COMPILATION OF EPA MIXING ZONE DOCUMENTS

United States Environmental Protection Agency
Office of Water
Washington, DC 20460
(4305T)

EPA 823-R-06-003
July 2006

Compilation of EPA Mixing Zone Documents

Please Note

The discussions in the documents collected in this Compilation are intended solely as guidance. The statutory provisions and EPA regulations described in this Compilation contain legally binding requirements. This document (or the documents referenced herein) are not a regulations, nor do they change or substitute for those statutory provisions and regulations. Thus, this document or the documents collected here do not impose legally binding requirements on EPA, states, authorized tribes, territories, or the regulated community. This Compilation does not confer legal rights or impose legal obligations upon any member of the public.

While EPA has made every effort to ensure the accuracy of the discussion in this Compilation, the obligations of the regulated community are determined by statutes, regulations, or other legally binding requirements. In the event of a conflict between the discussion in this Compilation and any statute or regulation, this Compilation would not be controlling.

The general description provided here may not apply to every circumstance. Interested parties are free to raise questions and objections about the substance of this guidance and the appropriateness of its application to a particular situation. EPA and other decision-makers retain the discretion to adopt approaches on a case-by-case basis that differ from those described in this guidance where appropriate.

Mention of trade names or commercial products does not constitute endorsement or recommendation for their use.

This is a living document and may be revised periodically without public notice. EPA welcomes public input on this document at any time.

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

Code of Federal Regulations (CFR) Language 3

Technical and Policy Guidance Documents 6
- Technical Support Document for Water Quality-based Toxics Control (1991). 6
- Water Quality Standards Handbook: Second Edition (1994) 6
- Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (1996) 7
- Allocated Impact Zones for Areas of Non-Compliance (1995) 7
- Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (1992) 8
- U.S. EPA NPDES Permit Writer's Manual (1996) 9

Modeling Documents 9
- Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes) (2003) 9
- Dilution Models for Effluent Discharges, 3rd Edition (1994) 10
- CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges (1991) 10
- User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters (1997) 11
- Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1) (1990) 12
- Compendium of Tools for Watershed Assessment and TMDL Development (1997) 12

Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1 – Procedures and Applications (1985)..... 13

Great Lakes Rule..... 13
Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern (2000)..... 13

Tables

Comparison of Mixing Zone Documents from EPA Headquarters by Topic 4
Major Topics in EPA Headquarters Mixing Zone Documents..... 5

Appendices

Appendix A: EPA Regional Documents..... A-1
Appendix B: State Documents..... B-1
Appendix C: Other Documents to Consider When Establishing Mixing Zones C-1

Other Resources

Resources Resources-1

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.

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 1—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

	Technical guidance	Policy guidance	Recommends states specify whether mixing zones are allowed	Effluent characterization—WET	Effluent characterization—specific pollutants	Effluent characterization—bioconcentratable pollutants	Application of criteria in mixing zones	Size and/or area considerations	Lethality to passing organisms	Determining WLAs	Special situations: lake, marine, estuarine	Cautions about mixing zones in certain situations (e.g., near fish harvesting)	Mixing zone analyses (e.g., models)
Technical and Policy Guidance Documents													
Technical Support Document for Water Quality-based Toxics Control (USEPA, 1991)	●		●	●	●	●	●	●	●	●	●	●	●
Water Quality Standards Handbook: Second Edition (USEPA, 1994)	●		●					●	●				
Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (USEPA, 1996)		●	●										
Allocated Impact Zones for Areas of Non-Compliance (USEPA, 1995)	●							⊙					
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)	●						●	●		●			●
U.S. EPA NPDES Permit Writer's Manual (USEPA, 1996)	●		●										●
Modeling Documents													
Dilution Models for Effluent Discharges, 4th ed. (Visual Plumes) (USEPA, 2003)	●												●
Dilution Models for Effluent Discharges, 3rd ed. (USEPA, 1994)	●												●
CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges (USEPA, 1991)	●	⊙											●
User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters (USEPA, 1997)	●							⊙	●				●
Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1) (USEPA, 1990)	●												●
Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997)	●												●
Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications (USEPA, 1985)	●												●
Great Lakes Rule													
Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern (USEPA, 2000)		●				●							

● The document describes in detail the associated topic; ⊙ The document provides very little detail concerning the associated topic.

