Mixing Zones, Metals and NPDES Effluent Limits

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Water Quality Based Effluent Limitations

- WQBEL = Water Quality Based Effluent Limitation
- An effluent limitation that is determined to be necessary to ensure compliance with water quality criteria in the receiving water
- Types of numeric water quality criteria
  - acute and chronic aquatic life
  - carcinogenic and noncarcinogenic human health

Sample Fresh Water Criteria - Zinc

Aquatic Life *(for hardness = 100 mg/l)*		
Acute	120 ug/l	dissolved
Chronic	120 ug/l*	dissolved
Human Health		
Water + Organism	7,400 ug/l	total
Organism Only	26,000 ug/l	total

**same as FL Class I and Class III fresh water criteria*

Water Quality Based Effluent Limitations

- ***Why would a WQBEL be required?***
  - Impaired waterway; actual receiving water concentrations exceed criteria
  - Cause or Reasonable Potential to Cause exceedance of water quality criterion
  - New more stringent water quality criteria
  - New monitoring data for receiving water or WWTP
  - Improved laboratory detection limits

Critical Factors for WQBELs

I. Numerical value for the water quality criterion
   - For Metals
     - Hardness – generally higher at low flow; limits at low flow
     - Dissolved versus Total Recoverable
     - Bioavailability and Water Effect Ratio (WER)

II. Dilution factor
   - In small streams, rapid and complete mixing of discharge with upstream flow
   - In coastal areas and large bodies of water (rivers and lakes) must define dilution factor at edge of mixing zone

Metals Water Quality Criteria

- *Criteria for Protection of Aquatic Life*
  - *Hardness dependent for several metals*[1]
  - *Criterion basis*
    - *Acute:* $\exp\{ m_A [\ln(\text{hardness})] + b_A$
    - *Chronic:* $\exp\{ m_C [\ln(\text{hardness})] + b_C\}$

[1] *e.g., in Florida – cadmium, chromium III, copper, lead, nickel and zinc*

Metals Water Quality Criteria

- *Recognition that criteria should be expressed as dissolved metal*[1]
  - *Apply conversion factor (CF)*
  - *Acute:* $\exp\{ m_A [\ln(\text{hardness})] + b_A\} * CF$
  - *Chronic:* $\exp\{ m_C [\ln(\text{hardness})] + b_C\} * CF$

[1] e.g., in Florida – cadmium, chromium, copper, lead, nickel, silver and zinc

Metals Water Quality Criteria

- *Recognition that site specific natural waters are less toxic than laboratory test waters*
  - *Apply Water Effect Ratio (WER)*
  - *Acute:* $WER * \exp\{m_A [\ln(\text{hardness})] + b_A\} * CF$
  - *Chronic:* $WER * \exp\{m_C [\ln(\text{hardness})] + b_C\} * CF$

Translators

- Translator = ratio of dissolved concentration to total recoverable concentration.
- Water quality criteria are dissolved; effluent data and limits are total recoverable
- Need method to convert
- Translator < 1.0 -- ***the smaller the better!***
  - Multiply total recoverable effluent concentration by translator to get dissolved effluent concentration
  - Divide dissolved criterion by translator to get effective site specific total recoverable criterion

Actual Translators

	Default Freshwater Acute	Default Freshwater Chronic	***Typical Actual***
Copper	0.96	0.96	***0.4 – 0.6***
Lead	0.791	0.791	***0.4 – 0.6***
Zinc	0.978	0.986	***0.6 – 0.8***

Water Effect Ratio - WER

- WER is the ratio of site specific toxicity to laboratory toxicity
- Many metals are less toxic in site specific waters than in lab waters
- WER > 1.0 -- ***the larger the better!***
- Multiply water quality criterion by WER
- WER effectively increases the water quality criterion
- Applicable to aquatic life criteria only

