setting is not recommended due to the lack of established protocol and comparative data bases.

Minimum data set

To increase statistical certainty, it is recommended that a minimum of 8 sets of multiple species tests as outlined in Table 10, be conducted on the effluent in question. The sampling should be carried out during periods that will encompass the possible range of effluent variability present. This will in most cases mean equally spaced (temporal) sets, but cases can be made for focusing sampling during specific periods. The most sensitive responding species (acute, and chronic) and endpoint should be used in the calculation of the 99th percentile effluent TU's and the reasonable potential screening exercise.

Table 10 Whole Effluent Toxicity Reference

Species	Test	Endpoint	Method[13]
rainbow trout	acute	LC_{50}	Acute Lethality Test using Rainbow Trout. EPS 1/RM/9, July, 1990. & Reference Method for Determining the Acute Lethality of Effluent to Rainbow Trout. EPS 1/RM/13, July, 1990
Daphnia magna	acute	LC_{50}	Acute Lethality Test using Daphnia spp. EPS 1/RM/11, July, 1990. & Reference Method for Determining Acute Lethality of Effluents to *Daphnia magna*. EPS 1/RM/14, July, 1990
Ceriodaphnia dubia	chronic	NOEC, IC_{25}	Test of Reproduction and Survival using the Cladoceran *Ceriodaphnia dubia*. EPS 1/RM/21, February, 1992
fathead minnow	sublethal	NOEC, IC_{25}	Test of Larval Growth and Survival using the Fathead Minnows. EPS 1/RM/22, February, 1992
Selenastrum capricornutum	chronic	NOEC, IC_{25}	Growth Inhibition Test Using the Freshwater Alga (*Selenastrum capricornutum*). EPS 1/RM/25, November, 1992

6.3 Mixing Zones

Effluent discharges rarely mix instantaneously with a receiving stream. Mixing zones for initial dilution of the effluent plume are a practical necessity. Water quality based limits setting allows, where necessary, limited mixing zones within which instream guidelines may be exceeded. These exceedance areas should be small enough so as not to interfere with beneficial uses. They should be established to ensure protection of the waterbody as a whole (chronic) and to limit acute lethality to organisms passing through the plume (acute). This is depicted in the Figure below.

A partial discussion of the principles of mixing zones and the fraction of flow technique for mixing zone restriction appeared earlier in the manual in the subsection entitled "Streamflows and mixing zone restrictions for screening." However, the following subsection should be considered the main source for mixing zone information in this manual.

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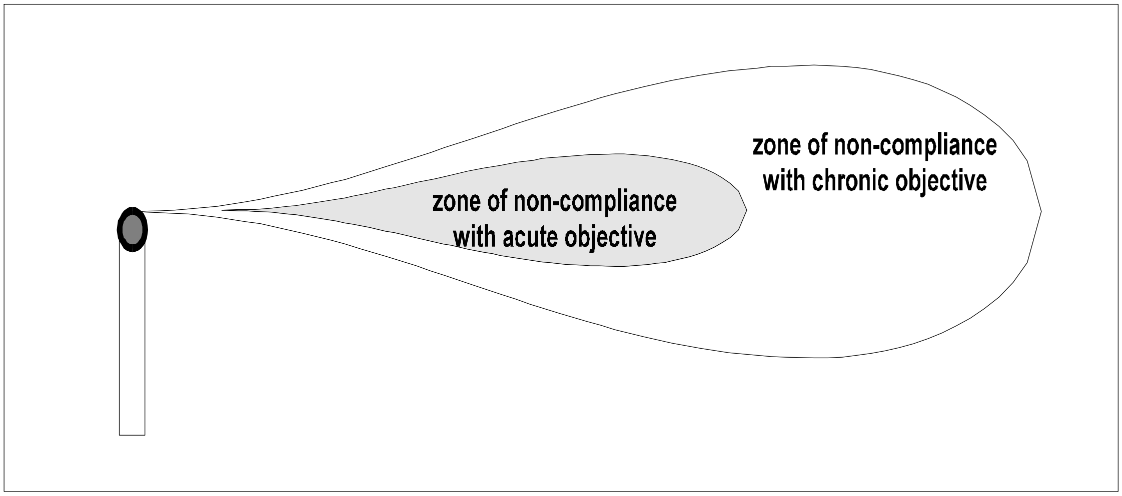
[13] All methods listed are available as Environment Canada's Environmental Protection Series, Biological Test Method Series.

Figure 5 Stylized mixing zone diagram



Rule of thumb mixing zone restrictions

The following **rule of thumb** restrictions (Table 11) should be resolved to the extent practicable in order to satisfy fundamental mixing zone concerns:

Table 11 Rule of thumb mixing zone restrictions:

	Rule of Thumb Mixing Zone Restrictions[14]
●	*protection from acute lethality is afforded to passing organisms;*[a]
●	*the chronic or sublethal zone is limited to the extent that the water body as a whole is protected;* [a]
●	*fish spawning grounds are avoided;*[b]
●	*drinking water intakes are not impinged upon;* [a, b]
●	*acute mixing zones do not overlap;* [a]
●	*chronic zones for the same substance do not overlap;* [a]
●	*existing uses are not interfered with;* [b]
●	*mixing zones are not used as an alternative to reasonable and practical treatment;* [a]
●	*mixing zone allowance is not extended to bioaccumulative substances or hazardous substances for which instream guidelines, provincially, nationally, or internationally, do not exist, unless it can be specifically demonstrated that they will not cause an adverse impact ;* [b]
●	*mixing zone allowance is not extended where it attracts organisms, resulting in prolonged exposures;* [a]
●	*mixing zone allowance is not extended where it creates a barrier to the migration of aquatic life.* [a]

[a] This condition, or part of the condition will usually be considered to be satisfied through specified fraction of flow or spatial restrictions (see following discussion).

[b] This condition may require site specific assessment. It may be partially satisfied through specified fraction of flow or spatial restrictions (see following discussion).

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[14] In addition to these restrictions, fraction of flow or spatial restrictions may apply. See mixing zone restrictions in Table 12.

The need for mixing zone restrictions

Theoretically, because every stream and effluent are unique, satisfying each of the above rule of thumb constraints would result in varying mixing zone sizes. Practically, many of these restrictions are difficult if not impossible to determine. The growth and application of uniform spatial restrictions, as practiced in many jurisdictions, has grown out of the pragmatic recognition that scientific techniques and lack of resources do not enable many of the above constraints to be accurately resolved. For example, warm effluent plumes in the winter may attract fish, but this may be very difficult to determine in practice. As a result, uniform spatial or fraction of flow restrictions are applied which are believed to, on balance, achieve the above stated rule of thumb principles.

The ^{a} and ^{b} superscripts in the above Table indicate which restrictions are considered satisfied with the spatial and/or fraction of flow restrictions. Judgment must be exercised in all cases to ensure that the intent of the restriction is being properly addressed through the fraction of flow or spatial approach.

Spatial restrictions versus fraction of flow

In general, the techniques that are employed involve either taking a fraction of design streamflow or a spatial dimension approach, or both. There is no consistent mathematical relationship between the two; it depends on the characteristics of the effluent and the stream hydraulics. The advantage of the fraction of flow technique is that it is easy to understand and compute. The disadvantage is that, depending on the stream hydraulics, it may allow a plume to extend for a considerable distance downstream creating an unacceptably large zone where instream guidelines may be exceeded. US EPA Region 8 has indicated that a 10% fraction of the 7Q10 flow will usually yield more restrictive limits than a spatial restriction equal to 10 times the stream width for a length scale. However, as is the case with other methodologies reviewed in this manual, the more complex spatial method is preferred because it will yield more accurate results.

Preferred mixing zone restriction approaches

The following fraction of flow or spatial mixing zone restrictions should be applied when deriving a wasteload allocation:

Table 12 Recommended mixing zone restriction approaches

Guideline	Fraction of Flow or Spatial Mixing Zone Conditions
Acute	***Acute guidelines** should be met end-of-pipe. If adequate justification is provided for not meeting acute guidelines end-of-pipe, acute guidelines should either be attained at 30 metres surrounding the discharge point at design flow, or, alternatively acute guidelines should be complied with at 5% of the 1Q10.*[15] *An LC50 >100% at end-of-pipe (using rainbow trout and/or Daphnia magna) will in most cases be required.*
Chronic	*For **chronic guidelines**, rule-of-thumb considerations must be addressed to the extent resolvable. Chronic guidelines are preferably met before 10 times the stream width for a length restriction and 1/2 the streamwidth laterally (streamwidth calculated at design flow), or using 10% of the 7Q10.*[16, 17]
Near-instantaneous mixin*g*	*In the case where **near-instantaneous mixing** is achieved through multiport diffusers, no mixing zone restriction need be considered (for chronic guidelines). Near-instantaneous mixing is defined as no measurable difference in the concentration of a substance across a lateral transect of the stream (eg., does not vary by more than 10%) at a distance equal to two stream widths downstream of the outfall.*

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[15] If spatial restrictions are calculated and the value results in a more stringent allocation, the spatial restriction should be adopted.

