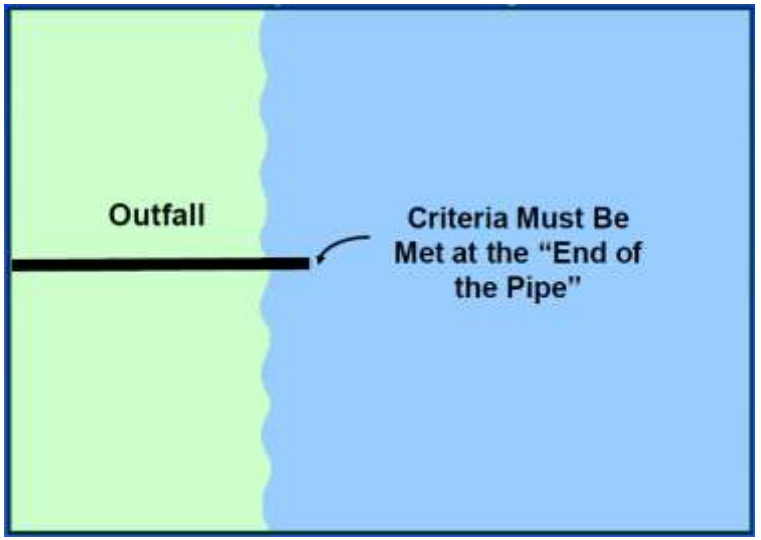
Geosyntec consultants

Mixing Zones – How can they be utilized?

Rishab Mahajan and Adrienne Nemura | February 1, 2018
DuPage River Salt Creek Workgroup