WER Example – Copper

	Default Criterion *WER = 1*	Actual Criterion *WER = 2*	Actual Criterion *WER = 4*	Actual Criterion *WER = 6*
Acute Aquatic Life	12.7 ug/l*	25.4 ug/l*	50.8 ug/l*	76.2 ug/l*
Chronic Aquatic Life	8.5 ug/l*	17.0 ug/l*	34 ug/l*	51 ug/l*

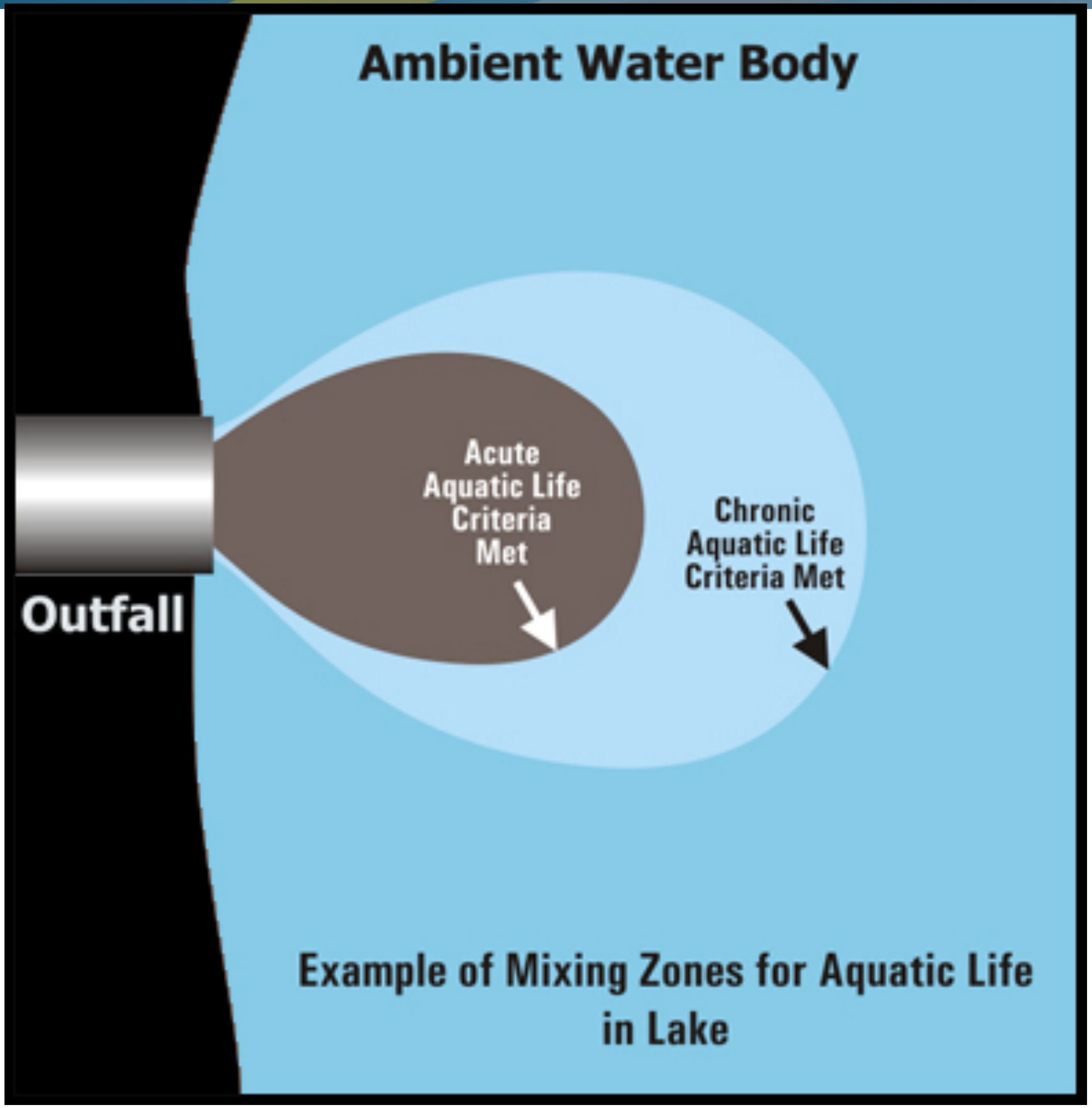