[16] If spatial restrictions are calculated and the value results in a more stringent allocation, the spatial restriction should be adopted.

[17] Provided rule-of-thumb mixing zone restrictions are complied with (to the extent resolvable), and near-instantaneous mixing is demonstrated, full dilution with the specified design flows may be justifiable.

Tools to calculate mixing zones

The algorithms contained in WL Screen can be used for length and width scale estimations. These algorithms are based on Fischer et al, 1979. Any scale assumption can be used with these algorithms.

The general approach should be to employ either end-of-pipe, fraction of flow, or spatial techniques using available tools at steady state. The discharger may also carry out more sophisticated modelling studies (using agreed upon parameters). Field studies (dye tracer) to prove that the discharger would remain within the calculated zone restriction would not normally be required. More sophisticated modelling and/or field studies would be required where there is a dispute associated with overlapping plumes, or proximity to spawning grounds or drinking water intakes. Models such as Plumes or Cormix may then be employed.

Multiport diffusers to attain near-instantaneous mixing

If near-instantaneous mixing can be attained, no zone restriction is necessary. Objectives can be met at full dilution (at design flows). Near instantaneous mixing means no more than a 10% difference in bank-to-bank concentrations within a longitudinal distance not greater that two stream/river widths.

Multiple discharges

Multiple discharge scenarios can be handled relatively easily where the distance separating them is sufficient that upstream plumes are fully mixed and adequate instream monitoring data is available. Where plumes have not mixed and may overlap, more sophisticated approaches may be warranted. Nevertheless, simple screening approaches and conservative assumptions should be used to initially determine whether more refined approaches are warranted.

6.4 Data Screening and Editing

Recommending which procedures to follow for data editing is difficult and requires case specific analysis. However, some guidelines that may prove helpful follow:

The analyst should only exclude upset or apparent outlier data from statistical calculations of mean and standard deviation if it can demonstrated:

- the upset(s) occurred infrequently (no more than once every three years);
- they do not occur or are not correlated to low river flow periods;
- the amount of data is sufficient to establish an upset;
- the cause of the upset has been isolated and mitigative actions have been taken to prevent their future occurrence.

However, all data should be graphed and strategies dealing with treatment of upsets should be defensible.

6.5 Mass versus Concentration Based Effluent Limits

Mass based limits are preferred since they control the overall load of a substance being discharged. Some substances cannot be expressed appropriately by mass. Examples of such pollutants are pH, temperature, radiation, and whole effluent toxicity. Mass limitations in terms of kilograms per day can be calculated for all chemical specific substances such as copper or ammonia.

Mass based limits are particularly important for control of bioaccumulative substances. Concentration based limits will not adequately control discharges of these substances if the effluent concentrations are below detection levels (concentration limits alone would not necessarily control total loadings). For these pollutants, controlling mass loadings to the receiving waters is critical for preventing adverse environmental impacts.

However, mass based limits alone will not assure attainment of stream guidelines in waters with low dilution. In these waters, the quantity of effluent discharged has a strong effect on the instream dilution and therefore upon the receiving stream concentration. At the extreme case of a stream that is 100 percent effluent, it is the substance concentration rather than the substance mass that dictates the instream concentration.

6.6 Selection of Monitoring Frequencies

There is no fixed guidance on establishment of monitoring frequencies for discharges. The decision on effluent monitoring frequency is case specific and needs to consider a number of factors, including those listed below:

- Type of treatment process, including retention time
- Environmental significance and nature of the pollutant or pollutant parameter
- Cost of monitoring relative to the dischargers capabilities and benefit obtained
- Compliance history
- Number of monthly samples used in developing the permit limit
- Effluent variability

Based upon an array of data analyzed for both individual substances and whole effluent toxicity, and independent or other considerations, it has been observed that ideally 10 or more samples per month provides the greatest statistical likelihood that the average of various monthly values will approach the true monthly LTA value. In practice, however, selection of monitoring frequencies will need to consider the previously mentioned factors and arrive at a reasonable compromise of the appropriate considerations.

6.7 Detection Levels in Discharges

If a substance has consistently been measured as non-detectable, no statistics can be calculated for that substance. Where some portion of the data set is reported as non-detectable, these values may typically be left out of the statistical calculations, or a delta lognormal approach could be used.

Various approaches are taken to represent substances that include non-detectable values for the purposes of reasonable potential to exceed screenings. This is not a trivial problem. Apparent reasonable potential to exceed occurrences will often occur for metals and priority pollutants if less refined approaches are taken. Various approaches that can be taken are:

1. Use the detection limit where all values are non-detectable.
2. Use zero or 1/2 the detection limit if all values are non-detectable.
3. Use the delta-lognormal statistical approach.

6.8 Background Characterization

The selection of proper background substance concentrations is critical to the assessment of reasonable potential to exceed and development of limits. In many cases it is the dominant factor governing compliance with instream guidelines.

The following factors are important in the characterization of a representative background value:

- number of analysis and period of record;
- variability of the data base;
- validity and integrity of the values or record available;
- potential hazard of each substance or parameter;
- seasonality and relationship to flow;
- metals and nutrients may have the highest concentrations during periods of streamflow higher than the typical design flows
- potential for bioaccumulation of each substance.

In general, the median or mean seasonal **low flow** background substance concentration should be used. The reason for this is that if the 99th percentile or similar value is used, then the probability of exceedance of the instream guideline in combination with the uncertainty associated with the reasonable potential to exceed screen and the wasteload allocation calculations becomes increasingly remote.

On the other hand, certain substances may be present at significantly higher concentrations during higher flow seasons. For example, nutrients and metals are often found at elevated levels in the spring or summer due to natural leaching or complexing with suspended sediments. Under these situations, the relevant streamflows and background substance concentrations during this period should be used in reasonable potential to exceed screening or wasteload allocation modelling. However, it may still be found that the low flow season with the associated lower background substance concentration is the most limiting or worst case condition due to the higher proportional contribution of substance load from the discharger under these restrictive flow conditions.

These considerations are not an issue with probability or dynamic modelling, provided enough data exist to support this type of approach. An important exception to the mean or median rule is ammonia. Because ammonia is such a fast acting toxicant, a higher background representation is justifiable, such as the 85th percentile for ammonia, pH, and temperature.

6.9 Determining a Representative Coefficient of Variation

Use of the statistical method of approval limit derivation requires an estimate of the CV of the distribution of the daily measurements of the substance after the facility complies with the requirements. If variability is mostly related to production, current data may be used to estimate the CV. If future variability is expected to be substantially different, the CV must be estimated. Discharges of toxic substances are generally more variable than discharges of conventional substances. It is important to use the best estimate of the CV that can be reasonably achieved. A minimum of 10 samples is needed to reasonably quantify the CV.

Variability associated with effluent levels of both individual substances and whole effluent toxicity is difficult to predict for an individual situation. It is **recommended that a value of 0.6 be applied as a default CV, if the analyst does not have more accurate information on the CV for the substance**.

Limits are usually not extremely sensitive to small changes in the CV. The value of 0.6 is typical of the range of variability of effluents measured and represents a reasonable degree of effluent variability. However where possible it is recommended that data on effluent variability for the substance of concern be collected to define a CV rather than selecting a default value.

6.10 Water Effects Ratio

The water effects ratio (WER) procedure is based on the assumption that physical and/or chemical characteristics of water at an individual site may influence the biological availability and/or toxicity of a substance contained in an effluent. The concept is rather simple: side-by-side toxicity tests are conducted - one set of tests with laboratory dilution water and the other using site water. The endpoint obtained using site water is divided by the endpoint obtained with laboratory dilution water. The quotient is the WER, which is multiplied by the instream guideline which is subsequently used in developing the WLA.

The WER concept can be applied for any compound, but is especially useful for metals. Metals are present in different forms, depending on physical and chemical conditions in water. Some of these forms are toxic and others are not.

Application of the WER approach, although simple in concept, is not a trivial endeavor and can incur significant expenditure. Guidance to the WER approach is provided in Appendix L of the US EPA Water Quality Standards Handbook (1994).

6.11 Assessing Compliance with Metals Guidelines

The EPA has recently recognized the use of dissolved metals fraction to be used for compliance with instream guideline values. The analyst may also consider using the WER approach.