Major Topics in EPA Headquarters Mixing Zone Documents

	Technical and Policy Guidance Documents	*Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991)	*Water Quality Standards Handbook: Second Edition* (USEPA, 1994)	*Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits* (USEPA, 1996)	*Allocated Impact Zones for Areas of Non-Compliance* (USEPA, 1995)	*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)	*U.S. EPA NPDES Permit Writer's Manual* (USEPA, 1996)	Modeling Documents	*Dilution Models for Effluent Discharges, 4th ed. (Visual Plumes)*, (USEPA, 2003)	*Dilution Models for Effluent Discharges, 3rd ed. (USEPA, 1994)*	*CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges* (USEPA, 1991)	*User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters* (USEPA, 1997)	*Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges* (CORMIX1) (USEPA, 1990)	*Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997)	*Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications* (USEPA, 1985)	Great Lakes Rule	*Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of concern* (USEPA, 2000)
Application of criteria in mixing zones		●				●											
Cautions about mixing zones in certain situations (e.g., near fish harvesting)		●															
Determining WLAs		●				●											
Effluent characterization— bioconcentratable pollutants		●															●
Effluent characterization—specific pollutants		●															
Effluent characterization—WET		●															
Lethality to passing organisms		●	●									●					
Mixing zone analyses (e.g., models)		●				●	●		●	●	●	●	●	●	●		
Recommends states specify whether mixing zones are allowed		●	●	●			●										
Size and/or area considerations		●	●		⊙	●						⊙					
Special situations: lake, marine, estuarine		●															

● The topic is discussed in detail in the associated document; ⊙ Very little detail about the topic is provided in the associated document

Technical and Policy Guidance Documents

1) USEPA. 1991. *Technical Support Document for Water Quality-based Toxics Control.* EPA 505-290-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/npdes/pubs/owm0264.pdf.

EPA's 1991 *Technical Support Document for Water Quality-based Toxics Control* (TSD) provides guidance to states and EPA Regions for the water quality-based control of toxic pollutants. It includes recommendations for controlling point source discharges of toxic pollutants to waters of the United States.

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.

2) USEPA. 1994. *Water Quality Standards Handbook: Second Edition*. EPA 823-B-94-005a. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/standards/handbook.

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).

The Handbook provides information on the general provisions of 40 CFR Part 131 Subpart A, designated uses, water quality criteria, antidegradation, procedures for review and revision of water quality standards, and water quality-based approaches to pollution control. According to the Handbook, both it and the *Technical Support Document for Water Quality-based Toxics Control* (TSD) (USEPA, 1991) evolved from and supersede the following resources: *Water Quality Criteria 1968* (the "Green Book"), *Water Quality Criteria 1972* (the "Blue Book"), *Quality Criteria for Water 1976* (the "Red Book"), and the first edition of the *Water Quality Standards Handbook* (1983).

3) USEPA. 1996. *Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits*. U.S. Environmental Protection Agency. Memo from Robert Perciasepe to Water Program Directors, dated August 6, 1996. http://www.epa.gov/waterscience/library/wqstandards/mixingguide.pdf.

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.

4) USEPA. 1995. *Allocated Impact Zones for Areas of Non-Compliance*. EPA 823-R-95-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/library/modeling/zones.pdf.

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.

5) USEPA. 1992. *Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations*. EPA 823-R-92-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
http://www.epa.gov/waterscience/library/modeling/wlabook3part3.pdf.

Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (Part 3) is the third of a series of manuals that provide information and guidance for preparing waste load allocations. Book I of the series provides general guidance for performing waste load allocations. Book II provides guidance specifically directed toward streams and rivers, while Book III provides guidance for preparing waste load allocations in estuaries.

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.

6) USEPA. 1996. *U.S. EPA NPDES Permit Writer's Manual*. EPA 833-B-96-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/npdes/pubs/owm0243.pdf.

