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.