**for stream hardness of 100 mg/l*

Actual Copper WERs

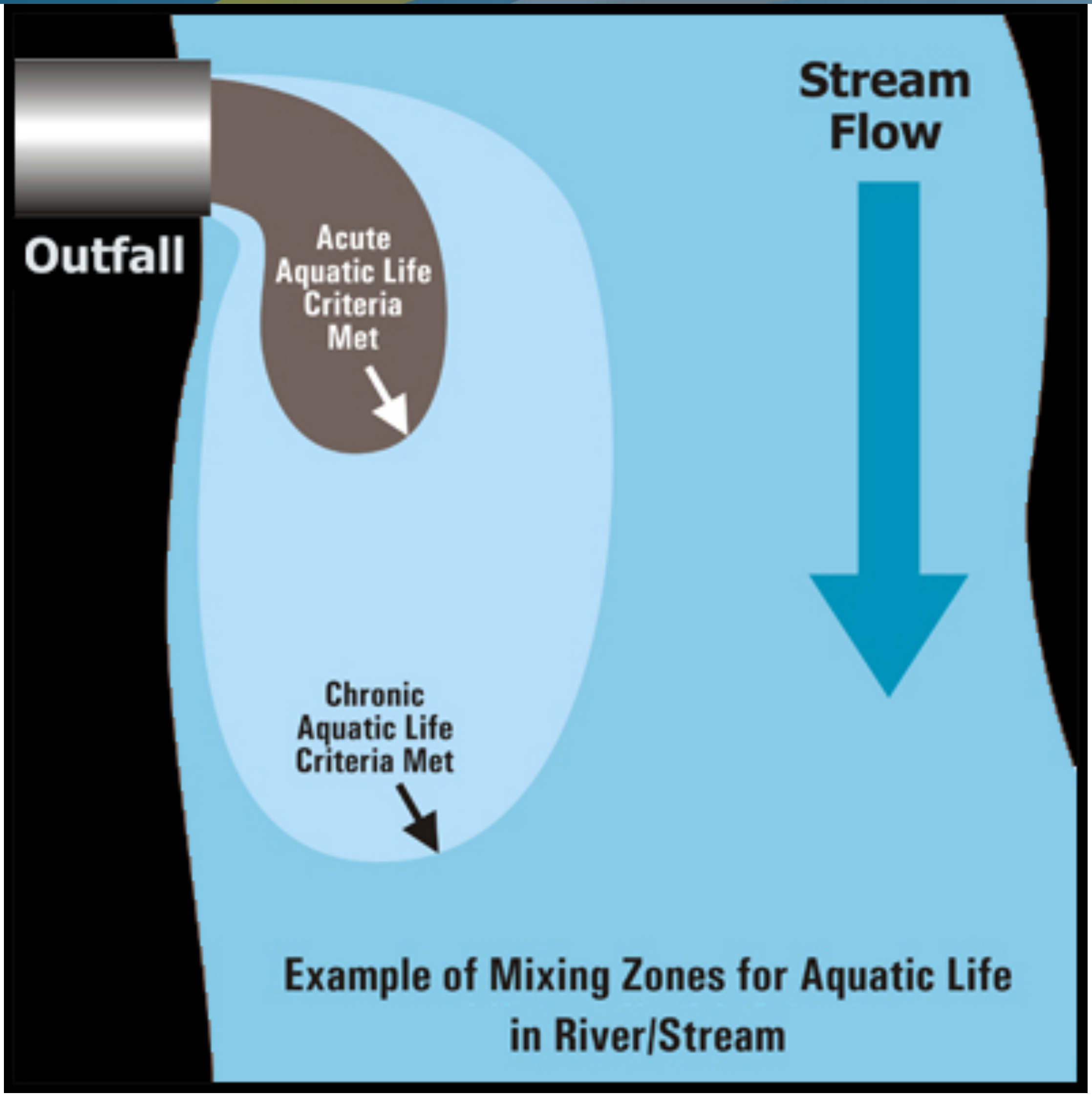
Facility	WER
Facility A, 23 mgd, DF = 3.7	2.56
Facility B, 3 mgd, DF = 1.6	6.45
Facility C, 3.9 mgd, DF = 1.3	4.23
Facility D, 0.286 mgd, DF = 1	4.76
Facility E, 16 mgd, dynamic model	2.63