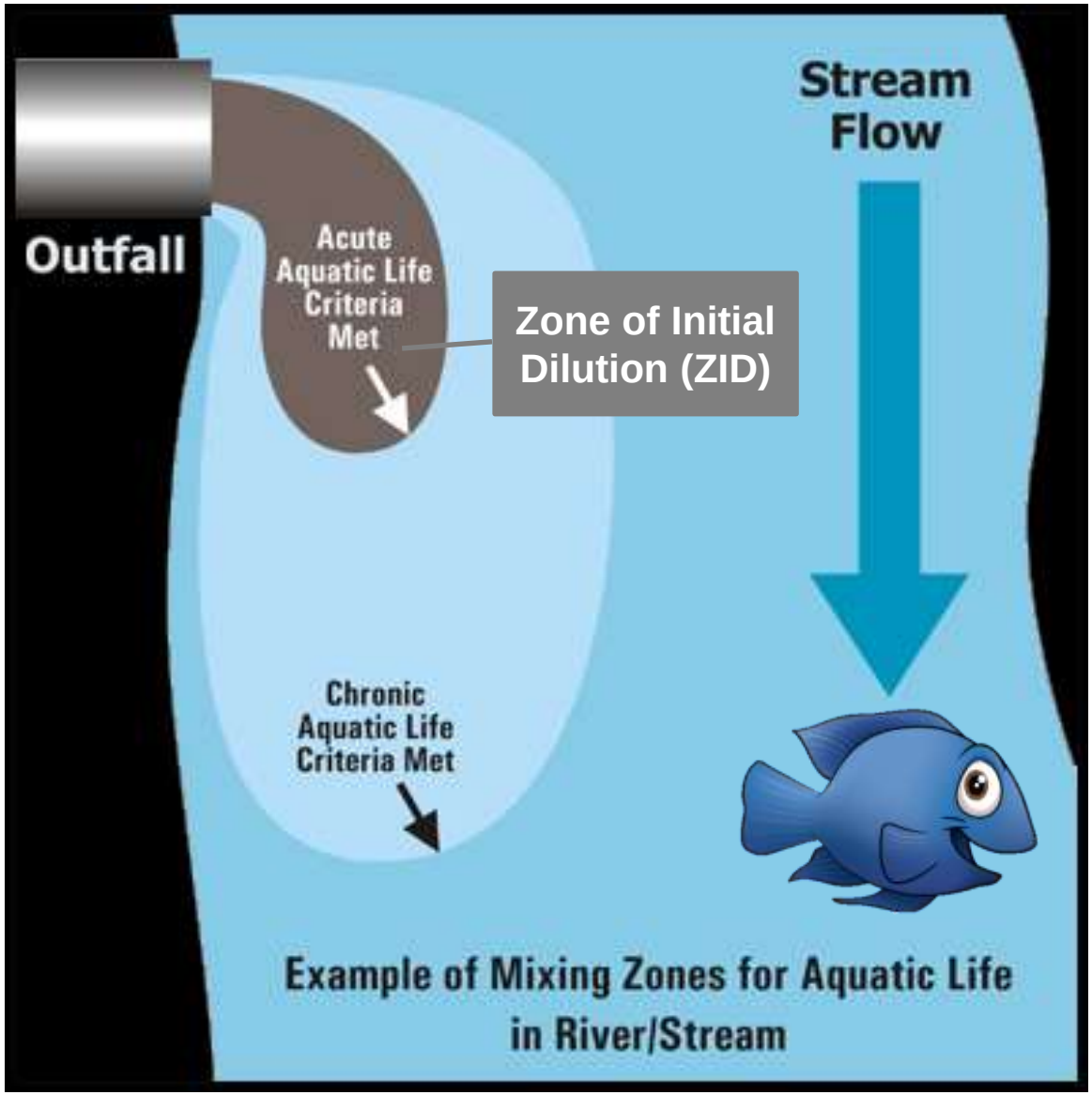
Mixing Zone Models: Outline

- Mixing Zone Basics
- Models
- Example: Wastewater Treatment Plant (WWTP) Discharge



www3.epa.gov/npdes/pubs/wqbels_part_ii.pdf

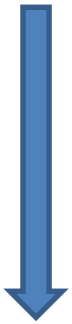
Mixing Zone Basics



A mixing zone is a regulatory construct.

Motivation

- Instream water quality standards (WQS)
  - Ammonia
  - Metals
  - Total dissolved solids, sulfate, chloride
- Typically applied “end-of-pipe” in discharge permits
  - Stringent effluent limits
  - Expensive treatment upgrades
- The Clean Water Act and EPA’s WQS regulations provide flexibility
  - Mixing zones
  - Metals translators
  - Whole effluent toxicity
  - Variances
  - Site-specific standards



Level of Complexity

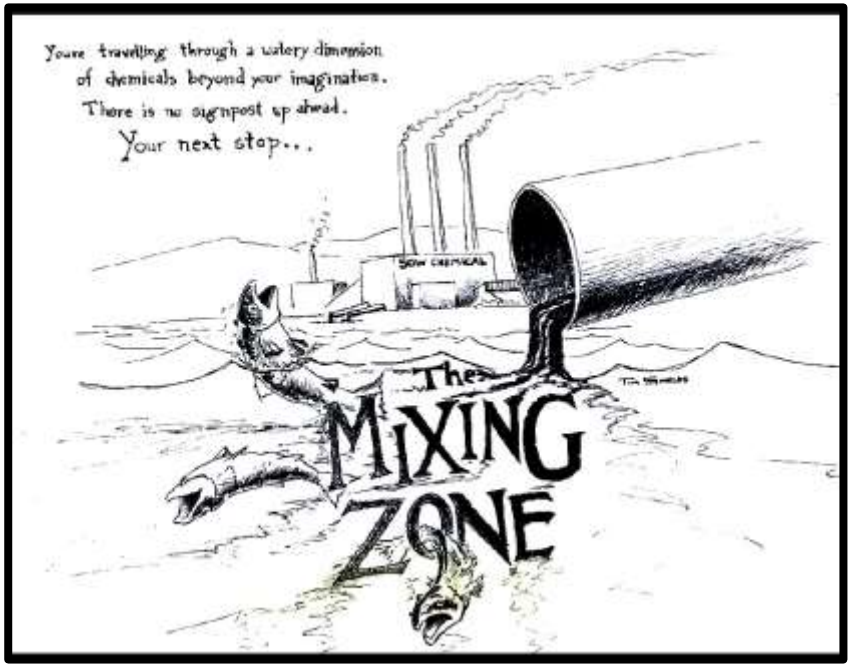
What is a Mixing Zone?

EPA's Water Quality Standards Handbook

"A mixing zone is a **limited area or volume** of water where **initial dilution** of a discharge takes place and where **certain numeric water quality criteria may be exceeded**."