6.12 Other Effluent Limit Considerations

Seasonal limits

There may be situations where seasonal limits can be justified. This circumstance may arise when meeting water quality based limitations has a high operational cost and there is considerable difference in magnitude between the limits that would be required during worst case conditions and those that would be required under non-worst case conditions. Generally seasonal effluent limitations are developed based on a semi annual or quarterly basis.

Upstream substance concentrations exceed instream guidelines

Occasionally, upstream substance concentrations may be found to exceed instream guidelines due to natural, anthropogenic, or a combination of the two influences. In this case the concentration (and/or load) of the substance should be limited so that it will meet the instream guideline at end-of-pipe. If the problem is due to industrial and/or municipal basin loading, and the guideline is based on protection of aquatic life, a regional loading reduction may be appropriate.

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8.0 Glossary of Terms and Acronyms

1Q10	One day in ten year low flow
30Q5	Consecutive thirty day in five year low flow
7Q10	Consecutive seven day in ten year low flow
acute	Acute refers to a stimulus severe enough to rapidly induce an effect; in aquatic toxicity tests, an effect observed in 96-hours or less is typically considered acute. When referring to aquatic toxicology or human health, an acute effect is not always measured in terms of lethality.
acute to chronic ratio (ACR)	Acute to chronic ratio is the ratio of the acute toxicity of an effluent or a toxicant to its chronic toxicity. It is used as a factor for estimating chronic toxicity on the basis of acute toxicity data, or for estimating acute toxicity on the basis of chronic toxicity (TSD).
AML	Average Monthly Limit This limit accounts for the relationship between the variability of the substance, the number of samples that are taken and the average result that they should yield.
ASWQG	Alberta Surface Water Quality Guidelines
BADT	Best Available Demonstrated Technology
BAT	Best Available Technology
BPT	Best Practicable Technology
biological flow	The biologically based flow method does not require the flow data to follow any numeric distribution. An empirical analysis is performed on the flow record to determine what X-day flow has occurred on the average every Y-years. The biologically-based method uses all the data and performs an analysis of all flows and their long term trends through time. The US EPA (1986) Technical Guidance Manual for Performing Waste Load Allocation: Book VI; Design Conditions; Office of Water, should be consulted for a further review of the subject.

case-specific technology limit	This is a subcategory of technology based limits. It is a limit based on existing performance, or performance from similar facilities. Unlike a sector-specific technology limit, it is not a published limit. It is derived using best professional judgment.
sector-specific technology limit	Technology limits form the minimum effluent restrictions for industrial or municipal discharges. These limits are based on the capabilities of proven pollution control technologies and are applied uniformly across an industrial sector consistent with the age and type of facility. Economic considerations are always factored into the development of a technology limit. Common Technology limit designations are: Best Practicable Technology (BPT - applied to older facilities), and Best Available Demonstrated Technology (BADT - generally applied to new facilities). Technology limits do not inherently consider ambient constraints, except to the extent that good technology limits will offer some level of protection by virtue of the use of modern pollution control technology.
chronic	defines a stimulus that lingers or continues for a relatively long period of time, often one-tenth of the life span or more. Chronic should be considered a relative term depending on the life span of the organism. The measurement of a chronic effect can be reduced growth, reduced reproduction, etc., in addition to lethality. (TSD)
criteria	In this manual, criteria refers to the USEPA Gold Book values
Coefficient of variation (CV)	The coefficient of variation (CV) is a standard statistical measure of the relative variations of a distribution or set of data, defined as the ratio of the standard deviation to the mean.
CWQG	Canadian Water Quality Guidelines
dynamic model	*"Dynamic modelling techniques explicitly predict the effects of receiving water and effluent flow and of concentration variability. The three dynamic modelling techniques recommended by the USEPA are continuous simulation, Monte Carlo simulation and lognormal probability modelling. These methods create a probability distribution for receiving water concentrations rather than a single, worst case*

	concentration based on critical conditions. Predictions of complete probability distributions allows the risk inherent in alternative treatment strategies to be directly quantified." (TSD)
end-of-pipe (EOP)	End-of-pipe limits are either technology or water quality based. If they are water quality based, then the limits are calculated to support a wasteload allocation value, the value required to maintain instream guidelines. A technology limit is formulated on some statistical derivation of existing performance, or published sector-specific limits. The average monthly limit (AML) and the maximum daily limit (MDL) are end-of-pipe limits that are calculated either to ensure that the wasteload allocation is not exceeded at some specified frequency, or they are based on technological capability (i.e., the limits are either sector-specific or case-specific technology based).
fraction of flow	Refers to using a portion or fraction of the extreme low flow design condition for dilution and meeting surface water quality guidelines.
harmonic mean flow (HMF)	The number of daily flow measurements divided by the sum of the reciprocals of the flows. That is, it is the reciprocal of the mean of the reciprocals (TSD).
human health criteria	Refers to USEPA Gold Book human health values
long term average (LTA)	The long term mean.
MDL	A maximum daily limit represents the absolute maximum allowable load or concentration of a substance for a facility. This limit may be based on water quality constraints, sector-specific technology limitation, or case specific technology considerations. The value is typically calculated based on the 99th percentile of existing or required performance.
mixing zone	The approach to water quality based effluent limits setting allows, where necessary, limited zones for initial dilution where instream objectives may be exceeded. These zones are areas where the instream objectives may be exceeded but they are small enough so as not to interfere with beneficial uses. They are established to ensure protection of the waterbody as a whole (chronic) and to limit acute

	lethality to organisms passing through the plume (acute).
OMOE	Ontario Ministry of the Environment
percentile	Percentiles are statistical point estimates of a distribution. The derivation of end-of-pipe limits requires the application of percentiles.
reasonable potential to exceed	An approval holder has a reasonable potential to exceed a water quality guideline if it cannot be demonstrated with a high confidence level that the upper bound of the lognormal distribution of effluent concentrations is below the receiving water guideline at specified low flow periods.
reasonable potential multiplier	It may be necessary for the analyst to compensate for a lack of adequate data by using reasonable potential multipliers. The estimated maximum effluent concentration would then be calculated as the upper bound (typically 99 percentile) of the expected lognormal distribution of effluent concentrations at a high confidence level (typically 95 percent). The projected effluent concentration after consideration of dilution can then be compared to an appropriate surface water quality objective to determine the potential for exceeding that objective under worst case conditions and hence determine the need for developing an effluent limit.
steady state model	Steady-state modelling considers only a single concentration; effluent flow and loading are assumed to be constant. The impact of receiving water flow variability on the duration for which and frequency with which criteria are exceeded is implicitly included in the design conditions if these conditions explicitly reflect the desired toxicological effects regime. (TSD)
SWQG	Surface water quality guideline
toxic units	For acute:100/LC_{50}, for chronic: 100/NOEC(or IC_{25})
US EPA Gold Book	Quality Criteria for Water 1986. USEPA, Office of Water, Regulations and Standards, Washington, DC 20460. EPA 440/5-86-001.
water quality based	Water Quality Based Source Limits are derived by

effluent limit (WQBEL)	calculating how much of a given contaminant can be discharged under certain restrictive (or worst case) conditions while still maintaining instream objectives.[18] These worst case conditions are chosen to occur infrequently enough that if water quality objectives are exceeded, it will not cause undo stress on the receiving environment (the ecosystem can rapidly recover). The approach ensures that during all other conditions, instream objectives will be maintained.
WL Screen	Steady state model developed by Source Standards Branch.
WLA	Wasteload allocation refers to the amount of substance that can be discharged while maintaining instream objectives under specified conditions.

---

[18] Objectives, criteria, and guidelines are all considered to be instream values for the purposes of this document.

