COMPILED BY EPA MIXING ZONE DOCUMENTS
Compilation of EPA Mixing Zone Documents
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# Table of Contents

Purpose............................................................................................................................................ 1

Organization of Information ........................................................................................................... 1

Mixing Zone Definition .................................................................................................................. 1

Types of Mixing Zones Covered ........................................................................................................ 1
  Allocated impact zone................................................................................................................ 1
  Legal mixing zone ..................................................................................................................... 2
  Toxic dilution zone .................................................................................................................... 2
  Zone of initial dilution ............................................................................................................... 2

Types of Pollutants Addressed ........................................................................................................... 2
  Toxic pollutants ......................................................................................................................... 2
  Conventional pollutants ............................................................................................................. 2
  Nonconventional pollutants ....................................................................................................... 2

Types of Concentrations Discussed ................................................................................................ 2
  CMC (criterion maximum concentration) ................................................................................ 2
  CCC (criterion continuous concentration) ................................................................................ 2
  RAC (reference ambient concentration) ................................................................................... 3


Technical and Policy Guidance Documents ...................................................................................... 6
  Allocated Impact Zones for Areas of Non-Compliance (1995) ................................................ 7

Modeling Documents ......................................................................................................................... 9
Purpose

The purpose of this Compilation is two-fold: (1) to provide a source of information for states, authorized tribes, and territories to use when developing and refining their mixing zone policies and (2) to assist NPDES permit writers when implementing mixing zones.

This Compilation presents a number of regulatory, guidance, and policy documents available from EPA on mixing zones. It also provides information and links to state and EPA regional information on this subject.

Organization of Information

The Compilation is organized as follows:

- Basic information
- Technical and policy guidance documents (6 documents)
- Modeling documents (7 documents)
- Great Lakes Rule (1 document)
- Appendices
  - Appendix A: EPA regional documents (3 documents)
  - Appendix B: Reference list of state documents (16 documents)
  - Appendix C: Reference list of other EPA and Federal documents (6 documents)
- Resources

A brief overview is included with each document except those in Appendices B and C.

The Compilation is available electronically at [http://www.epa.gov/waterscience/standards/mixingzone](http://www.epa.gov/waterscience/standards/mixingzone).

Mixing Zone Definition

According to EPA’s *Technical Support Document for Water Quality-based Toxics Control* (TSD) (USEPA, 1991), “a mixing zone is an area where an effluent discharge undergoes initial dilution and is extended to cover the secondary mixing in the ambient waterbody. A mixing zone is an allocated impact zone where water quality criteria can be exceeded as long as acutely toxic conditions are prevented.” (Water quality criteria must be met at the edge of a mixing zone.)

Types of Mixing Zones Covered

*Allocated impact zone (AIZ)*: According to *Allocated Impact Zones for Areas of Non-Compliance* (USEPA, 1995), an allocated impact zone is the same as a mixing zone. The term is also used in *Water Quality Standards Regulation; Proposed Rule* (USEPA, 1998).
Legal mixing zone (LMZ): Refers to a mixing zone in a regulatory sense (e.g., the dimensions of the zone as the state has defined them) as opposed to the mixing zone that naturally occurs in a stream. This term is used in Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (USEPA, 1992) and CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges (USEPA, 1991).

Toxic dilution zone (TDZ): According to Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (USEPA, 1992), the toxic dilution zone, which is a short distance from the outfall or in the pipe itself, is an additional subregion within the usual mixing zone. The TDZ is usually more restrictive than the legal mixing zone for conventional and nonconventional pollutants. This term is also used in CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges (USEPA, 1991).

Zone of initial dilution (ZID): According to Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (USEPA, 1992), the zone of initial dilution is a regularly shaped area (e.g., circular or rectangular) surrounding the discharge structure (e.g., submerged pipe or diffuser line) that encompasses the regions of high (exceeding standards) pollutant concentrations under design conditions. This term is also used in Initial Mixing Characteristics of Municipal Ocean Discharges: Volume I—Procedures and Applications (USEPA, 1985).

Types of Pollutants Addressed

Toxic pollutants: sometimes referred to as “priority pollutants.” EPA identified 126 pollutants from the 65 families of pollutants specified in Section 307(a) of the Clean Water Act. These pollutants are listed at 40 CFR Part 423, Appendix A.

Conventional pollutants: the five pollutants as defined by Section 304(a)(4) of the Clean Water Act and listed at 40 CFR 401.16. Those are biochemical oxygen demand (BOD), total suspended solids (nonfilterable) (TSS), pH, fecal coliform, and oil and grease.

