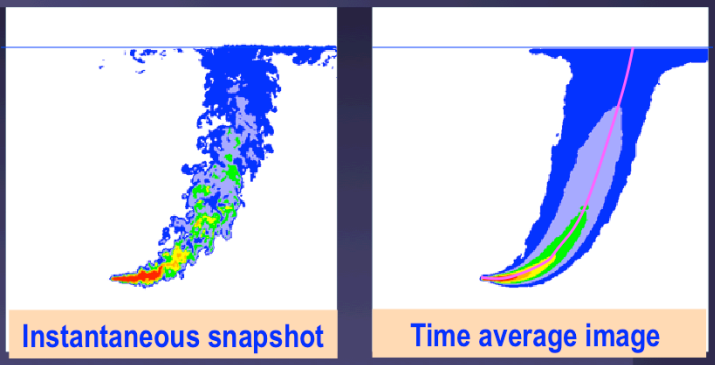
What to look for when reviewing a Mixing Zone Study in WA

EPA Mixing Zone Webinar Workshop Series
January 22-24, 2013



Instantaneous snapshot | Time average image

Based on: Phil Roberts, Georgia Tech, 2003

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How dilution is defined in WA?

- Volumetric Dilution factor:

$$DF = \frac{V_a + V_e}{V_e}$$

$$= \frac{V_a}{V_e}$$

- Concentration based dilution factor:

$$DF = \frac{Ce - Ca}{Cp - Ca} \longrightarrow DF = \frac{Ce}{Cp}$$

Mixing Zones in WA (WAC-173-201A-400)

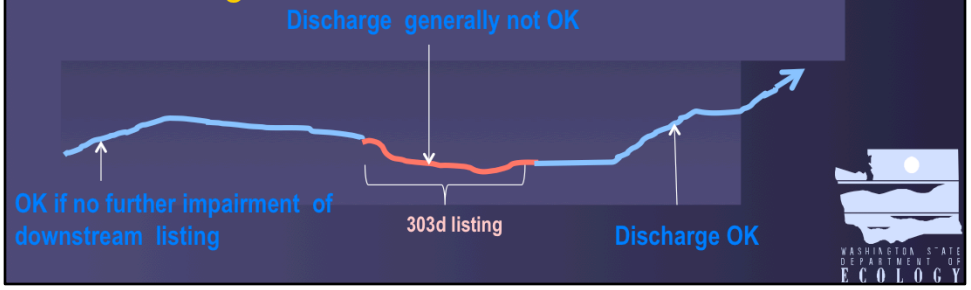
- Apply AKART prior to mixing zone authorization
- Maximum size of mixing zone
- Minimize mixing zones
- Must prove no environmental harm
- Consider critical conditions

Other Mixing zone regulations

- Overlapping mixing zones
- Extended mixing zones
- Mixing zones for stormwater
- Mixing zones for CSOs

Mixing zones and 303(d) listing

- Cannot authorize discharge that contributes to an impairment
- Mixing zone may be authorized if no impairment is found at the point of discharge



Mixing Zone Models used in WA

- Theoretical Models
  - Visual PLUMES (UM3, VSW, etc.)
  - RIVPLUME
  - CFD (being reviewed)
- Empirical Models
  - RSB (NRFIELD)
- Semi-Empirical
  - CORMIX

Farfield Predictions

Method of Brooks

$\varepsilon = \alpha L^{n}$

ε = lateral dispersion characteristics, $m^2 s^{-1}$

L = length scale, m

α = dispersion coefficient for Brooks algorithm (units dependent on n)

n = Brook's law exponent

= 4/3 (Oceans)

= 1 (Coastal and estuarine areas)

= 0 (rivers)

Spreadsheet for estimating far-field dilution : http://www.ecy.wa.gov/programs/eap/pwspread/pwspread.html

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model
as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)

INPUT

	Linear Eddy Diffusivity Fc=(alpha)(width) (Grace/Brooks equation 7-45)
1. Plume and diffuser characteristics at start of far-field mixing	
Flux-average dilution factor after initial dilution (e.g. dilution at end of computations with UM/HDFN)	19.98
Estimated initial width (B) of plume after initial dilution (meters) (e.g. eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)	12.07 meters
Travel distance of plume after initial dilution (meters) (e.g. "Y" from UDKHDEN or horizontal distance from PLUMES output)	5.47 meters
2. Distance from outfall to mixing zone boundary (meters) (e.g. distance to the chronic mixing zone boundary)	66.5 meters
3. Diffusion parameter "alpha" per equations 7-60 of Grace, where Fc=(alpha)(width) (This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. Initial diffusion coefficients (Eo in m^2/sec) are calculated as follows on this sheet. 4/3 power law, Eo = (alpha)(we/a)^(4/3), linear eddy diffusivity, Ec = (alpha)(width), constant eddy diffusivity, Eo = (alpha).)	6.88E-04 m/sec
4. Horizontal current speed (m/sec) (e.g. same value specified for UDKHDEN or PLUMES)	0.05 m/sec
5. Pollutant initial concentration and decay (optional) (these inputs do not affect calculated far-field dilution factors)	
Pollutant concentration after initial dilution (any units) (e.g. effluent volume fraction = 1/initial dilution)	5.11E-02 any units
Pollutant first-order decay rate constant (day^-1) (e.g. enter 0 for conservative pollutants)	0.00E+00 day^-1