Appendix 1 Conditions to Employ for Deriving Water Quality Based Limits

Sequence of guidelines use:

Sequence	Guideline
1.	*ASWQG, treated as chronic, 4-day averaged guidelines. USEPA Gold Book values for acute and human health guidelines for the same substances.*
2.	*If ASWQG does not exist, use CWQG, treated as chronic, 4-day averaged guidelines. USEPA Gold Book values for acute and human health guidelines for the same substances.*
3.	*If ASWQO or CWQG do not exist, USEPA Gold Book acute, chronic, and human health guidelines should be used with the appropriate design averaging periods.*

Mass balance and wasteload allocation equations:

Mass balance dilution equation	Wasteload allocation equation
$C = \left(QeCe + ff(Qs)Cs\right) / \left(Qe + ff(Qs)\right)$	$WLA = \left[SWQG \times \left(Qe + (Qs \times ff)\right) - (Qs \times ff) \times Cs\right] / Qe$
C = instream substance concentration	WLA = wasteload allocation
Qe = effluent flow	$SWQG$ = surface water quality guideline
Qs = instream flow	Qe = effluent flow
Cs = upstream substance concentration	Qs = instream flow
ff = fraction of flow[19]	Cs = upstream substance concentration

Rule of thumb mixing zone restrictions:

	Rule of Thumb Mixing Zone Restrictions[20]
●	*protection from acute lethality is afforded to passing organisms;*[a]
●	*the chronic or sublethal zone is limited to the extent that the water body as a whole is protected;*[a]
●	*fish spawning grounds are avoided;*[b]
●	*drinking water intakes are not impinged upon;*[a, b]
●	*acute mixing zones do not overlap;*[a]
●	*chronic zones for the same substance do not overlap;*[a]
●	*existing uses are not interfered with;*[b]
●	*mixing zones are not used as an alternative to reasonable and practical treatment;*[a]
●	*allowance is not extended to bioaccumulative substances for which instream guidelines, do not exist, unless it can be specifically demonstrated that they will not cause an adverse impact;*[b]
●	*allowance is not extended where it attracts organisms, resulting in prolonged exposures;*[a]
●	*mixing zone allowance is not extended where it creates a barrier to the migration of aquatic life.*[a]

---

[19] See mixing zone restrictions in Summary Table

[20] In addition to these restrictions, fraction of flow or spatial restrictions may apply. See mixing zone restrictions in Summary Table

[a] This condition, or part of the condition will usually be considered to be satisfied through specified fraction of flow or spatial restrictions (see following Table).

[b] This condition may require site specific assessment. It may be partially satisfied through specified fraction of flow or spatial restrictions (see following Table).

Appendix 1 Conditions to employ for deriving water quality based limits Cont...

Design conditions to employ for screening and limits setting

Parameter	**Water Quality Based Effluent Limits Design Conditions**		
	streamflow	**averaging period**	**mixing zone restriction**
acute guidelines (USEPA)	*1Q10 (or 1 day in 3 year biological flow)*[bf]	*1 hour to 1 day averaging period*	*end-of-pipe, or with adequate justification, 30 metres surrounding outfall*[sz] *(at design streamflow), or 5% fraction of design streamflow*[21]*, provided rule of thumb*[rt] *restrictions are complied with to the extent resolvable*
chronic guidelines (ASWQG, CWQG, USEPA)	*7Q10 (or 4 day in 3 year biological flow)*[bf]	*1 day to 30 days averaging period (default 4 days)*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable, or with adequate justification, the more stringent of 10 times stream width for length and 1/2 stream width*[sz]*, (both determined at 7Q10), and 10% fraction of design streamflow*[22]
human health non-carcinogen (USEPA)	*30Q5 (or 4 day in 3 year biological flow)*[bf]	*4 day to 30 day averaging period (default 4 days)*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*
human health carcinogen (USEPA)	*harmonic mean flow*	*NA*	*comply with rule of thumb*[rt] *restrictions to the extent resolvable*
reasonable potential screening	$\mathrm{C} = \left(QeCe + ff\,(Qs)Cs\right) / \left(Qe + ff\,(Qs)\right)$ *ff = fraction of flow, Qe = effluent flow, Qs = streamflow, Cs = upstream substance concentration*		
wasteload allocation (WLA)	$WLA = \left[SWQG \times \left(Qe + (Qs \times ff\,)\right) - (Qs \times ff\,) \times Cs\right] / Qe$ *SWQG = surface water quality guideline, ff = fraction of flow, Qe = effluent flow* *Qs = streamflow, Cs = upstream substance concentration*		
long term average (LTA)	$\mathrm{LTA} = \mathrm{WLA} \bullet \mathrm{e}^{[0.5\, s_n{}^2 - \mathrm{Z}\, s_n]}$ $s_{\mathrm{n}}{}^2 = \ln((\mathrm{CV}^2\ /\, \mathrm{n}) + 1)$[cv], *z=2.236, default averaging periods: acute n=1, chronic n=4*		
average monthly limit (AML)	$\mathrm{AML} = \mathrm{LTA} \bullet \mathrm{e}^{[\mathrm{z}\, s_{\mathrm{n}} - 0.5\, s_{\mathrm{n}}{}^2\,]}$ $s_{\mathrm{n}}{}^2 = \ln((\mathrm{CV}^2\ /\, \mathrm{n}) + 1)$[cv], *z=1.642, number of samples per month (4<n<30)*		
maximum daily limit (MDL)	$\mathrm{MDL} = \mathrm{LTA} \bullet \mathrm{e}^{[\mathrm{z}\, s - 0.5\, s^2\,]}$ $s^2 = \ln(\mathrm{CV}^2 + 1)$[cv], z = 2.236		

[bf] If biological flow is calculated, it should be used instead of hydrologic flow.

[sz] If the spatial zone calculated results in a more stringent WLA than the fraction of flow, then the spatial restriction should be employed.

[21] An LC50 >100% at EOP (using rainbow trout and/or *Daphnia magna*) will in most cases be required.

[rt] See Mixing Zone section for description of rule of thumb crestrictions

[22] In the case where near-instantaneous mixing is achieved through multiport diffusers, no mixing zone restriction need be considered (for chronic guidelines), provided rule of thumb principles are complied with. Near-instantaneous mixing is defined as no measurable difference in the concentration of a substance across a lateral transect of the stream (eg., does not vary by more than 10%) at a distance equal to two stream widths downstream of the outfall.

[cv] Use CV of 0.6 for data sets less than 10 (unless evidence suggests a higher value). Use calculated CV for data sets greater than 10 .

Appendix 2 Recommendations for Statistically Derived Effluent Limits

There is often discussion related to the calculation and interpretation of the AML. The following text is extracted from the TSD and reviews the various effects of variability on the limits setting process.

> *"The statistically based method for limit derivation results in an MDL that does not depend on monitoring frequency. However the AML decreases as monitoring frequency increases, and a greater number for "n" is inserted in the relevant equations. Some permit writers are concerned with this outcome because facilities with more frequent sampling requirements appear to receive more stringent limits than those with less frequent monthly sampling requirements.*
>
> *The AML decreases as the number of monthly samples increases because an average of 10 samples, for example, is closer to the LTA than an average based on 4 samples. This phenomenon makes AML's based on 10 samples appear to be more stringent than the monthly limit based on 4 samples. However, the stringency of these procedures is constant across monitoring frequencies the probability basis and the targeted LTA performance are the same regardless of the number of samples taken. Thus, a permittee performing according to the LTA and variability associated with the wasteload allocation will, in fact, meet either of these AMLs when taking the corresponding number of monthly samples.*
>
> *For water quality based permitting, effluent quality is determined by the underlying distribution of daily values, which is determined by the LTA associated with a particular WLA and by the CV of the effluent concentrations. Increasing or decreasing monitoring frequency does not affect this underlying distribution or treatment performance, which should, at a minimum, be targeted to comply with the values dictated by the WLA.* ***Therefore it is recommended that the actual planned frequency of monitoring be used to determine the value of n for calculating the AML. However, in situations where monitoring frequency is once per month or less, a higher value of n must be assumed for AML derivation purposes****. This is particularly applicable for addressing situations such where as where a single criterion is applied at the end of the pipe and a single monthly sample is contemplated for monitoring compliance purposes, or where monitoring frequency is only quarterly. In this case, both the average monthly and the MDL would exceed the criterion. (for example, for a CCC of 1.0 chronic toxic unit [TUc] applied as a WLA at the end of the pipe, both the MDL and the AML would be 1.6 TUc; assuming CV=0.6, n=1, and a 99 percent probability basis.) A discharger could thus comply with the permit limit but routinely exceed the criterion. Under these circumstances, the statistical procedure should be employed using an assumed number of samples of a least <u>four</u> for the AML derivation."*
>
> *and...*
>
> *"It is extremely important to recognize that the various statistical principles and relationships discussed above operate in any discharge situation - whether or not they are specifically recognized or accounted for. Where a limit derivation procedure does not*

address these principles specifically, the regulator will be implicitly assuming that there are enough conservative assumptions built into other steps in the process (e.g., water quality models, "buffer" between limits and actual operating conditions) to ensure that there will be no reasonable potential for excursions above water quality objectives"

Effect of Changes of Statistical Parameters on Permit Limits (adapted directly from p. 105 of TSD) Note, this Table is of more use after the reader has gained familiarity with wasteload allocation techniques as defined in the next Section