What is a Mixing Zone?

- A limited area within a receiving water adjacent to the point of discharge within which the water quality criteria are permitted to be exceeded.
- Allows some distance for mixing of the effluent with the receiving water.
  - Applicable in coastal areas / lakes, and rivers / estuaries where complete mixing across the width of the river is not rapidly achieved.
- Water quality criteria must be satisfied at the edge of the mixing zone, but can be exceeded within the mixing zone.

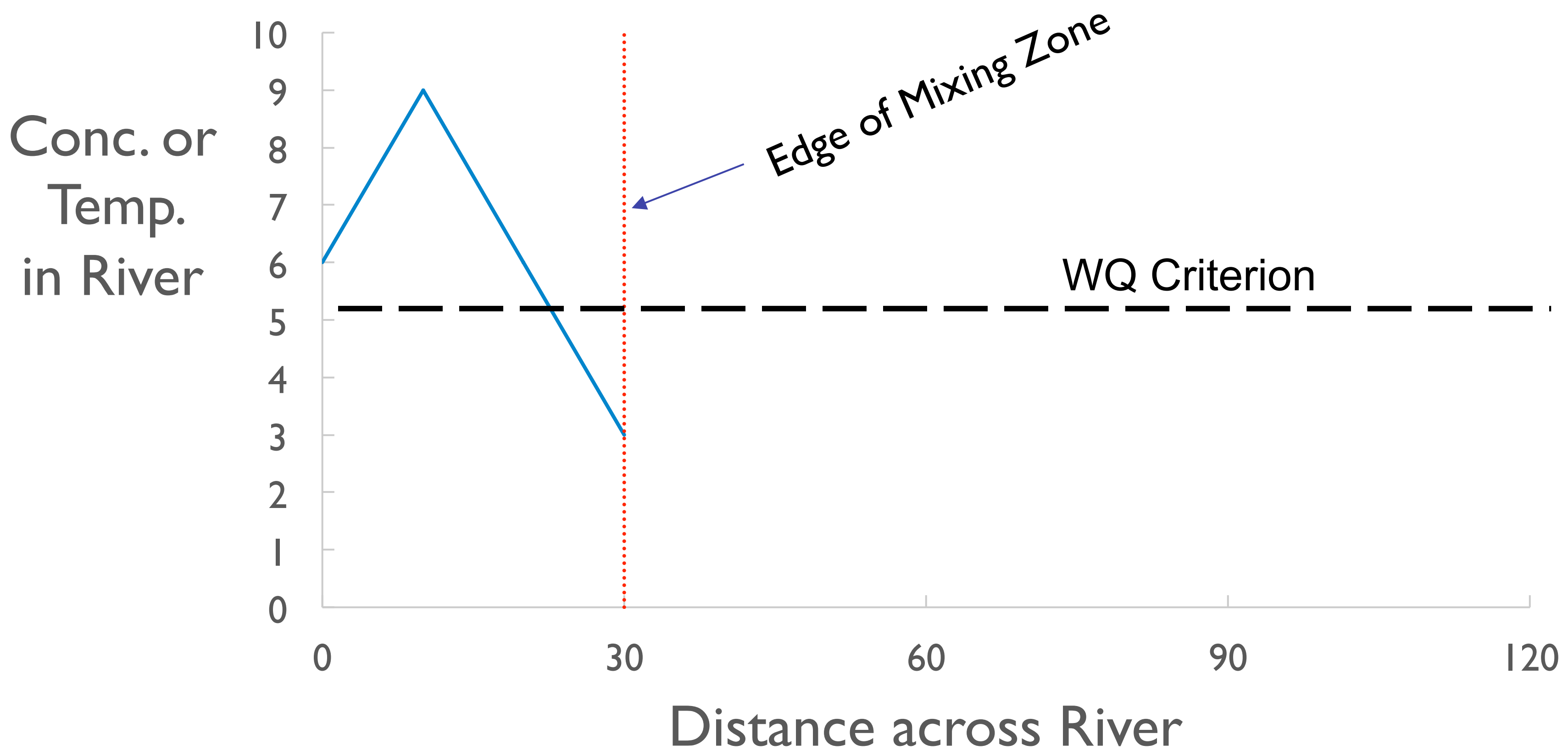


http://water.epa.gov/scitech/swguidance/standards/mixingzones/pop_pic1.cfm