- ✗ Typically not for bio-accumulative chemicals
- ✗ License to pollute
- √ Small portion of waterbody
- √ Protects uses of the waterbody
- √ Re-evaluate with individual NPDES permit renewals

www.epa.gov/sites/production/files/2014-09/documents/handbook-chapter5.pdf



earthisland.org/csaw/MZ_files_web_docs/CSAW_MZ_Manual.pdf

Mixing Zone Rules

Incorporated into state WQS - vary by state and size of receiving waters

- Illinois (35 Ill. Adm. Code 302.102)
  - Allow aquatic life a zone of passage,
  - Not more than 25% of the cross-sectional area or flow of the receiving stream*, and
  - Be as small as practicable and have a surface area less than 26 acres.
- West Virginia
  - 1/3 of receiving stream width
  - 1/2 cross-sectional area of stream
- Missouri
  - 25% of the width
  - 0.25 mile length

- Numerous, important narrative rules that may affect sizing
  - e.g., critical habitat, municipal water intakes, swimming areas, overlapping mixing zones, etc.
  - Not for effluent-dominated systems

* In Illinois, if dilution ratio is less than 3:1, not more than 50% of flow of the receiving stream

When is a Mixing Zone Allowed?

- In Illinois (Title 35)
  - Provide “best degree of treatment” (Section 304.102)
    - Technological feasibility
    - Economic reasonableness
    - Sound engineering judgment
    - Consider waste reduction and segregating/combining individual process wastewaters

    www.ipcb.state.il.us/documents/dsweb/Get/Document-33356
  - 1993 guidance lists other considerations
    - Plant operations
    - Housekeeping
    - Useful life of treatment facilities
    - New evaluation if upstream concentrations increase
    - Design of outfall structure

    www.epa.gov/sites/production/files/2014-12/documents/il_5_permitting.pdf

When is a Mixing Zone Allowed?

- Title 35, Section 302.102
  - No effluent standard exists or WQS is more restrictive
- Exceptions
  - WQS already being violated
  - If mixing occludes a tributary mouth or restricts movement of aquatic life in/out of tributary
  - Waters adjacent to bathing beaches, bank fishing areas, boat ramps or dockages, or any other public access area
  - Mussel beds, endangered species habitat, fish spawning, areas of important aquatic life habitat
  - Intake structures for water supplies, irrigation, watering areas by wild or domestic animals

www.ipcb.state.il.us/documents/dsweb/Get/Document-33354

Illinois Examples

- City of Ottawa – ammonia
- City of Morris – ammonia, total residual chlorine, chloride
  - Illinois EPA concerned about future chloride loads from Costco Wholesale Corporation
- Power plants - temperature

DRSCW Permits: Mixing Zones

- DuPage River Salt Creek Workgroup
  - Demonstrate reasonable potential to exceed WQS
  - Develop appropriate water quality based effluent limits
  - Submit to agency a mixing zone study plan within two months of effective date of permit to account for mixing

- Village of Addison
- Village of Bartlett
- Village of Bensenville
- Village of Bloomingdale
- Village of Bolingbrook
- Village of Carol Stream
- Village of Clarendon Hills
- DuPage County
- Village of Glendale Heights
- Village of Hanover Park
- Village of Roselle
- City of West Chicago
- Village of Woodridge

Increasing Impetus for Mixing Zone Modeling

- Increased scrutiny by states agencies
  - Default mixing zone no longer the norm
  - Requires site-specific studies

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- Higher marginal costs with little real benefit to water quality
  - Mixing zone allowance typically least expensive of regulatory flexibility options

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- Many situations
  - WWTP discharges to a small tributary
  - Save money by discharging to nearby river with a mixing zone

Mixing Zone Models

"Essentially, all models are wrong, but some are useful.“

George E.P. Box

Typical Models

- Visual Plumes
  - Limited application to “shallow water” conditions with no local recirculation
- Cornell Mixing Zone Expert System (CORMIX)
  - Mix of theory and best professional judgment
  - Most widely used for mixing zone analysis
- Computational Fluid Dynamics
  - More complex, typically more accurate
  - Addresses non-standard discharges
  - Accommodates geographic features (wing dams, sharp bends in river)

Model selection depends upon potential pain, resources, and site-specific conditions.