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

7) USEPA. 2003. *Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes)*. EPA/600/R-03/025. U.S. Environmental Protection Agency, Ecosystems Research Division, Athens, Georgia. http://www.epa.gov/ceampubl/swater/vplume/VP-Manual.pdf.

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).

8) USEPA. 1994. *Dilution Models for Effluent Discharges, 3rd Edition*. EPA /600/R-94/086. U.S. Environmental Protection Agency, Pacific Ecosystems Branch, ERL-N, Newport, Oregon.
http://www.epa.gov/waterscience/standards/mixingzone/files/RSB_UM_PLUMES.pdf.

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.

9) USEPA. 1991. *CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges*. EPA 600-3-91-073. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.
http://www.epa.gov/waterscience/standards/mixingzone/files/1991_CORMIX2.pdf.

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.

10) USEPA. 1997. *User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model 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.) http://www.epa.gov/waterscience/models/cormix.html.

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.

11) USEPA. 1990. *Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1)*. Technical Report EPA/600/3-90/012. U.S. EPA Environmental Research Laboratory, Athens, GA. http://www.epa.gov/waterscience/standards/mixingzone/files/1990_CORMIX1.pdf.

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.

12) USEPA. 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. EPA 841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/standards/mixingzone/files/1997_Tool_Compendium.pdf.

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

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.

13) USEPA. 1985. *Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications*. EPA 600385073a. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/waterscience/standards/mixingzone/files/1985_Municipal_Ocean_Discharges.pdf.

> *Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Application* (the Ocean Discharges document) describes the behavior of plumes generated when municipal wastewater is discharged into the open ocean). Volume I contains analytical solutions and descriptions of five mathematical models that address a variety of discharge, diffuser, and receiving water characteristics. Model output includes rise height and initial dilution. The Ocean Discharges document provides guidance for the range of values within which analytical solutions provide acceptable estimates. The format of model input data is the same for all five computer programs.

Great Lakes Rule

14) USEPA. 2000. Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern. U.S. Environmental Protection Agency. 40 CFR Part 132 *Federal Register*, November 13, 2000, 65:67638. http://www.epa.gov/fedrgstr/EPA-WATER/2000/November/Day-13/w28709.htm.

> *Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern* (the Final Rule) was written to revise EPA's 1995 *Final Water Quality Guidance for the Great Lakes System.* The original 1995 rule was challenged in court and, although the court upheld most of the provisions contained in the 1995 rule, it remanded the provisions that would have eliminated mixing zones for bioaccumulative chemicals of concern (BCCs). The court held that EPA failed to address whether the measure was cost-justified and remanded the issue to EPA.
>
> In response, EPA reexamined the factual record and cost analyses and published a proposal to amend the 1995 rule to reinstate the provision to prohibit mixing zones for BCCs. This provision (Procedure 3C) is described in more detail in Appendix F of the rule. After reviewing and analyzing information in the rule-making record and public comments on the *Proposal to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern* (published in the *Federal Register* on October 4, 1999), EPA finalized the rule in 2000.

Appendix A: EPA Regional Documents

Note: No guidance has been developed specifically by Regions 1, 2, 3, 5, 6, 7, 9, and 10.

USEPA. 1995. *EPA Region VIII Mixing Zones and Dilution Policy*. U.S. Environmental Protection Agency, Region 8, Water Management Division, Denver, CO. http://www.epa.gov/waterscience/standards/mixingzone/files/1995_Reg_8_MZ_and_Dilution_Policy.pdf.

> The objective of *Region VIII Mixing Zones and Dilution Policy* is to help states and Indian tribes upgrade methods for deriving water quality-based permit limits, improve the technical defensibility of National Pollutant Discharge Elimination System (NPDES) permits, and reduce risks associated with mixing zone and dilution practices. The basis for the policy was the desire of the region to clarify the approaches for using mixing zones in NPDES permits. Prior to the policy, some applications of mixing zones presumptively provided the entire stream flow for dilution, which often resulted in effluent plumes (with elevated pollutant concentrations) extending far downstream of the discharge. The clarifications sought to prevent applications of mixing zones that did not adequately control effluent plume size or quality, possibly posing considerable risk to sensitive downstream uses.