Nonconventional pollutants: any pollutant not already defined as a toxic or conventional pollutant.

Types of Concentrations Discussed

CMC (criterion maximum concentration): the EPA national water quality criteria recommendation for the highest instream concentration of a toxicant or an effluent to which organisms can be exposed for a brief period of time without causing an acute effect (USEPA, 1991). The term applies to all pollutant types.

CCC (criterion continuous concentration): the EPA national water quality criteria recommendation for the highest instream concentration of a toxicant or an effluent to which
organisms can be exposed indefinitely without causing unacceptable effect (USEPA, 1991). The term applies to all pollutant types.

*RAC (reference ambient concentration):* the concentration of a chemical in water which will not cause adverse impacts to human health; RAC is expressed in units of mg/L (USEPA, 1991).

**Code of Federal Regulations (CFR) Language**

*Section 131.13 general policies.* States may, at their discretion, include in their state standards, policies generally affecting their application and implementation, such as mixing zones, low flows and variances. Such policies are subject to EPA review and approval.
### Comparison of Mixing Zone Documents from EPA Headquarters by Topic

<table>
<thead>
<tr>
<th>Technical and Policy Guidance Documents</th>
<th>Technical guidance</th>
<th>Policy guidance</th>
<th>Recommendations states whether mixing zones are allowed</th>
<th>Effluent characterization—WET</th>
<th>Effluent characterization—specific pollutants</th>
<th>Effluent characterization—bioconcentratable pollutants</th>
<th>Application of criteria in mixing zones</th>
<th>Size and/or area considerations</th>
<th>Lethality to passing organisms</th>
<th>Determining WLAs</th>
<th>Special situations: lake, marine, estuarine</th>
<th>Cautions about mixing zones in certain situations (e.g., near fish harvesting)</th>
<th>Mixing zone analyses (e.g., models)</th>
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<tbody>
<tr>
<td>Technical Support Document for Water Quality-based Toxics Control (USEPA, 1991)</td>
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<td>U.S. EPA NPDES Permit Writer's Manual (USEPA, 1996)</td>
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<td>User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters (USEPA, 1997)</td>
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<td>Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1) (USEPA, 1990)</td>
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- The document describes in detail the associated topic; © The document provides very little detail concerning the associated topic.
### Technical and Policy Guidance Documents

<table>
<thead>
<tr>
<th>Topic</th>
<th>Reference</th>
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<tr>
<td>Memorandum: EPA Guidance on Application of State Mixing Zone Policies</td>
<td>(USEPA, 1996)</td>
</tr>
<tr>
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<td>(USEPA, 1995)</td>
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</tbody>
</table>

### Modeling Documents

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<thead>
<tr>
<th>Topic</th>
<th>Reference</th>
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**Technical and Policy Guidance Documents**


States and EPA Regions can use this document’s “standards to permits” approach to guide water quality protection from development of water quality standards through development of compliance monitoring. The standards to permits approach incorporates both human health and aquatic toxicity issues and uses an integrated approach to water quality-based toxics control. This includes whole effluent and chemical-specific approaches and the use of biological assessment to control toxic pollutants. The concept of mixing zones is introduced in Chapter 2 (Water Quality Criteria and Standards) of the TSD. More detailed guidance is provided in Chapter 3 (Effluent Characterization) and Chapter 4 (Exposure and Wasteload Allocation).

The TSD recommends that mixing zones be designed to avoid lethality to aquatic organisms and to ensure that the designated use of the waterbody as a whole is protected. The TSD also recommends that states have a definitive statement in their standards on whether or not mixing zones are allowed and describe the procedures for defining mixing zones consistent with CWA goals.


The second edition of the *Water Quality Standards Handbook* (the Handbook) is a compilation of EPA’s guidance on the water quality standards program and provides direction for states in reviewing, revising, and implementing water quality standards. This edition incorporates subsequent guidance issued since the 1983 handbook. The Handbook is subject to future revisions as the water quality standards program moves forward to reflect the needs and experiences of EPA and the states.

The handbook’s overview of the water quality standards program provides a brief discussion of mixing zones, including:

- How states have the discretion to use mixing zones in their water quality standards, subject to EPA approval.
- How state water quality standards describe methods for determining location, size, shape, and other factors of mixing zones.
How states should give careful consideration to the appropriateness of a mixing zone depending on the pollutants in the discharge (e.g., bioaccumulative, persistent).