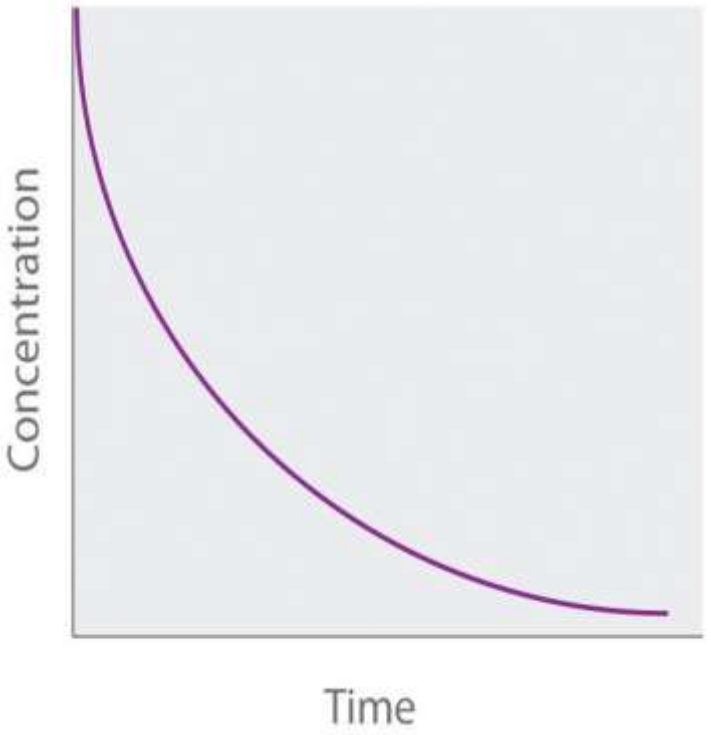
Model Assumptions

- Steady-state

  Flow conditions do not change with time

- Rectangular cross-section (CORMIX & Plumes)

- First-order decay for non-conservative pollutants



Model Framework

River Flow, Characteristics

Upstream Concentration

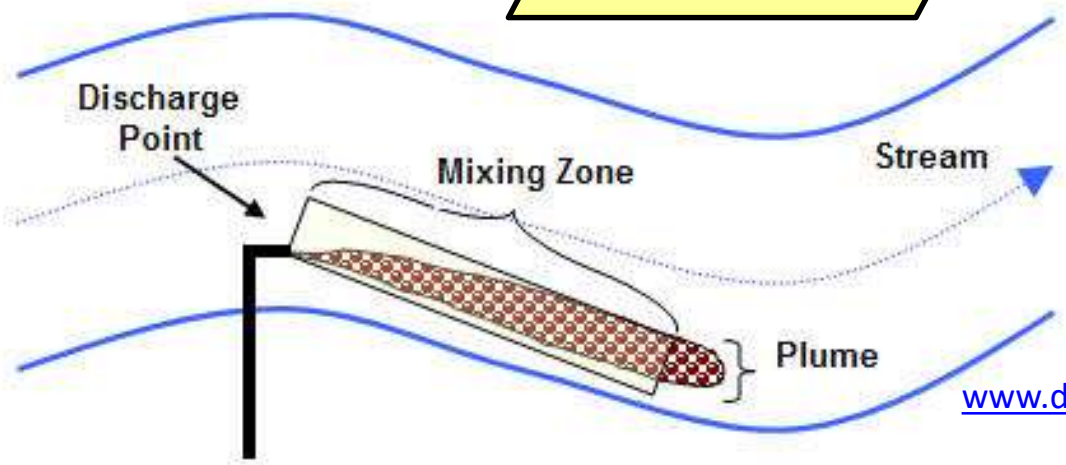
Mixing Zone Model

Effluent Discharge Characteristics

Outfall Characteristics

Dilution Factor, DF

Plume Dilution and Trajectory



www.deq.state.or.us/wq/wqpermit/mixingzones.htm

Model Inputs

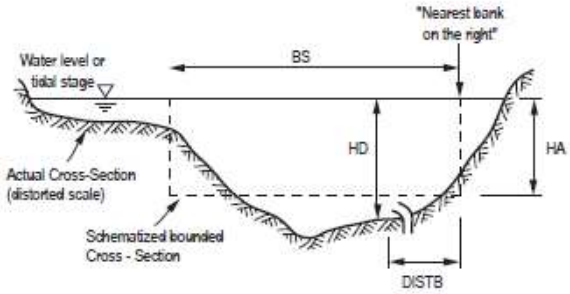
River flow

- Dilution assessed during lowest flows

- 7Q10 flow - lowest average flow that would be experienced during a consecutive 7-day period with an average recurrence interval of ten years
  - USGS records
  - State water survey records
  - Discharge permits