Effect of changes:	Reason
in CV on derivation of LTA from WLA: *As the CV increases, the LTA decreases; and conversely, as the CV decreases, the LTA increases.*	*The LTA must be lower relative to the WLA to account for the extreme values observed with high CV's. An LTA with zero CV equals the WLA.*
on CV on derivation of permit limits for a fixed probability basis*: As the CV increases the permit limits increase (become less stringent); and conversely, as the CV decreases, the permit limits decrease (become more stringent).*	*A higher value for the permit limit is produced for the same LTA's as the CV increases in order to allow for fluctuations about the mean.*
in the number of monthly samples on permit limits*: As the value for "n" (number of observations) increases in the average monthly permit limit derivation equations, the average monthly permit limit decreases to a certain point. The effect on the average monthly permit limit is minimal for values of n greater than approximately 10. Conversely, as the value for "n" decreases, the AML increases until n=1, at which point the AML equals the MDL. (editors note: provided the AML percentile equals the MDL percentile).*	*As n increases, the probability distribution of the n-day average values become less variable (narrower) around the LTA. Therefore, the 99th or 95th percentile value for an n-day average decreases in absolute value as n increases.*
in probability basis for permit limits*: As the probability basis for the permit limits expressed in percentiles (e.g., 95 percent and 99 percent) increases, the value for the permit limits increases (becomes less stringent). The converse is true as the probability basis decreases.*	*There is a higher probability that any randomly chosen effluent sample will be in compliance with its permit limits, if those limits are statistically designed to be greater than a high percentage (e.g., 99 percent) of all possible values for a given LTA and CV.*

Appendix 3 WL Screen

A tool available for performing reasonable potential to exceed screening and subsequent development of water quality based effluent limits is WL Screen (wasteload screen). This steady state model is available as a standalone visual basic program and an excel based spreadsheet macro. The following features are presently available in WL Screen:

- guidelines data base of all ASWQO, US EPA Gold Book criteria and all protection of aquatic life Canadian Water Quality Guidelines.
- formula guidelines supported such as ammonia, metals and pentachlorophenol
- capability to screen or set limits based on fraction of flow and spatial (lateral and length scales) mixing zones
- two value steady state analysis for acute, chronic, and human health carcinogen and non-carcinogen Gold Book criteria - selects the most stringent based on user specified design criteria for each type of guideline
- adjustable percentiles for all limits, confidence levels, screening levels, reasonable potential multipliers
- adjustable averaging periods for all guidelines
- custom guidelines development
- automatic reasonable potential to exceed flagging
- automatic limits calculation with adjustable AML sample numbers
- batch processing
- print functions
- help program

Appendix 4 List of Models for Water Quality Based Limits Setting (note: to be revised)

Plumes
Cormix
WASP
WL Screen
DOSTOC
DFLOW
Streamix I (Region 8 lotus spreadsheet - spatial mixing zone model)

Appendix 5 List of Support Documents

US EPA Treatability Manual. July, 1986. Office of Research and Development. EPA 600-8-80-042a.

US EPA NPDES Industrial Permit Abstracts. October, 1993. Office of Water. EPA 833-B-93-005.

Mixing Zones and Dilution Policy. EPA Region VIII. December, 1994. Water Management Division (8WM) 99 18th Street, Suite 500, Denver, CO.

Technical Support Document for Water Quality-Bases Toxics Control. Office of Water, US EPA, March 1991. EPA/505/2-90-001.

Technical Guidance Manual for Performing Waste Load Allocations. Book VII, Permit Averaging Periods. 1984. US EPA, Office of Water Regulations and Standards, Monitoring and Data Support Division. Washington, D.C. 20460. EPA 440/4-84-023. July 1984. Final

Appendix 6 List of Statistics Documents

Technical Support Document for Water Quality-Bases Toxics Control. Office of Water, US EPA, March 1991. EPA/505/2-90-001.

Training Manual for NPDES Permit Writer's. Office of Water, US EPA, March 1993. EPA 833-B-93-003.

Gilbert, Richard O. Statistical Methods for Environmental Pollution Monitoring. 1987. Van Nostrand Reinhold Company Inc.

Uri, Noel D. Detecting a trend in water quality. WPCF Journal, September/October, 1991. Volume 63, Number 6.

Berthourex, P.M. Ian Hau. Difficulties related to using extreme percentiles for water quality regulations. September/October, 1991. Journal WPCF, Volume 63. Number 6.

Kahn, Henery D. and Marvin B. Rubin. Use of Statistical Methods in Industrial Water Pollution Control in the United States. Environmental Monitoring and Assessment 12: 129-148, 1989.

Appendix 7 Reasonable Potential Multipliers

As explained in the TSD, the reasonable potential multiplier statistical approach has two parts. The first involves the relationship between the desired confidence level expressed thus:

$$\mathrm{Pn} = (1 - \mathrm{confidence\_level})^{\frac{1}{n}}$$

where Pn is the percentile represented by the highest concentration in the data and n is the number of samples. Therefore at the 99th percent confidence level, the largest value of 5 samples is computed to be larger than the 40 percentile:

$$\mathrm{Pn} = (1 - .99)^{\frac{1}{5}} = 0.40$$

The second part of the approach describes the relationship between the percentile described above and the selected upper bound of the lognormal effluent distribution. Therefore, extending the previous example:

$$\frac{C_{99}}{C_{40}} = \frac{e^{\left(2.326\,s - 0.5\,s^2\right)}}{e^{\left(-0.258\,s - 0.5\,s^2\right)}} = 4.2$$

where: $s^2 = \ln\left(CV^2 + 1\right)$
and 2.236 and -0.258 equal the normal distribution values for the 99th and 40th percentiles, respectively.

That is, if 5 samples were collected, (representing the 40 th percentile as described earlier), the coefficient of variation is 0.6 (conventional default value), and the desired upper bound of the effluent distribution is the 99th percentile, then the above equation result of 4.2 is multiplied by the highest effluent value in the data set to yield an estimated 99th percentile. This value is subsequently used in the reasonable potential to exceed calculation.

Appendix 7 Cont...

# of samples	Reasonable Potential Multiplying Factors: 99% desired percentile and 99% desired confidence level																			
	Coefficient of Variation																			
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**
1	1.6	2.5	3.9	6.0	9.0	13.2	18.9	26.4	36.0	48.1	63.0	81.0	102.3	127.3	156.2	189.2	226.5	268.3	314.7	366.0
2	1.4	2.0	2.9	4.0	5.5	7.4	9.8	12.6	16.1	20.2	24.8	30.2	36.2	42.9	50.2	58.3	67.0	76.4	86.5	97.2
3	1.4	1.9	2.5	3.3	4.4	5.6	7.1	8.9	11.0	13.4	16.0	18.9	22.1	25.6	29.4	33.4	37.7	42.2	47.0	52.0
4	1.3	1.7	2.3	2.9	3.8	4.7	5.9	7.2	8.7	10.3	12.2	14.1	16.3	18.6	21.0	23.6	26.3	29.1	32.0	35.1
5	1.3	1.7	2.1	2.7	3.4	4.2	5.1	6.2	7.3	8.6	10.0	11.5	13.1	14.8	16.5	18.4	20.3	22.3	24.4	26.5
6	1.3	1.6	2.0	2.5	3.1	3.8	4.6	5.5	6.4	7.5	8.6	9.8	11.1	12.4	13.8	15.2	16.7	18.2	19.8	21.4
7	1.3	1.6	2.0	2.4	2.9	3.5	4.2	5.0	5.8	6.7	7.6	8.6	9.7	10.8	11.9	13.1	14.3	15.5	16.8	18.1
8	1.2	1.5	1.9	2.3	2.8	3.3	3.9	4.6	5.3	6.1	6.9	7.8	8.7	9.6	10.5	11.5	12.5	13.6	14.6	15.7
9	1.2	1.5	1.8	2.2	2.7	3.2	3.7	4.3	4.9	5.6	6.3	7.1	7.9	8.7	9.5	10.4	11.2	12.1	13.0	13.9
10	1.2	1.5	1.8	2.2	2.6	3.0	3.5	4.1	4.6	5.3	5.9	6.6	7.3	8.0	8.7	9.4	10.2	11.0	11.7	12.5
11	1.2	1.5	1.8	2.1	2.5	2.9	3.4	3.9	4.4	4.9	5.5	6.1	6.7	7.4	8.0	8.7	9.4	10.0	10.7	11.4
12	1.2	1.4	1.7	2.0	2.4	2.8	3.2	3.7	4.2	4.7	5.2	5.8	6.3	6.9	7.5	8.1	8.7	9.3	9.9	10.5
13	1.2	1.4	1.7	2.0	2.3	2.7	3.1	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.6	8.1	8.7	9.2	9.8
14	1.2	1.4	1.7	2.0	2.3	2.6	3.0	3.4	3.8	4.3	4.7	5.2	5.7	6.2	6.6	7.1	7.6	8.1	8.6	9.1
15	1.2	1.4	1.6	1.9	2.2	2.6	2.9	3.3	3.7	4.1	4.5	5.0	5.4	5.9	6.3	6.8	7.2	7.7	8.1	8.6