USEPA. 1993. *EPA Region VIII Interim Guidance: Water Quality Standards for Indian Tribes*. U.S. Environmental Protection Agency, Region 8, Water Management Division, Denver, CO. http://epa.gov/region8/water/wqs/GUIDANCE.pdf.

> *EPA Region VIII Interim Guidance: Water Quality Standards for Indian Tribes* is intended to assist the Indian tribes in EPA Region 8 to qualify to administer water quality standards programs and to develop water quality standards pursuant to Clean Water Act (CWA) sections 518 and 303(c). The guidance includes recommendations on mixing zone policy development.

USEPA. 1980. *EPA Region IV Guidance on Mixing Zones*. U.S. Environmental Protection Agency, Region 4, Atlanta, GA. http://www.epa.gov/waterscience/standards/mixingzone/files/1980_Reg_4_MZ_Guidance.pdf.

> *EPA Region IV Guidance on Mixing Zones* provides a basis for Region 4 review and approval of state use of mixing zones in the development of effluent limitations. The guidance provides detailed descriptions of (1) appropriateness of assigning a mixing zone to a discharger, (2) the level of water quality that should be maintained in a mixing zone and surrounding waters, and (3) the factors governing the size and shape of a mixing zone.

Appendix B: State Documents

California Environmental Protection Agency. 2005. *Policy for Implementation of Toxics Standards for Inland Surface Waters, Enclosed Bays, and Estuaries of California*. California Environmental Protection Agency, State Water Resources Control Board. http://www.waterboards.ca.gov/iswp/docs/final.pdf. Accessed July 2006.

Colorado Department of Public Health and Environment. 2002. *Colorado Mixing Zone Implementation Guidance*. Colorado Department of Public Health and Environment, Water Quality Control Division. http://www.cdphe.state.co.us/op/wqcc/Guidance/comixzoneimplguid.pdf. Accessed July 2006.

Massachusetts Department of Environmental Protection. 1993. *Massachusetts Surface Water Quality Standards Implementation Policy for Mixing Zones*. Massachusetts Department of Environmental Protection, Boston, MA. http://www.epa.gov/ost/wqs/ma/ma_1_mswqs.pdf. Accessed July 2006.

New York State Department of Environmental Conservation. 1996. *Total Maximum Daily Loads and Water Quality Based Effluent Limits*. Memo dated July 8, 1996. Reissued February 26, 1998. http://www.dec.state.ny.us/website/dow/togs/togs131.pdf. Accessed July 2006.

North Carolina Department of the Environment and Natural Resources. 1999. *Mixing Zones in North Carolina*. North Carolina Department of the Environment and Natural Resources, Division of Water Quality. Available online: http://h2o.enr.state.nc.us/NPDES/documents/mixing.pdf. Accessed July 2006.

Oregon Department of Environmental Quality. 2000. *A Mixing Zone Guidance Document Prepared for the Oregon Department of Environmental Quality*. S. Schnurbusch. Portland State University. http://www.esr.pdx.edu/ESR/docs/mem/schnurbusch.pdf. Accessed July 2006.

South Carolina Department of Health and Environmental Control. 1997. *Groundwater Mixing Zone Application Guidance*. South Carolina Department of Health and Environmental Control, Columbia, SC. http://www.scdhec.gov/water/pubs/mixingzone.pdf. Accessed July 2006.

South Dakota Department of Environmental and Natural Resources. 1998. *Mixing Zone and Dilution Implementation Procedures*. South Dakota Department of Environmental and Natural Resources. http://www.epa.gov/ost/standards/wqslibrary/sd/sd_8_zone_dil.pdf. Accessed July 2006.

Utah Division of Water Quality. 2000. *Mixing Zone Implementation Procedure*. Utah Division of Water Quality. http://www.epa.gov/waterscience/standards/wqslibrary/ut/ut_8_wq.pdf. Accessed July 2006.