- Also other flow conditions (e.g. 30Q10)

Model Inputs



River characteristics

- Cross-sectional data
  - Width and depth under flow conditions
- Level of stratification (vertical mixing)
- Manning's n
- Meandering characteristics of the river
  - Straight
  - Slight meander
  - Highly meandering

Upstream water quality concentration- Ambient Data

Model Inputs

Effluent discharge characteristics

- Discharge flow – design flow
- Concentration – monitoring reports

Outfall characteristics

- Single port: size & location
- Multi-port diffuser: length & configuration

Single Port

www.cormix.info/methodology.php

Diffuser

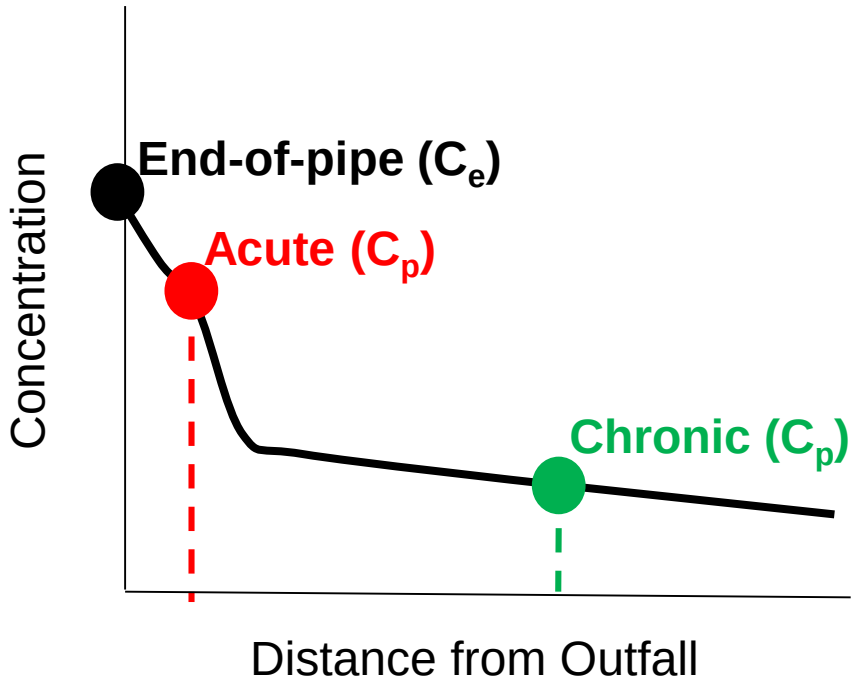
www.cormix.info/methodology.php

Model Output

- Dilution Factor (DF) = C_e/C_p

  C_e : Effluent concentration
  C_p : Downstream concentration

- Length can matter! Established by
  - WQS
  - Model results
  - Negotiations



Example : Wastewater Treatment Plant (WWTP) Discharge

Background

- Illinois city operates a WWTP discharging to a large river
- 3-cell aerated lagoon
- Design flow of 1.5 million gallons per day
- IEPA requested mixing zone modeling as part of permit renewal process for ammonia

Modeling Approach

- CORMIX model developed to simulate mixing
- Assess whether discharge has “reasonable potential” to exceed ammonia criteria
- Available discharge and receiving water data used to parameterize the CORMIX model
- Worst case effluent concentration – 25 mg/L (based on effluent monitoring data)

Criteria and Mixing Zone Lengths

- Ammonia criteria calculated based on historical 75th percentile pH and temperature as per IL regulations