# of samples	Reasonable Potential Multiplying Factors: 95% desired percentile and 99% desired confidence level																			
	Coefficient of Variation																			
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**
1	1.5	2.2	3.2	4.6	6.5	9.0	12.3	16.3	21.3	27.3	34.3	42.5	52.0	62.6	74.5	87.8	102.4	118.3	135.5	154.2
2	1.3	1.8	2.4	3.1	4.0	5.1	6.3	7.8	9.5	11.4	13.5	15.9	18.4	21.1	24.0	27.0	30.3	33.7	37.3	41.0
3	1.3	1.6	2.0	2.6	3.2	3.9	4.6	5.5	6.5	7.6	8.7	9.9	11.2	12.6	14.0	15.5	17.0	18.6	20.2	21.9
4	1.2	1.5	1.9	2.3	2.7	3.2	3.8	4.5	5.1	5.9	6.6	7.4	8.3	9.1	10.0	10.9	11.9	12.8	13.8	14.8
5	1.2	1.5	1.7	2.1	2.5	2.9	3.3	3.8	4.3	4.9	5.4	6.0	6.6	7.3	7.9	8.5	9.2	9.8	10.5	11.2
6	1.2	1.4	1.7	2.0	2.3	2.6	3.0	3.4	3.8	4.2	4.7	5.1	5.6	6.1	6.6	7.1	7.6	8.0	8.5	9.0
7	1.2	1.4	1.6	1.9	2.1	2.4	2.7	3.1	3.4	3.8	4.2	4.5	4.9	5.3	5.7	6.1	6.5	6.8	7.2	7.6
8	1.2	1.3	1.5	1.8	2.0	2.3	2.6	2.8	3.1	3.5	3.8	4.1	4.4	4.7	5.0	5.3	5.7	6.0	6.3	6.6
9	1.1	1.3	1.5	1.7	1.9	2.2	2.4	2.7	2.9	3.2	3.5	3.7	4.0	4.3	4.5	4.8	5.1	5.3	5.6	5.9
10	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	3.0	3.2	3.4	3.7	3.9	4.1	4.4	4.6	4.8	5.1	5.3
11	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8
12	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.7	2.8	3.0	3.2	3.4	3.6	3.8	3.9	4.1	4.3	4.4
13	1.1	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.9	3.0	3.2	3.4	3.5	3.7	3.8	4.0	4.1
14	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.3	3.5	3.6	3.7	3.9
15	1.1	1.2	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.3	3.4	3.5	3.6

note: values not identical to TSD (p.57) due to round-off error. This spreadsheet available as excel worksheet.

Appendix 7 Cont...

# of samples	**Reasonable Potential Multiplying Factors: 95% desired percentile and 95% desired confidence level**																			
	Coefficient of Variation																			
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**
1	1.5	2.2	3.2	4.6	6.5	9.0	12.3	16.3	21.3	27.3	34.3	42.5	52.0	62.6	74.5	87.8	102.4	118.3	135.5	154.2
2	1.4	1.8	2.5	3.3	4.3	5.5	7.0	8.8	10.8	13.1	15.6	18.4	21.5	24.9	28.5	32.4	36.5	40.8	45.4	50.2
3	1.3	1.7	2.2	2.8	3.5	4.4	5.4	6.5	7.8	9.2	10.7	12.4	14.1	16.0	18.0	20.1	22.3	24.5	26.9	29.3
4	1.3	1.6	2.0	2.5	3.1	3.8	4.5	5.4	6.3	7.3	8.4	9.6	10.8	12.1	13.5	14.9	16.3	17.8	19.3	20.9
5	1.2	1.5	1.9	2.3	2.8	3.4	4.0	4.7	5.5	6.3	7.1	8.0	8.9	9.9	10.9	12.0	13.0	14.1	15.2	16.3
6	1.2	1.5	1.8	2.2	2.6	3.1	3.7	4.2	4.9	5.5	6.2	7.0	7.7	8.5	9.3	10.1	11.0	11.8	12.7	13.6
7	1.2	1.5	1.8	2.1	2.5	2.9	3.4	3.9	4.4	5.0	5.6	6.2	6.9	7.5	8.2	8.9	9.5	10.2	11.0	11.7
8	1.2	1.4	1.7	2.0	2.4	2.8	3.2	3.6	4.1	4.6	5.1	5.7	6.2	6.8	7.3	7.9	8.5	9.1	9.7	10.3
9	1.2	1.4	1.7	2.0	2.3	2.6	3.0	3.4	3.9	4.3	4.8	5.2	5.7	6.2	6.7	7.2	7.7	8.2	8.7	9.2
10	1.2	1.4	1.6	1.9	2.2	2.5	2.9	3.3	3.6	4.0	4.5	4.9	5.3	5.8	6.2	6.6	7.1	7.5	8.0	8.4
11	1.2	1.4	1.6	1.9	2.1	2.4	2.8	3.1	3.5	3.8	4.2	4.6	5.0	5.4	5.8	6.2	6.6	7.0	7.4	7.8
12	1.2	1.4	1.6	1.8	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.4	4.7	5.1	5.4	5.8	6.1	6.5	6.9	7.2
13	1.2	1.3	1.6	1.8	2.0	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.5	4.8	5.1	5.5	5.8	6.1	6.4	6.8
14	1.2	1.3	1.5	1.8	2.0	2.2	2.5	2.8	3.1	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4
15	1.2	1.3	1.5	1.7	2.0	2.2	2.4	2.7	3.0	3.2	3.5	3.8	4.1	4.4	4.6	4.9	5.2	5.5	5.7	6.0

# of samples	**Reasonable Potential Multiplying Factors: 99% desired percentile and 95% desired confidence level**																			
	Coefficient of Variation																			
	0.1	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	**1.1**	**1.2**	**1.3**	**1.4**	**1.5**	**1.6**	**1.7**	**1.8**	**1.9**	**2.0**
1	1.4	1.9	2.6	3.6	4.7	6.2	8.0	10.1	12.6	15.5	18.7	22.4	26.4	30.8	35.6	40.7	46.3	52.1	58.4	64.9
2	1.3	1.6	2.0	2.5	3.1	3.8	4.6	5.4	6.4	7.4	8.5	9.7	10.9	12.2	13.6	15.0	16.5	18.0	19.6	21.1
3	1.2	1.5	1.8	2.1	2.5	3.0	3.5	4.0	4.6	5.2	5.8	6.5	7.2	7.9	8.6	9.3	10.1	10.8	11.6	12.3
4	1.2	1.4	1.7	1.9	2.2	2.6	2.9	3.3	3.7	4.2	4.6	5.0	5.5	6.0	6.4	6.9	7.4	7.8	8.3	8.8
5	1.2	1.4	1.6	1.8	2.1	2.3	2.6	2.9	3.2	3.5	3.9	4.2	4.5	4.9	5.2	5.6	5.9	6.2	6.6	6.9
6	1.1	1.3	1.5	1.7	1.9	2.1	2.4	2.6	2.9	3.1	3.4	3.7	3.9	4.2	4.4	4.7	5.0	5.2	5.5	5.7
7	1.1	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.1	3.3	3.5	3.7	3.9	4.1	4.3	4.5	4.7	4.9
8	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.4	2.6	2.8	3.0	3.2	3.3	3.5	3.7	3.8	4.0	4.2	4.3
9	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.2	3.3	3.5	3.6	3.8	3.9
10	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.2	2.3	2.4	2.6	2.7	2.8	3.0	3.1	3.2	3.3	3.4	3.5
11	1.1	1.2	1.3	1.4	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.2	3.3
12	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.0
13	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.4	2.5	2.6	2.7	2.8	2.8
14	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.2	2.3	2.4	2.5	2.5	2.6	2.7
15	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.4	2.5	2.5

Appendix 8 Instream Guidelines (all values in mg/L)

The US EPA Gold Book values have been updated through the Toxics Rule, December 1992 as presented.