OUTPUT

Eo = 9.306E-03 m^2/s
Beta = 1.351E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Conc. or Dilution
Dilution along plume trajectory:	2.83E-02	4.73E+00	10.20	1.96E+01	5.11E-02
	5.23E-02	9.45E+00	14.92	1.96E+01	5.11E-02

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Mixing Zones Guidance in WA

http://www.ecy.wa.gov/programs/eap/mixzone/mixzone.html

The End

AKART

- All known, available, and reasonable treatment
- Similar to BAT but more restrictive, i.e. requires current reasonable technology
- Dilution only allowed after AKART

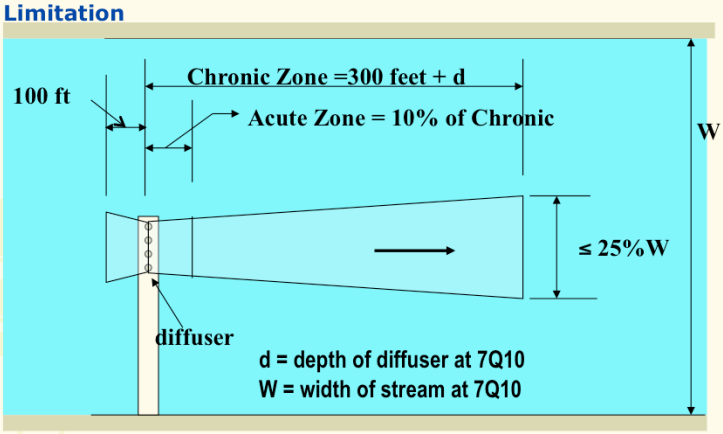
Maximum Size: Streams

Hydraulic Limitation

Can use only max stream flow of 25% 7Q10

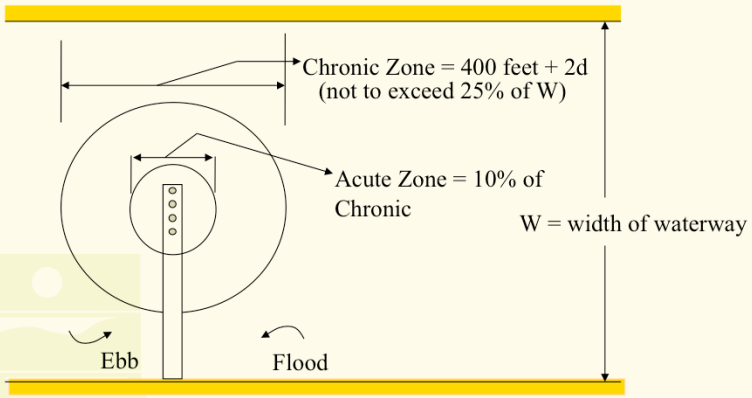
$$DF_{\max} = \frac{Q_{NPDES} + 0.25 * 7Q10}{Q_{NPDES}}$$

Distance Limitation



Maximum Size: Estuaries

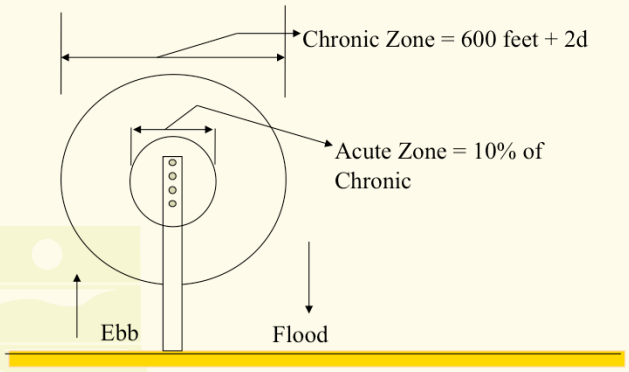
- **Distance Limitations**



d = depth of diffuser at MLLW
W = width of waterway at MLLW

Maximum Size: Oceans

- **Distance Limitations**



d = depth of diffuser at MLLW

Maximum Size: Lakes/Reservoirs (>15 days detention)