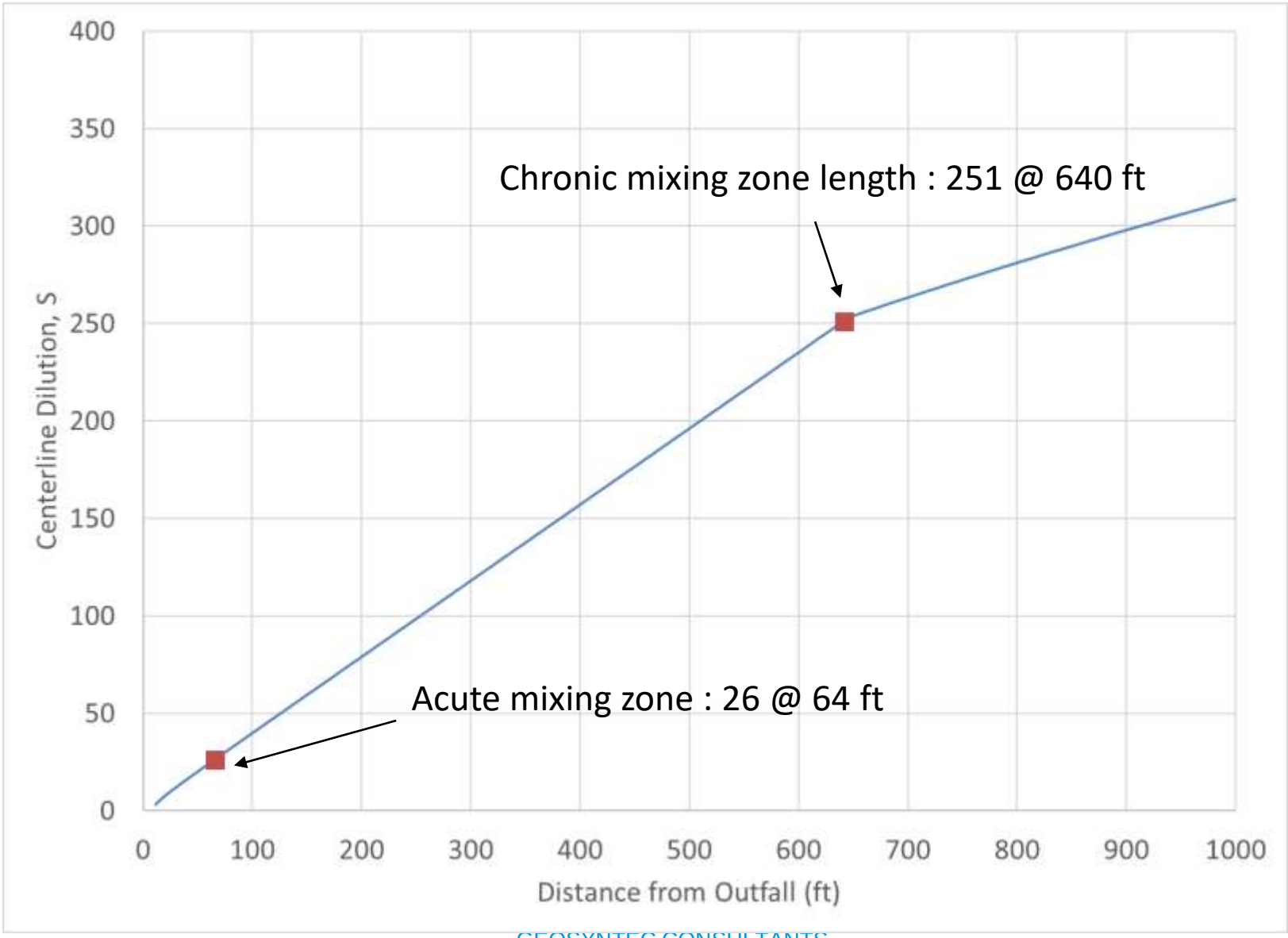
  Acute criterion – 3.9 mg/L (summer)

  Chronic criterion – 0.7 mg/L (summer)