EPA’s Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (the Guidance) is designed for EPA permit writers when EPA administers the National Discharge Elimination System (NPDES) for a state. It discusses the circumstances under which the EPA permit writer may include mixing zones in NPDES permits. Specifically, the Guidance presents policy guidelines for EPA permit writers for including mixing zones in EPA-issued permits for a state. The Guidance includes a summary of EPA’s water quality standards (WQS) Regulations, which allow states to adopt provisions authorizing mixing zones in their water quality standards.

State WQS regulations addressing mixing zones generally fall into one of two categories. Some states have regulations that generically authorize mixing zones without specifying who may exercise that authority. Other states have regulations that specifically confer discretionary authority to allow mixing zones only on the state agency. The guidance details when it is appropriate to interpret the state law to authorize EPA to grant a mixing zone.


Allocated Impact Zones for Areas of Non-Compliance (the AIZ document) presents an impact allocation procedure. This procedure is an attempt to assess cumulative impacts and addresses the potential limitations of state water quality standards mixing zone policies. It organizes and manages discharges by including all point source discharges within the decision making process. Specifically, this procedure can supplement mixing zone policies that might be limited to the cross-sectional or surface area of streams and lakes or a uniform linear distance limitation in mixing zone size determinations. For example, prior to 1995, some state guidance did not consider multiple source impacts, sensitivity of aquatic resources, and socioeconomic factors. In contrast, the impact
allocation procedure addresses many of the socioeconomic and ecological factors that can be considered in waste management decisions.

The procedure described in the AIZ document can be used to determine the environmentally acceptable size of mixing zones. It defines allocated impacted zones (AIZs) and provides a detailed discussion of the AIZ procedure. When using this procedure to perform analyses of mixing zones, the results are carefully evaluated for reasonableness using prior experience. In addition, the data requirements and socioeconomic decisions required to complete all levels of the AIZ procedure are extensive, and in most cases, not practically achievable. However, several of the initial steps provide a reasonable approach to help state water quality regulators meet designated use goals for a waterbody. A detailed discussion of the historical development of mixing zone guidance is presented in Appendix A of the document. It also includes several example allocation procedures.


Book III is divided into four parts. Part 1 provides technical information and policy guidance for preparing estuarine waste load allocations. Part 2 provides a guide to monitoring and model calibration and testing, and a case study tutorial on simulation of waste load allocation problems in simplified estuarine systems. Part 3, summarized here, describes the initial mixing of wastewater in estuarine and coastal environments and mixing zone requirements. Part 3 also details the important physical processes that govern the hydrodynamic mixing of aqueous discharges as well as application of available models to four case study situations. Part 4 summarizes several historical case studies, with critical review by experts.

Chapter 7 of Part 3, the first chapter of this document, describes initial mixing of wastewater in estuarine and coastal waters. It also describes mixing zone definitions and mixing zone recommendations, including special ones for toxic substances. Chapter 8 provides an overview of the important physical processes that govern the hydrodynamic mixing of aqueous discharges. The chapter also reviews the mathematical background and formulations for different mixing zone models. Chapter 9 illustrates the application of jet integral models and of the expert system CORMIX. Four case studies are also presented to demonstrate the capabilities and limitations of individual models.

*U.S. EPA NPDES Permit Writer’s Manual* (the Manual) provides guidance for writing and issuing legally defensible and enforceable National Pollutant Discharge Elimination System (NPDES) permits to dischargers, including technical and legal issues that should be considered in permitting decisions. The document outlines the minimum requirements that all state and regional NPDES permit programs share. The manual offers a variety of information, ranging from basic knowledge about what elements should be required in an NPDES permit to technical considerations related to the establishment of permit limits.

As a policy related to water quality-based effluent limits, mixing zones may be considered during the permitting process. If a mixing zone is being considered, permit writers consider site-specific characteristics of a given discharge in addition to the condition of the receiving water to determine the dilution that will occur from the point source and to determine the impact that a discharge will have on the receiving water.

This manual discusses a number of factors that should be considered to assess the fate and transport of pollutants and to determine how the mixing zone will affect water quality. It also discusses models for assessing mixing zones.

**Modeling Documents**


*Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes)* describes a mixing zone modeling system. Visual Plumes (VP) is a Microsoft Windows-based suite of models that supersedes the DOS PLUMES mixing zone modeling system. VP allows users to simulate single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. Among its additional features are:

- Graphics
- Time-series input files
- User specified units
- A conservative tidal background-pollutant buildup capability
- A sensitivity analysis capability
- A multistressor pathogen decay model that predicts coliform mortality using temperature, salinity, solar insolation (the amount of radiation hitting a surface or object), and water column light absorption

VP includes several models intended to encourage the continued improvement of plume models. VP also allows modelers to access the superseded DOS PLUMES if the user
requires consistency in modeling applications. A time-series file-linking capability provides a way to simulate outfall performance over long periods of time. Most effluent and ambient variables can be input from files that store data that vary over time. This is the heart of the pollutant buildup capability, designed for one-dimensional tidal rivers or estuaries to estimate pollution from the source in question. The time-series file linking capability is served by summary graphics (i.e., graphics that focus on overall performance indicators, like mixing zone dilutions or concentrations).