Substance[23]	Acute[24]	Chronic[25]	HHC[26]	HHNC[27]	Source
acenaphthene	1.7	0.52			USEPA
acrolein				0.32	USEPA
acrylonitrile			0.000059		USEPA
aldrin	3		0.00000013		USEPA
aldrin dieldrin		0.000004			CCME
aluminum total		0.1			CCME
ammonia total as (N)	=(0.52/(FTA*FPHA*2)*TOTAL)*0.822 see next Table for values	=(0.8/(FTC*FPHC*RATIO)*TOTAL)*0.822 see next Table for values			USEPA
ammonia total as (N)		=(0.8/(FTC*FPHC*RATIO)*TOTAL)*0.822 see next Table for values			CCME
anthracene			9.6		USEPA
antimony				0.014	USEPA
arsenic	0.36	0.19		0.000018	USEPA
arsenic		0.01			ASWQO
arsenic total		0.05			CCME
asbestos			7000000 f/L		USEPA
atrazine		0.002			CCME
barium				1	USEPA
barium		1			ASWQO
benzene			0.0012		USEPA
benzene		0.3			CCME
benzidine	2.5		0.00000012		USEPA
benzo a anthracene			0.0000028		USEPA
benzo a pyrene			0.0000028		USEPA
benzo k fluoranthene			0.0000028		USEPA
benzofluoranthene 3 4			0.0000028		USEPA
beryllium	0.13	0.0053			USEPA
BHC	0.1				USEPA
BHC alpha			0.0000039		USEPA
BHC beta			0.000014		USEPA
BHC gamma (lindane)	0.002	0.00008	0.000019		USEPA
boron		0.5			ASWQO
bromoform			0.0043		USEPA
butylbenzyl phthalate				5.2	USEPA
cadmium	=EXP(1.128*(LN(hardness))-3.828)/1000 see next Table for	=EXP(0.7852*(LN(hardness))-3.49)/1000 see next Table for			USEPA

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[23] all Table values are for freshwater only
[24] one hour to one day averaging period
[25] 4 day default averaging period
[26] human health carcinogen
[27] human health non-carcinogen

Substance[23]	Acute[24]	Chronic[25]	HHC[26]	HHNC[27]	Source
	values	values			
cadmium		0.01			ASWQO
cadmium		=EXP(0.7852*(LN(hardness))-3.49)/1000 see next Table for values			CCME
carbon tetrachloride			0.00025		USEPA
chlordane	0.0024	0.0000043	0.00000057		USEPA
chlordane		0.000006			CCME
chloride	860	230			USEPA
chlorinated benzenes	0.25	0.05			USEPA
chlorinated naphthalenes	1.6				USEPA
chlorine	0.019	0.011			USEPA
chlorine total residual		0.002			CCME
chloroalkyl ethers	238				USEPA
chlorobenzene	0.25	0.05		0.68	USEPA
chlorodane	0.0024	0.0000043	0.00000057		USEPA
chlorodibromomethane			0.00041		USEPA
chloroform	28.9	1.24	0.0057		USEPA
chlorophenol 2	4.38				USEPA
chlorophenol 4 methyl 3	0.03				USEPA
chlorophenoxy herbicide 2 4 5 tp				0.01	USEPA
chromium		0.05			ASWQO
chromium III	EXP(0.819*(LN(hardness))+3.688)/1000 see next Table for values	EXP(0.819*(LN(hardness))+1.581)/1000 see next Table for values			USEPA
chromium total		0.02			CCME
chromium VI	0.016	0.011			USEPA
chrysene			0.0000028		USEPA
cobalt		0.05			CCME
colour		30			ASWQO
copper	EXP(0.9422*(LN(hardness))-1.464)/1000 see next Table for values	EXP(0.8545*(LN(hardness))-1.465)/1000 see next Table for values			USEPA
copper		0.02			ASWQO
copper		(EXP(0.8545*(LN(hardness))-1.465)/1000)*0.2 see next Table for values			CCME
cyanazine		0.002			CCME
cyanide	0.022	0.0052		0.7	USEPA
cyanide		0.01			ASWQO
cyanide		0.005			CCME
2 4D		0.004			CCME
DBP		0.004			CCME
4,4' DDD (DDT metabolite)	0.0006		0.00000083		USEPA
4,4' DDE (DDT metabolite)	1.05		0.00000059		USEPA
DDT		0.000001			CCME

Substance[23]	Acute[24]	Chronic[25]	HHC[26]	HHNC[27]	Source
4,4' DDT	0.0011	0.000001	0.00000059		USEPA
di 2 ethylhexyl phthalate		0.0006			CCME
demeton		0.0001			USEPA
di 2 ethylhexyl phthalate			15		USEPA
diazinon		0.014			CCME
dibenzo (a, h) anthracene			0.0000028		USEPA
dibutyl phthalate				2.7	USEPA
1,2 dichlorobenzene		0.0025			CCME
1,2 and 1,3 dichlorobenzene		0.0025			CCME
1,4 dichlorobenzene		0.004			CCME
1,2 dichlorobenzene				2.7	USEPA
1,3 dichlorobenzene				0.4	USEPA
1,4 dichlorobenzene				0.4	USEPA
dichlorobenzenes		1.12		0.4	USEPA
3,3'dichlorobenzidine			0.00004		USEPA
dichlorobromomethane		0.00027			CCME
1,2 dichloroethane			0.00038		USEPA
1,2 dichloroethane		0.1			CCME
1,1 dichloroethylene			0.000057		USEPA
2,4 dichlorophenol		0.0002			CCME
2,4 dichlorophenol	2.02	0.365		0.093	USEPA
dichlorophenols		0.0002			CCME
dichloropropane	23	5.7			USEPA
dichloropropene	6.06	0.244			USEPA
1,3 dichloropropylene				0.01	USEPA
dieldrin	0.0025	0.0000019	0.00000014		USEPA
diethyl phthalate				23	USEPA
2,4 dimethyl phenol	2.12				USEPA
dimethyl phthalate				313	USEPA
2,4 dinitro o cresol				0.0134	USEPA
dinitrophenol				0.07	USEPA
2,4 dinitrophenol	2.02	0.365		0.07	USEPA
2 dinitrophenol 4 6 methyl				0.0134	USEPA
2,4 dinitrotoluene	0.33	0.23	0.00011		USEPA
dioxin 2 3 7 8 TCDD			0.000000000013		USEPA
1,2diphenylhydrazine	0.27		0.00004		USEPA
dlchlorobromomethane			0.00027		USEPA
endosulfan	0.00022	0.000056		0.074	USEPA
endosulfan		0.00002			CCME
endosulfan alpha	0.00022	0.000056		0.00093	USEPA
endosulfan beta	0.00022	0.000056		0.00093	USEPA
endosulfan sulfate				0.00093	USEPA
endrin	0.00018	0.0000023		0.00076	USEPA
endrin		0.0000023			CCME
endrin aldehyde				0.00076	USEPA
bis (2-chloroethyl)ether			0.000031		USEPA
bis (2-chloroisopropyl)ether				1.4	USEPA

Substance[23]	Acute[24]	Chronic[25]	HHC[26]	HHNC[27]	Source
bis (chloromethyl)ether			0.0000000038		USEPA
ethylbenzene				3.1	USEPA
ethylbenzene		0.7			CCME
fluoranthene	3.98			0.3	USEPA
fluorene			1.3		USEPA
fluoride		1.5			ASWQO
glyphosate		0.065			CCME
guthion		0.00001			USEPA
haloethers	0.36	0.122			USEPA
halomethanes	11		0.00019		USEPA
heptachlor	0.00052	0.0000038	0.00000021		USEPA
heptachlor and heptachlor epoxide		0.00001			CCME
heptachlor epoxide	0.00052	0.0000038	0.0000001		USEPA
hexachlorobenzene			0.00000075		USEPA
hexachlorobenzene		0.0000065			CCME
hexachlorobutadiene	0.09	0.0093	0.00044		USEPA
hexachlorobutadiene		0.0001			CCME
hexachlorocyclohexane isomers		0.00001			CCME
hexachlorocyclapentadiene				0.24	USEPA
hexachloroethane	0.98	0.54	0.0019		USEPA
hexachlrocyclohexane alpha			0.0000092		USEPA
hexachlrocyclohexane beta			0.0000163		USEPA
hexachlrocyclohexane gamma	2	0.08	0.0000186		USEPA
hexachlrocyclohexane lindane	0.002	0.00008	0.0000186		USEPA
hexachlrocyclohexane technical			0.0000123		USEPA
iron		1		0.3	USEPA
iron		0.3			ASWQO
iron		0.3			CCME
isophorone	117			0.0084	USEPA
lead	EXP(1.273*(LN(hardness))-1.46)/1000 see next Table for values	EXP(1.273*(LN(hardness))-4.705)/1000 see next Table for values			USEPA
lead		0.05			ASWQO
lead		EXP(1.273*(LN(hardness))-4.705)/1000 see next Table for values			CCME
lindane		0.004			CCME
malathion		0.0001			USEPA
manganese				0.05	USEPA
manganese		0.05			ASWQO
mercury	0.0024	0.000012		0.00014	USEPA
mercury		0.0001			ASWQO