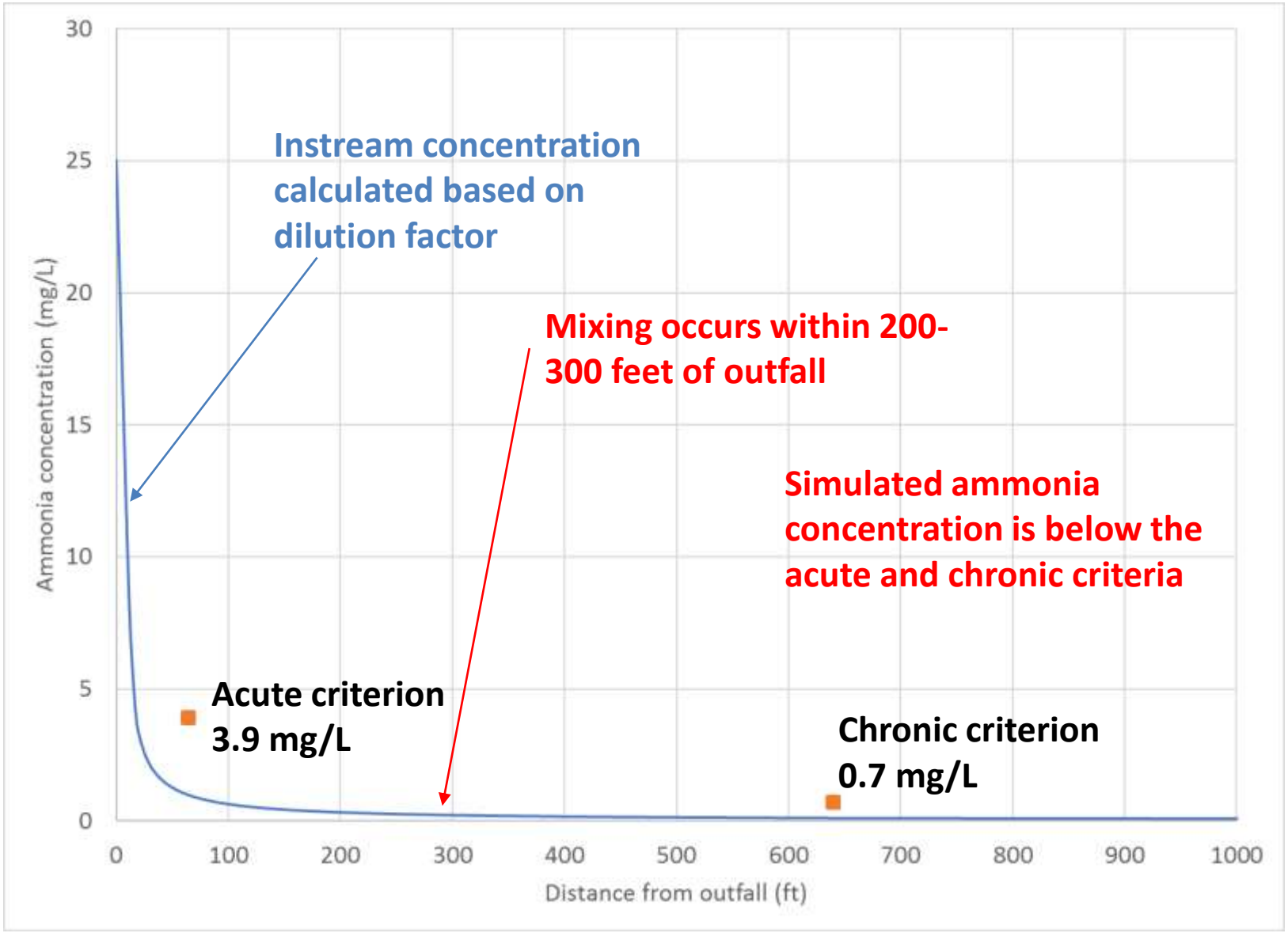
- Chronic mixing zone length assumed to be distance at which simulated plume started interacting river bottom (consultation with IEPA)

- Acute mixing zone length – 10% of chronic mixing zone length (US EPA Technical Support Document for Toxics Control - 1991)

Model Results- Dilution Factors



Model Results- Ammonia



Findings and Future Implications

Mixing zone modeling demonstrated

- Rapid and complete mixing of effluent discharge downstream
- Discharge does not have reasonable potential to exceed water quality criteria for ammonia
- Effluent permit limit for ammonia not required

If criteria are revised, model can be used to evaluate alternative options for compliance

- Different assumptions about upstream and effluent concentrations
- Diffusers
- Plant operational changes

Summary: Mixing Zone Models are

- Tools to evaluate whether instream water quality criteria can be met
  - Site-specific conditions
  - More complex models may help reduce cost of compliance
- Methods to evaluate alternative measures to meet criteria in case of non-compliance
  - Operational changes
  - Diffusers
  - Feasibility studies (in case of new discharges)
- Methods to evaluate impact of changes in criteria

THANK YOU

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www.geosyntec.com/pdf/Mixing-Zone-Analysis-Geosyntec.pdf

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