The document describes two initial dilution plume models (RSB and UM) and a model interface and manager (PLUMES) for preparing common model input and running the models. Two farfield algorithms are automatically initiated beyond the zone of initial dilution. In addition, PLUMES incorporates the flow classification scheme of the Cornell Mixing Zone Expert System (CORMIX), with recommendations for model usage, thereby providing a linkage between two existing EPA systems. The PLUMES models are intended for use with plumes discharged to marine and fresh water. Both buoyant and dense plumes, as well as single source and multiple diffuser outfall configurations may be modeled. The PLUMES software accompanies the document. The use of the model interface is explained in detail, including a user’s guide and a detailed tutorial. Other examples of RSB and UM usage are also provided. This document contains information that is not duplicated in the Visual Plumes version, notably plume modeling theory. Also, the software can be used to calculate similarity parameters.


*CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges* describes the Cornell Mixing Zone Expert System (CORMIX). CORMIX is a series of software systems that allows users to analyze, predict, and design aqueous toxic or conventional pollutant discharges into watercourses. It emphasizes the geometry and dilution characteristic of the initial mixing zone. CORMIX2 emphasizes rapid initial mixing and assumes no physical, chemical, or biological decay processes.

CORMIX2 models submerged multiport discharges into flowing water environments such as rivers, lakes, estuaries, and coastal waters. It includes effects of ambient stratification, dynamic attachment of the plume to the bottom of the receiving water, and the limiting case of stagnant conditions. This report documents the development and implementation of an engineering tool for analyzing submerged multiport diffuser discharges into waterbodies with variable and complex conditions.
CORMIX2 requires relevant data for the ambient and discharge situations, computes the physical parameters, and classifies the given discharge into one of many possible hydrodynamic configurations. CORMIX2 then (1) simulates the corresponding hydrodynamic simulation for the flow, (2) interprets the results of the simulation relative to applicable requirements of a mixing zone, including toxic discharge criteria, and (3) suggests possible design alternatives and improvements concerning the mixing characteristics.

The results of CORMIX’s hydrodynamic simulations have been validated and generally agree with available field and laboratory data. In particular, CORMIX2 correctly predicts highly complex discharge situations involving boundary interactions, internal layer formation, buoyant intrusions, and large-scale induced currents in shallow environments, all features that are beyond the predictive capabilities of other currently available initial mixing models for multiport diffusers.


The user’s manual gives a comprehensive description of the CORMIX system and provides guidance for assembly and preparation of required input data for the three subsystems (CORMIX1, CORMIX2, and CORMIX3). It also delineates ranges of acceptability, provides guidance for interpretation and graphical display of system output, and illustrates practical system application through several case studies.

The manual is designed for personnel in environmental management positions who want an overview of CORMIX systems capabilities and technical staff needing assistance in applications. Chapter II provides a summary of the physical processes of effluent mixing and an overview of the regulatory background and practice on mixing zone applications. Chapter III explains the general features of the CORMIX system, including summaries of (a) predictive capabilities and limitations, (b) overall system structure and method of processing information, (c) user interaction, and (d) individual computational elements. Detailed guidance on preparing and entering input data, as required by the three CORMIX subsystems, is provided in Chapter IV. Chapter V describes system output and contains descriptive, quantitative, and graphical information on the predicted effluent flow. Chapter VI describes the background and input and output features of both the CORJET jet integral model and the far-field plume locator program FFLOCATR. Finally, Chapter VII provides information on system availability and user support, as well as possible future developments and enhancements.

This document is a technical report for CORMIX1. It describes the development and implementation of an engineering tool (CORMIX1) for analysis of submerged single port discharges into a stratified or uniform density ambient environment with or without cross flow. Chapters of the document provide detailed information about hydrodynamic elements of mixing processes, hydrodynamic flow classification, an outline of the computer programs in CORMIX1, flow protocols and simulation modules for CORMIX1, system evaluation and verification, design case studies showing applications of CORMIX1, and conclusions and recommendations. Appendices provide further information such as online user advice for data input, flow classifications, and a case study.