Substance[23]	Acute[24]	Chronic[25]	HHC[26]	HHNC[27]	Source
mercury total		0.0001			CCME
methoxychlor		0.00003		100	USEPA
methyl mercaptan		0.05			ASWQO
methyl parathion		0.007			CCME
methylene chloride			0.0047		USEPA
metribuzin		0.001			CCME
mirex		0.000001	0.0047		USEPA
molybdenum		0.01			CCME
monochlorobenzene		0.015			CCME
monochlorophenols		0.007			CCME
naphthalene	2.3	0.62			USEPA
nickel	EXP(0.846*(LN(hardness))+3.3612)/1000 see next Table for values	EXP(0.846*(LN(hardness))+1.1645)/1000 see next Table for values		0.61	USEPA
nickel		EXP(0.76*(LN(hardness))+1.06)/1000 see next Table for values			CCME
nitrates				10	USEPA
nitrilotriacetic acid		0.05			CCME
nitrobenzene	27			0.017	USEPA
nitrogen total		1			ASWQO
nitrophenols	0.23	0.15			USEPA
nitrosamines	5.85		0.0000008		USEPA
nitrosodibutylamine n			0.0000064		USEPA
nitrosodiethylamine n			0.0000008		USEPA
nitrosodimethylamine n			0.00000069		USEPA
nitrosodiphenylamine n			0.005		USEPA
parathion	0.000065	0.000013			USEPA
parathion		0.035			CCME
PCB 1016		0.000014	0.000000044		USEPA
PCB 1221		0.000014	0.000000044		USEPA
PCB 1232		0.000014	0.000000044		USEPA
PCB 1242		0.000014	0.000000044		USEPA
PCB 1248		0.000014	0.000000044		USEPA
PCB 1254		0.000014	0.000000044		USEPA
PCB 1260		0.000014	0.000000044		USEPA
PCBs	0.002	0.000014	0.000000079		USEPA
PCBs		0.000001			CCME
PCBs total		0.00001			CCME
pentachlorobenzene		0.00003			CCME
pentachloroethane	7.24	1.1			USEPA
pentachlorophenol	EXP(1.005*pH-4.83)/1000	EXP(1.005*pH-5.29)/1000		0.00028	USEPA
pentachlorophenol		0.0005			CCME
phenol	10.2	2.56		21	USEPA
phenolics		0.005			ASWQO
phenols total		0.001			CCME

Substance[23]	**Acute**[24]	**Chronic**[25]	**HHC**[26]	**HHNC**[27]	**Source**
phenoxy herbicides 2 4 d		0.004			CCME
phosphorus PO_4 total		0.15			ASWQO
phthalate bis 2 ethylhexyl			0.0018		USEPA
phthalate esters	0.94	0.003			USEPA
phthalate esters other		0.0002			CCME
picloram		0.029			CCME
polychlorinated biphenols		0.000001			CCME
polynuclear aromatic hydrocarbons			0.0000028		USEPA
pyrene			0.96		USEPA
resin acids		0.1			ASWQO
selenium	0.02	0.005			USEPA
selenium		0.01			ASWQO
selenium total		0.001			CCME
silver	EXP(1.72*(LN(hardness))-6.52)/1000 see next Table for values				USEPA
silver		0.05			ASWQO
silver		0.0001			CCME
solids dissolved and salinity				250	USEPA
sulfide hydrogen sulfide		0.002			USEPA
sulphide		0.05			ASWQO
suspended solids		10			ASWQO
temperature		3			ASWQO
1,2,3,4-tetrachlorobenzene		0.0001			CCME
1,2,3,5-tetrachlorobenzene		0.0001			CCME
1,2,4,5-tetrachlorobenzene		0.00015			CCME
1,2,4,5-tetrachlorobenzene				0.038	USEPA
1,1,2,2-tetrachloroethane			0.00017		USEPA
tetrachloroethanes	9.32				USEPA
tetrachloroethylene	5.28	0.84	0.0008		USEPA
tetrachloroethylene		0.26			CCME
tetrachlorophenol		0.001			CCME
thallium				0.0017	USEPA
toluene	17.5			6.8	USEPA
toluene		0.3			CCME
toxaphene	0.00073	0.0000002	0.00000073		USEPA
toxaphene		0.000008			CCME
toxicity acute TU_a $(100/LC_{50})$	0.3				USEPA
toxicity chronic TU_c (100/NOEC)		1			USEPA
trichlorinated ethanes		18			USEPA
1,2,3-trichlorobenzene		0.0009			CCME
1,2,3,5-trichlorobenzene		0.0001			CCME
1,2,4-trichlorobenzene		0.0005			CCME
1,2,4,5-trichlorobenzene		0.00015			CCME
1,3,5-trichlorobenzene		0.00065			CCME

Substance[23]	**Acute[24]**	**Chronic[25]**	**HHC[26]**	**HHNC[27]**	**Source**
1,1,2-trichloroethane		9.4	0.0006		USEPA
trichloroethylene	45	21	0.0027		USEPA
trichloroethylene		0.02			CCME
2,4,5-trichlorophenol				2.6	USEPA
2,4,6-trichlorophenol		0.97	0.0021		USEPA
trichlorophenols		0.018			CCME
trihalomethanes		0.35			CCME
turbidity		25			ASWQO
uranium		0.01			CCME
vanadium		0.1			CCME
vinyl chloride			0.002		USEPA
zinc	EXP(0.8473*(LN(hardness))+0.8604)/1000 see next Table for values	EXP(0.8473*(LN(hardness))+0.7614)/1000 see next Table for values			USEPA
zinc		0.05			ASWQO
zinc		0.03			CCME

CWQG and US EPA Gold Book Guidelines for Metals (all values in mg/L)

Cadmium			
	US EPA	*US EPA*	*CWQG*
Hardness (CaCO$_3$)	Acute	Chronic	Chronic
100	0.00392	0.00113	0.00113
125	0.00504	0.00135	0.00135
150	0.0062	0.00156	0.00156
175	0.00737	0.00176	0.00176
200	0.00857	0.00195	0.00195
225	0.00979	0.00214	0.00214
300	0.01354	0.00269	0.00269
325	0.01482	0.00286	0.00286
350	0.01611	0.00303	0.00303

Chromium III		
	US EPA	*US EPA*
Hardness (CaCO$_3$)	Acute	Chronic
100	1.73651	0.21116
125	2.08472	0.25351
150	2.42045	0.29433
175	2.74616	0.33394
200	3.06353	0.37253
225	3.37377	0.41026
300	4.27012	0.51926
325	4.55943	0.55444
350	4.84473	0.58913

Copper			
	US EPA	*US EPA*	*CWQG*
Hardness (CaCO$_3$)	Acute	Chronic	Chronic
100	0.01773	0.01182	0.00236
125	0.02187	0.01431	0.00286
150	0.02597	0.01672	0.00334
175	0.03003	0.01907	0.00381
200	0.03406	0.02138	0.00428
225	0.03806	0.02364	0.00473
300	0.0499	0.03023	0.00605
325	0.05381	0.03237	0.00647
350	0.05771	0.03449	0.0069

Lead			
	US EPA	*US EPA*	*CWQG*
Hardness (CaCO$_3$)	Acute	Chronic	Chronic
100	0.08165	0.00318	0.00318
125	0.10847	0.00423	0.00423
150	0.1368	0.00533	0.00533
175	0.16646	0.00649	0.00649
200	0.19731	0.00769	0.00769
225	0.22922	0.00893	0.00893
300	0.3306	0.01288	0.01288
325	0.36606	0.01427	0.01427
350	0.40228	0.01568	0.01568

Nickel			
	US EPA	*US EPA*	*CWQG*
Hardness (CaCO$_3$)	Acute	Chronic	Chronic
100	1.41824	0.15767	0.09558
125	1.71292	0.19042	0.11324
150	1.99859	0.22218	0.13007
175	2.27699	0.25313	0.14624
200	2.54931	0.2834	0.16186
225	2.81642	0.3131	0.17702
300	3.59249	0.39937	0.22027
325	3.84418	0.42736	0.23409
350	4.09291	0.45501	0.24765

Silver	
	US EPA
Hardness (CaCO$_3$)	Acute
100	0.00406
125	0.00596
150	0.00815
175	0.01063
200	0.01337
225	0.01637
300	0.02686
325	0.03082
350	0.03501

CWQG and US EPA Gold Book Guidelines for Metals (all values in mg/L)

Zinc		
	US EPA	
Hardness ($CaCO_3$)	**Acute**	**Chronic**
100	**0.11702**	**0.10599**
125	**0.14138**	**0.12805**
150	**0.16499**	**0.14944**
175	**0.18802**	**0.17029**
200	**0.21054**	**0.19069**
225	**0.23263**	**0.21071**
300	**0.29685**	**0.26887**
325	**0.31768**	**0.28773**
350	**0.33826**	**0.30638**

US EPA acute and chronic and CWQG (chronic) guideline values for ammonia