Virginia Department of Environmental Quality. 2000. Guidance Memo No. 00-2011; *Guidance on Preparing VPDES Permit Limits*. Memo from Larry G. Lawson to Regional Directors, dated August 24, 2000. Virginia Department of Environmental Quality, Richmond, VA. http://www.deq.state.va.us/waterguidance/pdf/002011.pdf. Accessed July 2006.

Virginia Department of Environmental Quality. 2004. Guidance Memorandum No. 04-2021; *Guidance for Exceptional State Waters Designations in Antidegradation Policy Section of Virginia Water Quality Standards Regulation (9 VAC 25-260-30.A.3)*. Memo from Ellen Gilinsky to Regional Directors, dated November 15, 2004. Virginia Department of Environmental Quality, Richmond, VA. http://www.townhall.state.va.us/Utils/DisplayContent.cfm?fileName=E%3A%5Ctownhall%5Cdocroot%5CGuidanceDocs%5C440%5CGDoc%5FDEQ%5F2553%5Fv1%2Epdf. Accessed July 2006.

Washington Department of Ecology. No date. *Guidance for Conducting Mixing Zone Analyses*. Washington Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/programs/eap/mixzone/mixzone.doc. Accessed July 2006.

Washington Department of Ecology. 2005. *Water Quality Program Permit Writer's Manual*. Washington Department of Ecology, Olympia, WA. http://www.ecy.wa.gov/pubs/92109.pdf. Accessed July 2006.

West Virginia Division of Environmental Protection. 1997. *Water Quality Standards/Mixing Zones Implementation Guidance*. West Virginia Division of Environmental Protection Office of Water Resources. http://www.epa.gov/ost/wqs/wv/wv_3_wqs.pdf. Accessed July 2006.

Wisconsin Department of Natural Resources. 1992. *Mixing Zone Guidance for Chronic Toxicity and Zones of Initial Dilution*. Wisconsin Department of Natural Resources, Modeling and Analysis Unit, Bureau of Water Resources Management. http://www.epa.gov/ost/wqs/wi/wi_5_mixin_zone.pdf. Accessed July 2006.

Wyoming Department of Environmental Quality. 2001. *Wyoming Surface Water Quality Standards, Implementation Policies for Antidegradation, Mixing Zones, Turbidity, and Use Attainability Analysis*. Wyoming Department of Environmental Quality. http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/11968-doc.pdf. Accessed July 2006.

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.

FWPCA. 1968. *Water Quality Criteria* (Green Book). Federal Water Pollution Control Administration. Report of the National Technical Advisory Committee to the Secretary of the Interior. U.S. Department of Interior, Washington DC. (Superseded by USEPA, 1994.)

NAS/NAE. 1973. *Water Quality Criteria 1972* (Blue Book). A Report of the Committee on Water Quality Criteria. National Academy of Science and National Academy of Engineers, Washington, DC. NTIS-PB 236199. USGPO #5501-00520. (Superseded by EPA, 1994.)

USEPA. 1976. *Quality Criteria for Water* (Red Book). U.S. Environmental Protection Agency, Washington, DC.

USEPA. 1986. *Quality Criteria for Water* (Gold Book). EPA 440586001. U.S. Environmental Protection Agency, Office of Regulations and Standards, Washington, DC.

USEPA. 1987. *Permit Writers Guide to Water Quality-based Permitting for Toxic Pollutants*. EPA 440487005. U.S. Environmental Protection Agency, Office of Water, Washington, DC. (Rescinded)

USEPA. 1995. Final Water Quality Guidance for the Great Lakes System; Final Rule. U.S. Environmental Protection Agency. *Federal Register*, March 23, 1995, 60:15366. (Superseded by the 2000 Final Rule)

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 (EPA Office of Water)

http://www.cormix.info (CORMIX Home Page)

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.

http://www.cee.odu.edu/model/visual_plume.php (VP Home Page)