*Compendium of Tools for Watershed Assessment and TMDL Development* (the Compendium of Tools) represents an update to and expansion of previous EPA publication, *Compendium of Watershed-scale Model for TMDL Development* (EPA 841-R-92-002). The revised Compendium of Tools broadens the review of models and techniques to include receiving water models and ecological assessment techniques and models in addition to watershed loading models.

The Compendium of Tools summarizes available techniques and models that assess and predict physical, chemical, and biological conditions in waterbodies, including mixing zones for point source discharges. The compendium provides watershed managers and other users with helpful information for selecting models that are appropriate to their needs and resources. Specifically, this document includes information regarding:

- A wide range of watershed-scale loading models
- Field-scale pollutant loading models
- Receiving water models, including eutrophication/water quality models, toxics models, and hydrodynamic models
- Integrated modeling systems that can be used to link watershed-scale loading with receiving water processes
- Ecological techniques and models that can be used to assess or predict the status of habitat, single species, or biological community
The Compendium of Tools contains short descriptions of near-field models developed for coastal areas, rivers, and streams, including CORMIX, PLUME, PC-VirGIS, GISPLS, WSTT, LWWM, and BASINS.


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Appendix B: State Documents


Appendix C: Other Documents to Consider When Establishing Mixing Zones*

*Note: these documents are often referred to in mixing zone guidance, but they have been updated or superseded by newer guidance documents and rules.


Resources

Models

**Cornell Mixing Zone Expert System (CORMIX)**
The Cornell Mixing Zone Expert System (CORMIX) is a mixing zone model and decision support system for environmental impact assessment of regulatory mixing zones resulting from continuous point source discharges. CORMIX emphasizes the role of boundary interaction to predict steady state mixing behavior and plume geometry.

[http://www.epa.gov/waterscience/models/cormix.html](http://www.epa.gov/waterscience/models/cormix.html) (EPA Office of Water)


**Visual Plumes (VP)**
Visual Plumes (VP) is a windows-based computer application that supersedes the DOS-based version, called simply PLUMES. VP simulates single and merging submerged aquatic plumes in arbitrarily stratified ambient flow and buoyant surface discharges.


Training

**Water Quality Standards Academy**
The “Water Quality Standards Academy” is best known for the “Basic Course,” which is an introductory course designed for those with fewer than six months experience with water quality standards and criteria programs. However, others may benefit from the course, including veterans of the water quality standards program who want a refresher course.

[http://www.epa.gov/ost/standards/academy.html](http://www.epa.gov/ost/standards/academy.html)

**NPDES Permit Writers' Training Course**
The objective of the NPDES Permit Writers' Training Course is to provide the basic regulatory framework and technical considerations that support the development of wastewater discharge permits as required under the National Pollutant Discharge Elimination System (NPDES) Permit Program. The course is designed for new permit writers, highlighting the process of developing, issuing and complying with NPDES permits. The format of the course is a combination of lecture, case examples, and practical exercises that are geared to acquaint participants with the tools and resources available to assist them in writing NPDES permits.

[http://cfpub.epa.gov/npdes/courses.cfm?program_id=0&outreach_id=1&o_type=1](http://cfpub.epa.gov/npdes/courses.cfm?program_id=0&outreach_id=1&o_type=1)
Links to NPDES Permitting Information

Overview of the Water Quality Standards-to-Permits Process
http://cfpub.epa.gov/npdes/wqbasedpermitting/wqoverview.cfm

Water Quality and Technology-Based Permitting
http://cfpub.epa.gov/npdes/generalissues/watertechnology.cfm?program_id=45
Compilation of EPA Mixing Zone Documents

Comparison of All EPA Documents

Full document available at http://www.epa.gov/waterscience/standards/mixingzone

Standards and Health Protection Division
Office of Water
U.S. Environmental Protection Agency
Comparison of Mixing Zone Documents from EPA Headquarters by Topic

<table>
<thead>
<tr>
<th>Technical and Policy Guidance Documents</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (USEPA, 1996)</td>
</tr>
<tr>
<td>Allocated Impact Zones for Areas of Non-Compliance (USEPA, 1995)</td>
</tr>
</tbody>
</table>

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<thead>
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</tr>
</thead>
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<tr>
<td>Dilution Models for Effluent Discharges, 3rd ed. (USEPA, 1994)</td>
</tr>
<tr>
<td>Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997)</td>
</tr>
<tr>
<td>Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications (USEPA, 1985)</td>
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Compilation of EPA Mixing Zone Documents