http://water.epa.gov/scitech/swguidance/standards/mixingzones/pop_pic1.cfm

Constituent Concentration in Mixing Zone



Mixing Zones

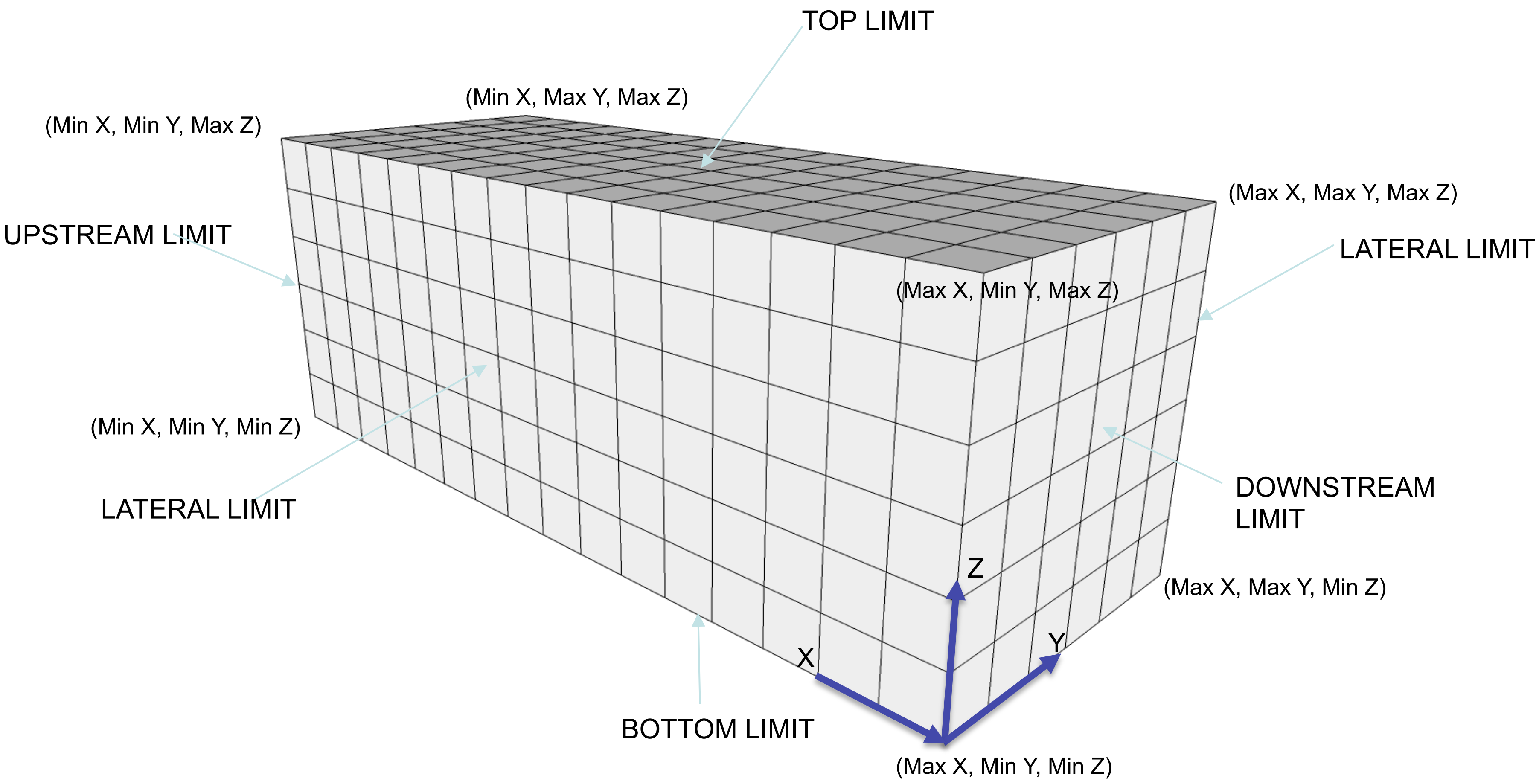
- Without a mixing zone, water quality criteria would have to be met at end-of-pipe
- Calculate dilution factor achieved at edge of mixing zone, and use it to determine effluent limits
  - Acute and chronic mixing zones
  - Acute and chronic dilution factors
- Computer simulation model or other method to calculate size of mixing zone and dilution factor
- Dye study may be needed to verify dilution factor
- If water quality criteria are met at edge of mixing zone, then no need for WQBEL