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

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

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

United States Environmental Protection Agency

EPA-823-R-06-003
July 2006

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

	Technical guidance	Policy guidance	Recommends states specify whether mixing zones are allowed	Effluent characterization—WET	Effluent characterization—specific pollutants	Effluent characterization—bioconcentratable pollutants	Application of criteria in mixing zones	Size and/or area considerations	Lethality to passing organisms	Determining WLAs	Special situations: lake, marine, estuarine	Cautions about mixing zones in certain situations (e.g., near fish harvesting)	Mixing zone analyses (e.g., models)
Technical and Policy Guidance Documents													
Technical Support Document for Water Quality-based Toxics Control (USEPA, 1991)	●		●	●	●	●	●	●	●	●	●	●	●
Water Quality Standards Handbook: Second Edition (USEPA, 1994)	●		●					●	●				
Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits (USEPA, 1996)		●	●										
Allocated Impact Zones for Areas of Non-Compliance (USEPA, 1995)	●							⊙					
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)	●						●	●		●			●
U.S. EPA NPDES Permit Writer's Manual (USEPA, 1996)	●		●										●
Modeling Documents													
Dilution Models for Effluent Discharges, 4th ed. (Visual Plumes) (USEPA, 2003)	●												●
Dilution Models for Effluent Discharges, 3rd ed. (USEPA, 1994)	●												●
CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges (USEPA, 1991)	●	⊙											●
User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters (USEPA, 1997)	●							⊙	●				●
Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1) (USEPA, 1990)	●												●
Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997)	●												●
Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications (USEPA, 1985)	●												●
Great Lakes Rule													
Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern (USEPA, 2000)		●				●							

● The document describes in detail the associated topic; ⊙ The document provides very little detail concerning the associated topic

EPA-823-R-06-003
July 2006

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

United States Environmental Protection Agency

EPA-823-R-06-003
July 2006

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

Overviews Only

Technical and Policy Guidance Documents

1) USEPA. 1991. *Technical Support Document for Water Quality-based Toxics Control.* EPA 505-290-001. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/npdes/pubs/owm0264.pdf.

EPA's 1991 *Technical Support Document for Water Quality-based Toxics Control* (TSD) provides guidance to states and EPA Regions for the water quality-based control of toxic pollutants. It includes recommendations for controlling point source discharges of toxic pollutants to waters of the United States.

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.

2) USEPA. 1994. *Water Quality Standards Handbook: Second Edition.* EPA 823-B-94-005a. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/standards/handbook.

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).

The Handbook provides information on the general provisions of 40 CFR Part 131 Subpart A, designated uses, water quality criteria, antidegradation, procedures for review and revision of water quality standards, and water quality-based approaches to pollution control. According to the Handbook, both it and the *Technical Support Document for Water Quality-based Toxics Control* (TSD) (USEPA, 1991) evolved from and supersede the following resources: *Water Quality Criteria 1968* (the "Green Book"), *Water Quality Criteria 1972* (the "Blue Book"), *Quality Criteria for Water 1976* (the "Red Book"), and the first edition of the *Water Quality Standards Handbook* (1983).

3) USEPA. 1996. *Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits*. U.S. Environmental Protection Agency. Memo from Robert Perciasepe to Water Program Directors, dated August 6, 1996. http://www.epa.gov/waterscience/library/wqstandards/mixingguide.pdf.

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.

4) USEPA. 1995. *Allocated Impact Zones for Areas of Non-Compliance*. EPA 823-R-95-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/library/modeling/zones.pdf.

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.

5) USEPA. 1992. *Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations*. EPA 823-R-92-004. U.S. Environmental Protection Agency, Office of Water, Washington, DC.
http://www.epa.gov/waterscience/library/modeling/wlabook3part3.pdf.

Technical Guidance Manual for Performing Waste Load Allocations, Book III: Estuaries. Part 3: Use of Mixing Zone Models in Estuarine Waste Load Allocations (Part 3) is the third of a series of manuals that provide information and guidance for preparing waste load allocations. Book I of the series provides general guidance for performing waste load allocations. Book II provides guidance specifically directed toward streams and rivers, while Book III provides guidance for preparing waste load allocations in estuaries.