Subject Comparison Table

Full document available at http://www.epa.gov/waterscience/standards/mixingzone

Standards and Health Protection Division
Office of Water
U.S. Environmental Protection Agency
Compilation of EPA Mixing Zone Documents

Overviews Only

Full document available at
http://www.epa.gov/waterscience/standards/mixingzone

Standards and Health Protection Division
Office of Water
U.S. Environmental Protection Agency
Technical and Policy Guidance Documents


States and EPA Regions can use this document’s “standards to permits” approach to guide water quality protection from development of water quality standards through development of compliance monitoring. The standards to permits approach incorporates both human health and aquatic toxicity issues and uses an integrated approach to water quality-based toxics control. This includes whole effluent and chemical-specific approaches and the use of biological assessment to control toxic pollutants. The concept of mixing zones is introduced in Chapter 2 (Water Quality Criteria and Standards) of the TSD. More detailed guidance is provided in Chapter 3 (Effluent Characterization) and Chapter 4 (Exposure and Wasteload Allocation).

The TSD recommends that mixing zones be designed to avoid lethality to aquatic organisms and to ensure that the designated use of the waterbody as a whole is protected. The TSD also recommends that states have a definitive statement in their standards on whether or not mixing zones are allowed and describe the procedures for defining mixing zones consistent with CWA goals.


The second edition of the Water Quality Standards Handbook (the Handbook) is a compilation of EPA’s guidance on the water quality standards program and provides direction for states in reviewing, revising, and implementing water quality standards. This edition incorporates subsequent guidance issued since the 1983 handbook. The Handbook is subject to future revisions as the water quality standards program moves forward to reflect the needs and experiences of EPA and the states.

The handbook’s overview of the water quality standards program provides a brief discussion of mixing zones, including:

- How states have the discretion to use mixing zones in their water quality standards, subject to EPA approval.
- How state water quality standards describe methods for determining location, size, shape, and other factors of mixing zones.
- How states should give careful consideration to the appropriateness of a mixing zone depending on the pollutants in the discharge (e.g., bioaccumulative, persistent).


EPA’s Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (the Guidance) is designed for EPA permit writers when EPA administers the National Discharge Elimination System (NPDES) for a state. It discusses the circumstances under which the EPA permit writer may include mixing zones in NPDES permits. Specifically, the Guidance presents policy guidelines for EPA permit writers for including mixing zones in EPA-issued permits for a state. The Guidance includes a summary of EPA’s water quality standards (WQS) Regulations, which allow states to adopt provisions authorizing mixing zones in their water quality standards.

State WQS regulations addressing mixing zones generally fall into one of two categories. Some states have regulations that generically authorize mixing zones without specifying who may exercise that authority. Other states have regulations that specifically confer discretionary authority to allow mixing zones only on the state agency. The guidance details when it is appropriate to interpret the state law to authorize EPA to grant a mixing zone.


Allocated Impact Zones for Areas of Non-Compliance (the AIZ document) presents an impact allocation procedure. This procedure is an attempt to assess cumulative impacts and addresses the potential limitations of state water quality standards mixing zone policies. It organizes and manages discharges by including all point source discharges within the decision making process. Specifically, this procedure can supplement mixing zone policies that might be limited to the cross-sectional or surface area of streams and lakes or a uniform linear distance limitation in mixing zone size determinations. For
example, prior to 1995, some state guidance did not consider multiple source impacts, sensitivity of aquatic resources, and socioeconomic factors. In contrast, the impact allocation procedure addresses many of the socioeconomic and ecological factors that can be considered in waste management decisions.

The procedure described in the AIZ document can be used to determine the environmentally acceptable size of mixing zones. It defines allocated impacted zones (AIZs) and provides a detailed discussion of the AIZ procedure. When using this procedure to perform analyses of mixing zones, the results are carefully evaluated for reasonableness using prior experience. In addition, the data requirements and socioeconomic decisions required to complete all levels of the AIZ procedure are extensive, and in most cases, not practically achievable. However, several of the initial steps provide a reasonable approach to help state water quality regulators meet designated use goals for a waterbody. A detailed discussion of the historical development of mixing zone guidance is presented in Appendix A of the document. It also includes several example allocation procedures.


Book III is divided into four parts. Part 1 provides technical information and policy guidance for preparing estuarine waste load allocations. Part 2 provides a guide to monitoring and model calibration and testing, and a case study tutorial on simulation of waste load allocation problems in simplified estuarine systems. Part 3, summarized here, describes the initial mixing of wastewater in estuarine and coastal environments and mixing zone requirements. Part 3 also details the important physical processes that govern the hydrodynamic mixing of aqueous discharges as well as application of available models to four case study situations. Part 4 summarizes several historical case studies, with critical review by experts.