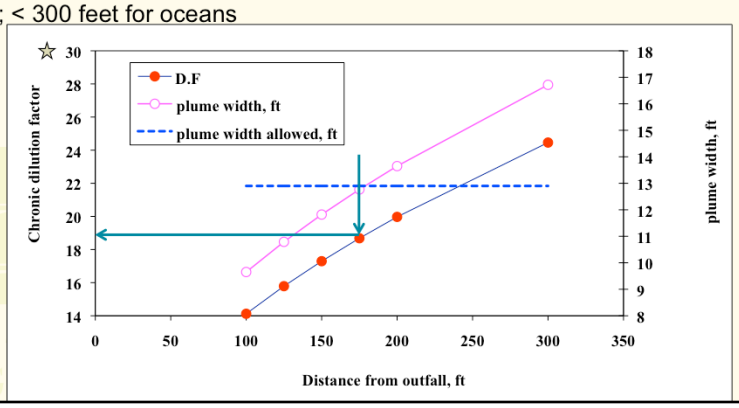
- **Mixing zones not allowed unless**:
  - All other options are exhausted
  - Overriding public interest
  - Advanced waste treatment is provided

- **If Allowed**:
  - Cannot use more than 10% of waterbody volume
  - Cannot use more than 10% of surface area
  - Cannot use more than 15% of width of waterbody.

Minimize Mixing Zones

Where possible

- Use less than 25% 7Q10 ambient flow
- Use less than 25% stream width
- Use smaller mixing zones: < 300 feet for streams; < 200 feet for estuaries; < 300 feet for oceans



No environmental harm

- No loss of sensitive or important habitat,
- No interference with existing or characteristic uses of the waterbody
- No resulting damage to the ecosystem
- No adverse public health affect

Critical Conditions

- Flow and Concentration
  - Ambient flow
  - Effluent flow
  - Ambient/Effluent concentrations
- Depth
- Stratification
- Dilution type

Ambient Flow

- Freshwater
  - Acute and Chronic …… 7Q10
  - Carcinogen …… Harmonic Flow
  - Non-Carcinogen …… 7Q10
- Saltwater
  - Acute …… 10th % or 90th % current velocity*
  - Chronic/ …… 50th % current velocity*
    Carcinogen/
    Non-Carcinogen

* Evaluated over a spring and neap tide

Effluent Flow

- Acute … highest daily Q_{max} in last 3 years
- Chronic/Non-Carcinogens … highest monthly Q_{avg} in last 3 years
- Carcinogens … Annual Average Flow
- Stormwater (Western WA):
  - Acute …… 1-hour peak flow from 2-yr 6-hr storm event
  - Chronic ..... Average flow from 2-yr 72-hr storm event
- Intermittent flow:
  - Estimate DF using Q_{max}
  - Increase DF by ($Q_{1\text{-hr avg}}/Q_{max}$) for acute
  - Increase DF by ($Q_{4\text{-day avg}}/Q_{max}$) for chronic

For Estimating Volumetric Dilution Factor

- Ambient Concentration:
  - Assume zero when no reflux
  - If reflux is present use reflux as ambient
- Effluent Concentration:
  - Assume 100% or 100 ppm

For Reasonable Potential Calculation

$$C_p = \frac{C_e}{DF} + (1 - \frac{1}{DF}) * C_a$$

- Ambient concentration (Ca)
  - Acute/Chronic …. 90th percentile
  - Carcinogen/Non-Carcinogen…Geometric Mean
- Effluent concentration (Ce)
  - (Acute/Chronic): Cmax x F*
  - (Carcinogen/Non-Carcinogen): 50th percentile

* uncertainty factor => based on number of samples, CV, and confidence interval (EPA, TSD, Table 3-1, 3-2)

Depth

- Freshwater
  - Acute and Chronic …… at 7Q10
  - Carcinogen …… at Harmonic Flow
  - Non-Carcinogen …… at 7Q10
- Tidally influenced Freshwater
  - Same as above but at MLLW
- Marine waters
  - At MLLW

Stratification

- Use density profile that gives the least mixing
- Evaluate both:
  - maxium stratification (largest differential in sigma-t values)
  - minimum stratification (smallest differential in sigma-t values)
- Human Health
  - Use average of maximum and minimum

Dilution Type

- Unidirectional flow:
  - Acute and Chronic …… Centerline
  - Human Health …… flux average
- Marine and rotating flows:
  - Acute and Chronic/ …… Flux average
    Human Health

Overlapping Mixing Zones

Allowed where:

- Combined size meets the maximum mixing zone size limitations
- No barrier to migration of indigenous organisms with potential for ecosystem damage

EXTENDED MIXING ZONES

May be considered for:

- Discharges existing prior to 1992
- Where altering the size increases protection
- Where volume of effluent is more beneficial than removing the discharge.
- Necessary for social or economic development in the area.