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.

6) USEPA. 1996. *U.S. EPA NPDES Permit Writer's Manual*. EPA 833-B-96-003. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/npdes/pubs/owm0243.pdf.

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

7) USEPA. 2003. *Dilution Models for Effluent Discharges, 4th Edition (Visual Plumes)*. EPA/600/R-03/025. U.S. Environmental Protection Agency, Ecosystems Research Division, Athens, Georgia. http://www.epa.gov/ceampubl/swater/vplume/VP-Manual.pdf.

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).

8) USEPA. 1994. *Dilution Models for Effluent Discharges, 3rd Edition*. EPA /600/R-94/086. U.S. Environmental Protection Agency, Pacific Ecosystems Branch, ERL-N, Newport, Oregon.
http://www.epa.gov/waterscience/standards/mixingzone/files/RSB_UM_PLUMES.pdf.

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.

9) USEPA. 1991. *CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges*. EPA 600-3-91-073. U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.
http://www.epa.gov/waterscience/standards/mixingzone/files/1991_CORMIX2.pdf.

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.

10) USEPA. 1997. *User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model 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.) http://www.epa.gov/waterscience/models/cormix.html.

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.

11) USEPA. 1990. *Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1)*. Technical Report EPA/600/3-90/012. U.S. EPA Environmental Research Laboratory, Athens, GA. http://www.epa.gov/waterscience/standards/mixingzone/files/1990_CORMIX1.pdf.

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.

12) USEPA. 1997. *Compendium of Tools for Watershed Assessment and TMDL Development*. EPA 841-B-97-006. U.S. Environmental Protection Agency, Office of Water, Washington, DC. http://www.epa.gov/waterscience/standards/mixingzone/files/1997_Tool_Compendium.pdf.

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

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.

13) USEPA. 1985. *Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications*. EPA 600385073a. U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/waterscience/standards/mixingzone/files/1985_Municipal_Ocean_Discharges.pdf.

Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Application (the Ocean Discharges document) describes the behavior of plumes generated when municipal wastewater is discharged into the open ocean). Volume I contains analytical solutions and descriptions of five mathematical models that address a variety of discharge, diffuser, and receiving water characteristics. Model output includes rise height and initial dilution. The Ocean Discharges document provides guidance for the range of values within which analytical solutions provide acceptable estimates. The format of model input data is the same for all five computer programs.

Great Lakes Rule

14) USEPA. 2000. Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern. U.S. Environmental Protection Agency. 40 CFR Part 132 *Federal Register*, November 13, 2000, 65:67638. http://www.epa.gov/fedrgstr/EPA-WATER/2000/November/Day-13/w28709.htm.

Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern (the Final Rule) was written to revise EPA's 1995 *Final Water Quality Guidance for the Great Lakes System.* The original 1995 rule was challenged in court and, although the court upheld most of the provisions contained in the 1995 rule, it remanded the provisions that would have eliminated mixing zones for bioaccumulative chemicals of concern (BCCs). The court held that EPA failed to address whether the measure was cost-justified and remanded the issue to EPA.

In response, EPA reexamined the factual record and cost analyses and published a proposal to amend the 1995 rule to reinstate the provision to prohibit mixing zones for BCCs. This provision (Procedure 3C) is described in more detail in Appendix F of the rule. After reviewing and analyzing information in the rule-making record and public comments on the *Proposal to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of Concern* (published in the *Federal Register* on October 4, 1999), EPA finalized the rule in 2000.

Appendix A: EPA Regional Documents

Note: No guidance has been developed specifically by Regions 1, 2, 3, 5, 6, 7, 9, and 10.

USEPA. 1995. *EPA Region VIII Mixing Zones and Dilution Policy*. U.S. Environmental Protection Agency, Region 8, Water Management Division, Denver, CO. http://www.epa.gov/waterscience/standards/mixingzone/files/1995_Reg_8_MZ_and_Dilution_Policy.pdf.