Model Considerations

- Need to simulate
  - Near field jet induced mixing
  - Far field ambient mixing and heat transport
- Most models do one or the other well, e.g.,
  - CORMIX – near field
  - WASP – Far field
- CFD family of models can do both
  - CFD = Computational Fluid Dynamics
  - CFD models represent the state of the art in hydrodynamic simulation

CFD Model – FLOW-3D

Three Dimensional Model Mesh



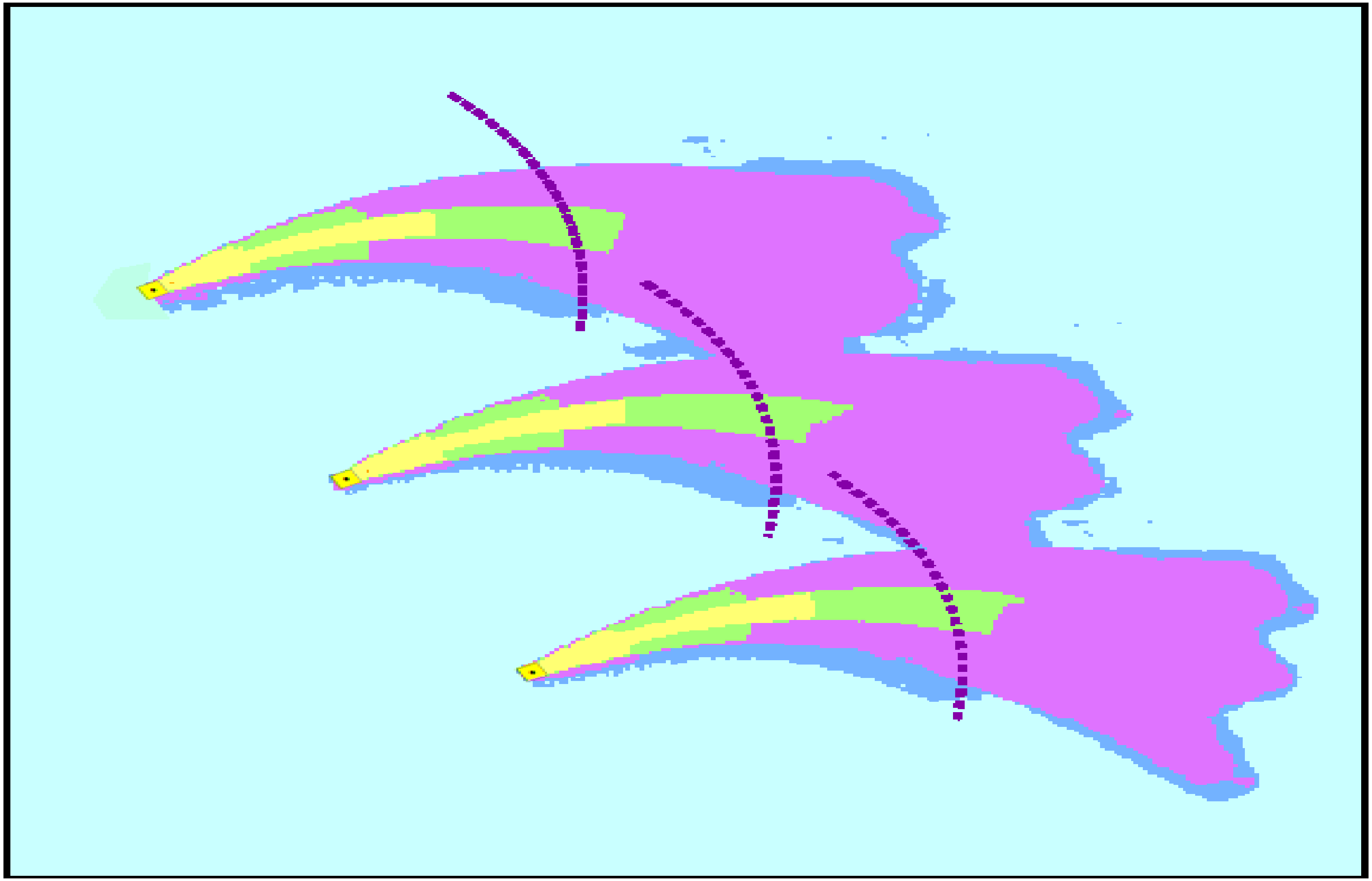
- *Video of thermal model*

Outfall Diffuser

- Spatial restriction on size of MZ – varies with agency and parameter
  - e.g., chronic MZ - 100 meters, xx% of river width / area
  - e.g., acute MZ - 50 * discharge length scale, or 5 * water depth, or 10% of chronic MZ
- Typical single outfall pipe may not be submerged and may not provide for rapid mixing
  - No mixing zone permitted; therefore effluent limits will be based on zero dilution, i.e., meet receiving water criteria at end of pipe
- Use outfall diffuser to enhance mixing
  - Evaluate alternative diffusers with simulation model

Outfall Pipe vs. Outfall Diffuser

Example: 3 Port Outfall Diffuser



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Outfall Diffuser

- Select outfall diffuser configuration to achieve desired dilution factor
  - Demonstrate no impact to aquatic life, and therefore no need for effluent limit
- Factors to consider
  - Depth of receiving water
  - Number of discharge ports
  - Angle of discharge ports
  - Size of discharge ports
- Use computer simulation model to evaluate possible outfall configurations

Conclusions

- **Critical Factors**
  - Numerical value for criterion
    - Site specific information to establish defensible numerical criterion; for metals - dissolved vs total, WER, hardness, translator
  - Dilution factor
    - Ensure correct flow is used in streams
    - Establish mixing zone in larger rivers, lakes, coastal areas
    - Consider outfall diffuser to enhance mixing and applicable dilution factor

Questions?