Chapter 7 of Part 3, the first chapter of this document, describes initial mixing of wastewater in estuarine and coastal waters. It also describes mixing zone definitions and mixing zone recommendations, including special ones for toxic substances. Chapter 8 provides an overview of the important physical processes that govern the hydrodynamic mixing of aqueous discharges. The chapter also reviews the mathematical background and formulations for different mixing zone models. Chapter 9 illustrates the application...
of jet integral models and of the expert system CORMIX. Four case studies are also presented to demonstrate the capabilities and limitations of individual models.


*U.S. EPA NPDES Permit Writer’s Manual* (the Manual) provides guidance for writing and issuing legally defensible and enforceable National Pollutant Discharge Elimination System (NPDES) permits to dischargers, including technical and legal issues that should be considered in permitting decisions. The document outlines the minimum requirements that all state and regional NPDES permit programs share. The manual offers a variety of information, ranging from basic knowledge about what elements should be required in an NPDES permit to technical considerations related to the establishment of permit limits.

As a policy related to water quality-based effluent limits, mixing zones may be considered during the permitting process. If a mixing zone is being considered, permit writers consider site-specific characteristics of a given discharge in addition to the condition of the receiving water to determine the dilution that will occur from the point source and to determine the impact that a discharge will have on the receiving water.

This manual discusses a number of factors that should be considered to assess the fate and transport of pollutants and to determine how the mixing zone will affect water quality. It also discusses models for assessing mixing zones.

**Modeling Documents**


*Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes)* describes a mixing zone modeling system. Visual Plumes (VP) is a Microsoft Windows-based suite of models that supersedes the DOS PLUMES mixing zone modeling system. VP allows users to simulate single and merging submerged plumes in arbitrarily stratified ambient flow and buoyant surface discharges. Among its additional features are:

- Graphics
- Time-series input files
- User specified units
- A conservative tidal background-pollutant buildup capability
- A sensitivity analysis capability
- A multistressor pathogen decay model that predicts coliform mortality using temperature, salinity, solar insolation (the amount of radiation hitting a surface or object), and water column light absorption
VP includes several models intended to encourage the continued improvement of plume models. VP also allows modelers to access the superseded DOS PLUMES if the user requires consistency in modeling applications. A time-series file-linking capability provides a way to simulate outfall performance over long periods of time. Most effluent and ambient variables can be input from files that store data that vary over time. This is the heart of the pollutant buildup capability, designed for one-dimensional tidal rivers or estuaries to estimate pollution from the source in question. The time-series file linking capability is served by summary graphics (i.e., graphics that focus on overall performance indicators, like mixing zone dilutions or concentrations).


The document describes two initial dilution plume models (RSB and UM) and a model interface and manager (PLUMES) for preparing common model input and running the models. Two farfield algorithms are automatically initiated beyond the zone of initial dilution. In addition, PLUMES incorporates the flow classification scheme of the Cornell Mixing Zone Expert System (CORMIX), with recommendations for model usage, thereby providing a linkage between two existing EPA systems. The PLUMES models are intended for use with plumes discharged to marine and fresh water. Both buoyant and dense plumes, as well as single source and multiple diffuser outfall configurations may be modeled. The PLUMES software accompanies the document. The use of the model interface is explained in detail, including a user’s guide and a detailed tutorial. Other examples of RSB and UM usage are also provided. This document contains information that is not duplicated in the Visual Plumes version, notably plume modeling theory. Also, the software can be used to calculate similarity parameters.


*CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges* describes the Cornell Mixing Zone Expert System (CORMIX). CORMIX is a series of software systems that allows users to analyze, predict, and design aqueous toxic or conventional pollutant discharges into watercourses. It emphasizes the geometry and dilution characteristic of the initial mixing zone. CORMIX2 emphasizes rapid initial mixing and assumes no physical, chemical, or biological decay processes.

CORMIX2 models submerged multiport discharges into flowing water environments such as rivers, lakes, estuaries, and coastal waters. It includes effects of ambient stratification, dynamic attachment of the plume to the bottom of the receiving water, and the limiting case of stagnant conditions. This report documents the development and
implementation of an engineering tool for analyzing submerged multiport diffuser
discharges into waterbodies with variable and complex conditions.

CORMIX2 requires relevant data for the ambient and discharge situations, computes the
physical parameters, and classifies the given discharge into one of many possible
hydrodynamic configurations. CORMIX2 then (1) simulates the corresponding
hydrodynamic simulation for the flow, (2) interprets the results of the simulation relative
to applicable requirements of a mixing zone, including toxic discharge criteria, and
(3) suggests possible design alternatives and improvements concerning the mixing
characteristics.