> The objective of *Region VIII Mixing Zones and Dilution Policy* is to help states and Indian tribes upgrade methods for deriving water quality-based permit limits, improve the technical defensibility of National Pollutant Discharge Elimination System (NPDES) permits, and reduce risks associated with mixing zone and dilution practices. The basis for the policy was the desire of the region to clarify the approaches for using mixing zones in NPDES permits. Prior to the policy, some applications of mixing zones presumptively provided the entire stream flow for dilution, which often resulted in effluent plumes (with elevated pollutant concentrations) extending far downstream of the discharge. The clarifications sought to prevent applications of mixing zones that did not adequately control effluent plume size or quality, possibly posing considerable risk to sensitive downstream uses.

USEPA. 1993. *EPA Region VIII Interim Guidance: Water Quality Standards for Indian Tribes*. U.S. Environmental Protection Agency, Region 8, Water Management Division, Denver, CO. http://epa.gov/region8/water/wqs/GUIDANCE.pdf.

> *EPA Region VIII Interim Guidance: Water Quality Standards for Indian Tribes* is intended to assist the Indian tribes in EPA Region 8 to qualify to administer water quality standards programs and to develop water quality standards pursuant to Clean Water Act (CWA) sections 518 and 303(c). The guidance includes recommendations on mixing zone policy development.

USEPA. 1980. *EPA Region IV Guidance on Mixing Zones*. U.S. Environmental Protection Agency, Region 4, Atlanta, GA. http://www.epa.gov/waterscience/standards/mixingzone/files/1980_Reg_4_MZ_Guidance.pdf.

> *EPA Region IV Guidance on Mixing Zones* provides a basis for Region 4 review and approval of state use of mixing zones in the development of effluent limitations. The guidance provides detailed descriptions of (1) appropriateness of assigning a mixing zone to a discharger, (2) the level of water quality that should be maintained in a mixing zone and surrounding waters, and (3) the factors governing the size and shape of a mixing zone.

Major Topics in EPA Headquarters Mixing Zone Documents

	Technical and Policy Guidance Documents	*Technical Support Document for Water Quality-based Toxics Control* (USEPA, 1991)	*Water Quality Standards Handbook: Second Edition* (USEPA, 1994)	*Memorandum: EPA Guidance on Application of State Mixing Zone Policies in EPA-Issued NPDES Permits* (USEPA, 1996)	*Allocated Impact Zones for Areas of Non-Compliance* (USEPA, 1995)	*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)	*U.S. EPA NPDES Permit Writer's Manual* (USEPA, 1996)	**Modeling Documents**	*Dilution Models for Effluent Discharges, 4th ed. (Visual Plumes)* (USEPA, 2003)	*Dilution Models for Effluent Discharges, 3rd ed.* (USEPA, 1994)	*CORMIX2: An Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Multiport Diffuser Discharges* (USEPA, 1991)	*User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters* (USEPA, 1997)	*Expert System for Hydrodynamic Mixing Zone Analysis of Conventional and Toxic Single Port Discharges (CORMIX1)* (USEPA, 1990)	*Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997)	*Initial Mixing Characteristics of Municipal Ocean Discharges: Volume 1—Procedures and Applications* (USEPA, 1985)	**Great Lakes Rule**	*Final Rule to Amend the Final Water Quality Guidance for the Great Lakes System to Prohibit Mixing Zones for Bioaccumulative Chemicals of concern* (USEPA, 2000)
Application of criteria in mixing zones		●				●											
Cautions about mixing zones in certain situations (e.g., near fish harvesting)		●															
Determining WLAs		●				●											
Effluent characterization—bioconcentratable pollutants		●															●
Effluent characterization—specific pollutants		●															
Effluent characterization—WET		●															
Lethality to passing organisms		●	●									●					
Mixing zone analyses (e.g., models)		●				●	●		●	●	●	●	●	●	●		
Recommends states specify whether mixing zones are allowed		●	●	●			●										
Size and/or area considerations		●	●		⊙	●						⊙					
Special situations: lake, marine, estuarine		●															

● The topic is discussed in detail in the associated document; ⊙ Very little detail about the topic is provided in the associated document