Mixing zones for Stormwater

Maybe granted exemption from size limitations if:

- All BMP'S have been applied
- No potential threat to
  - Sensitive habitat and ecosystem
  - Public health
  - Beneficial uses
- No barrier to migration of indigenous organisms with potential for ecosystem damage

Mixing zones for CSO's

- Must comply with all mixing zone requirements
- But, exempt from size criteria once a year provided "no environmental harm" clause is fulfilled

UM3

- Simulates 3D plume trajectory
- Predicts centerline based on 3/2 power (~gaussian) profile and top-hat (average) concentrations
- Multiport plume merging simulated with reflection technique
- Does not directly resolve lateral or bottom boundary constraints

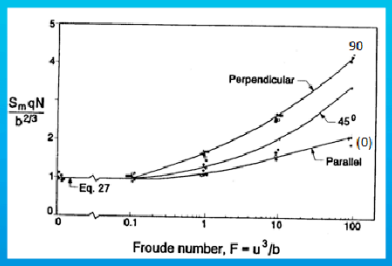
VSW

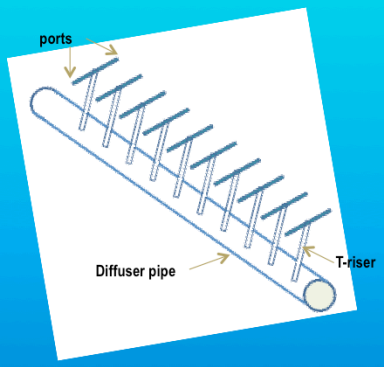
- Same as UM3 but applied to very shallow waters
- Resolves bottom constraint (bottom hit) by reflection technique

RSB…"range of experiment"

- Straight diffuser, uniformly spaced round ports on T-risers, horizontal ports in marine waters with plumes merging rapidly with length scale ratios:

$$0.31 < \frac{s}{l_b} < 1.92 \qquad 0.078 < \frac{l_m}{l_b} < 0.5$$





S = port spacing;
lb = relates buoyancy per unit diffuser length to brunt Vaisala density frequency;
lm = relates momentum to density per unit length

CORMIX

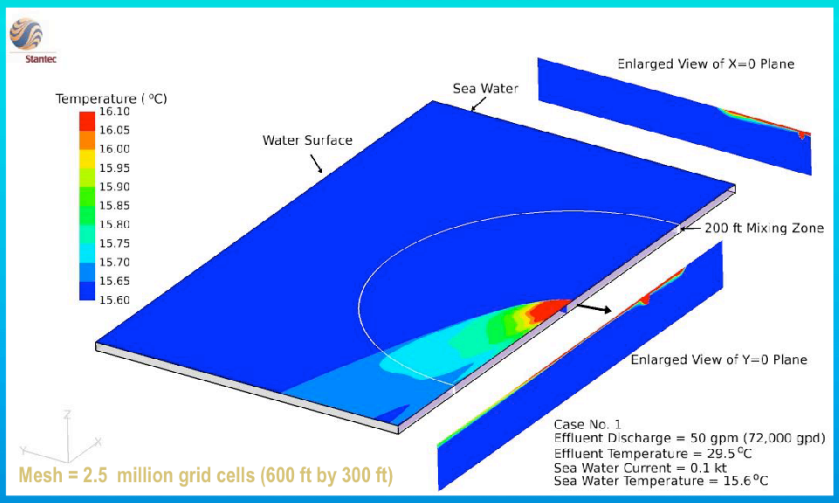
- CORMIX 1 single port positive/neutral buoyant discharges
- CORMIX 2 multiport positive/neutral buoyant discharges
  - Uses "equivalent slot diffuser"
  - May need CORMIX1 if plume details near each port are desired
- CORMIX 3 buoyant surface discharge

RIVPLUME (based on Fischer et al. 1979)

- Single port, short diffuser, or bank discharge
- Plume completely and rapidly vertically mixed within the acute zone. So a 2-D model
- Uses mean cross-sectional velocity
- It incorporates boundary effects of shoreline through superposition
- Cannot model ambient density stratification, dense plumes or tidal buildup
- Available at the following site:

http://www.ecy.wa.gov/programs/eap/pwspread/pwspread.html

CFD (Computational Fluid Dynamics)



Courtesy: Dr. Lin Fangbiao, Stantec Corporation