The results of CORMIX’s hydrodynamic simulations have been validated and generally
agree with available field and laboratory data. In particular, CORMIX2 correctly predicts
highly complex discharge situations involving boundary interactions, internal layer
formation, buoyant intrusions, and large-scale induced currents in shallow environments,
all features that are beyond the predictive capabilities of other currently available initial
mixing models for multiport diffusers.

and Decision Support System for Pollutant Discharges into Surface Waters*. EPA
823/B-97-006. U.S. Environmental Protection Agency, Office of Science and
Technology, Washington, DC. (Originally printed in 1996.)

The user’s manual gives a comprehensive description of the CORMIX system and
provides guidance for assembly and preparation of required input data for the three
subsystems (CORMIX1, CORMIX2, and CORMIX3). It also delineates ranges of
acceptability, provides guidance for interpretation and graphical display of system output,
and illustrates practical system application through several case studies.

The manual is designed for personnel in environmental management positions who want
an overview of CORMIX systems capabilities and technical staff needing assistance in
applications. Chapter II provides a summary of the physical processes of effluent mixing
and an overview of the regulatory background and practice on mixing zone applications.
Chapter III explains the general features of the CORMIX system, including summaries of
(a) predictive capabilities and limitations, (b) overall system structure and method of
processing information, (c) user interaction, and (d) individual computational elements.
Detailed guidance on preparing and entering input data, as required by the three
CORMIX subsystems, is provided in Chapter IV. Chapter V describes system output and
contains descriptive, quantitative, and graphical information on the predicted effluent
flow. Chapter VI describes the background and input and output features of both the
CORJET jet integral model and the far-field plume locator program FFLOCATR.
Finally, Chapter VII provides information on system availability and user support, as well
as possible future developments and enhancements.

This document is a technical report for CORMIX1. It describes the development and implementation of an engineering tool (CORMIX1) for analysis of submerged single port discharges into a stratified or uniform density ambient environment with or without cross flow. Chapters of the document provide detailed information about hydrodynamic elements of mixing processes, hydrodynamic flow classification, an outline of the computer programs in CORMIX1, flow protocols and simulation modules for CORMIX1, system evaluation and verification, design case studies showing applications of CORMIX1, and conclusions and recommendations. Appendices provide further information such as online user advice for data input, flow classifications, and a case study.


*Compendium of Tools for Watershed Assessment and TMDL Development* (the Compendium of Tools) represents an update to and expansion of a previous EPA publication, *Compendium of Watershed-scale Model for TMDL Development* (EPA 841-R-92-002). The revised Compendium of Tools broadens the review of models and techniques to include receiving water models and ecological assessment techniques and models in addition to watershed loading models.

The Compendium of Tools summarizes available techniques and models that assess and predict physical, chemical, and biological conditions in waterbodies, including mixing zones for point source discharges. The compendium provides watershed managers and other users with helpful information for selecting models that are appropriate to their needs and resources. Specifically, this document includes information regarding:

- A wide range of watershed-scale loading models
- Field-scale pollutant loading models
- Receiving water models, including eutrophication/water quality models, toxics models, and hydrodynamic models
- Integrated modeling systems that can be used to link watershed-scale loading with receiving water processes
- Ecological techniques and models that can be used to assess or predict the status of habitat, single species, or biological community
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## Major Topics in EPA Headquarters Mixing Zone Documents

<table>
<thead>
<tr>
<th>Technical and Policy Guidance Documents</th>
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<th>Modeling Documents</th>
<th>Modeling Documents</th>
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<th>Modeling Documents</th>
<th>Great Lakes Rule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application of criteria in mixing zones</td>
<td><strong>●</strong></td>
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<tr>
<td>Cautions about mixing zones in certain situations (e.g., near fish harvesting)</td>
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<td>Determining WLAs</td>
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<tr>
<td>Effluent characterization—bioconcentratable pollutants</td>
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<td>Effluent characterization—specific pollutants</td>
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<td>Effluent characterization—WET</td>
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<tr>
<td>Lethality to passing organisms</td>
<td><strong>●</strong></td>
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<td>Mixing zone analyses (e.g., models)</td>
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<tr>
<td>Recommends states specify whether mixing zones are allowed</td>
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<td>Size and/or area considerations</td>
<td><strong>●</strong></td>
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<tr>
<td>Special situations: lake, marine, estuarine</td>
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