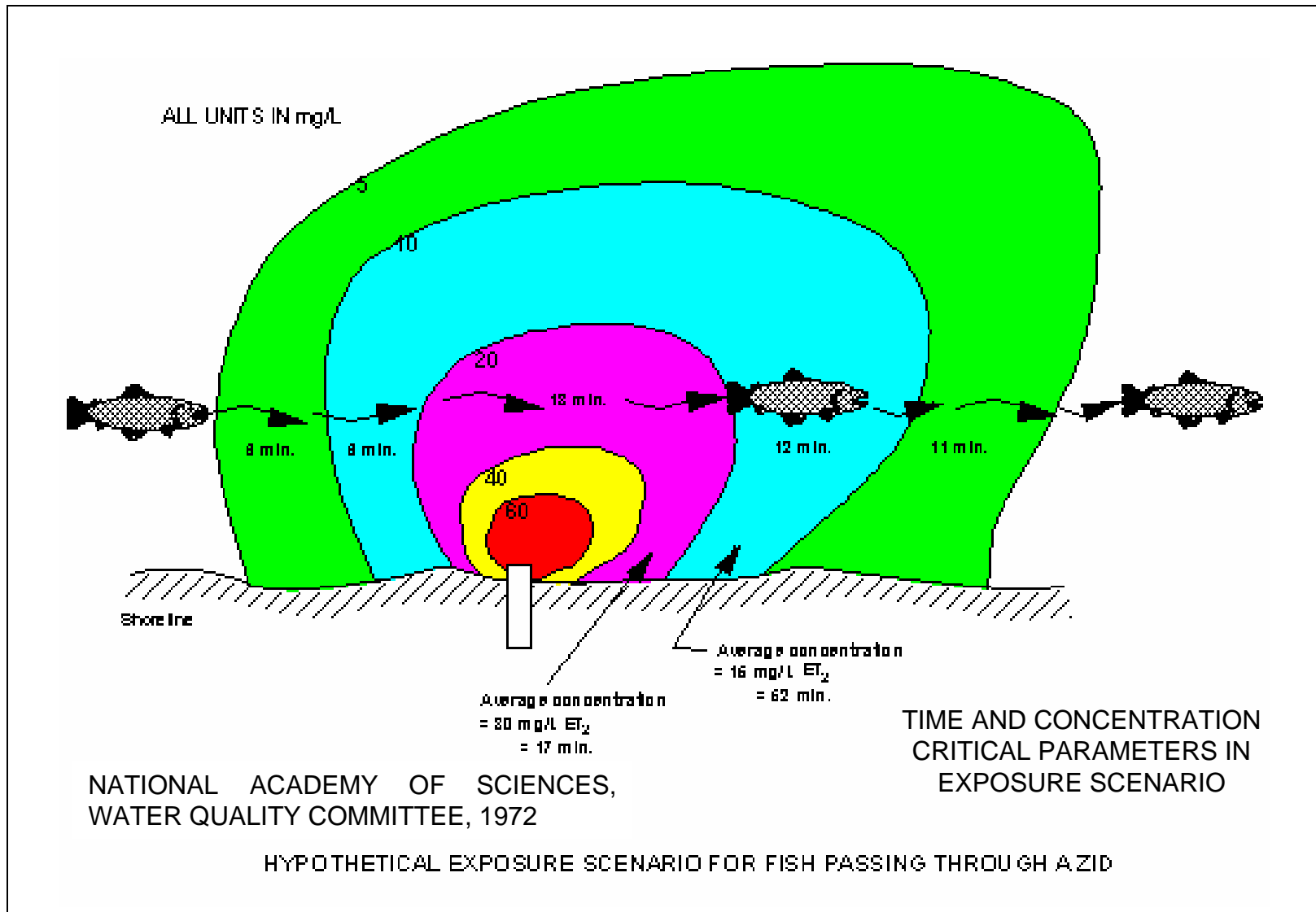
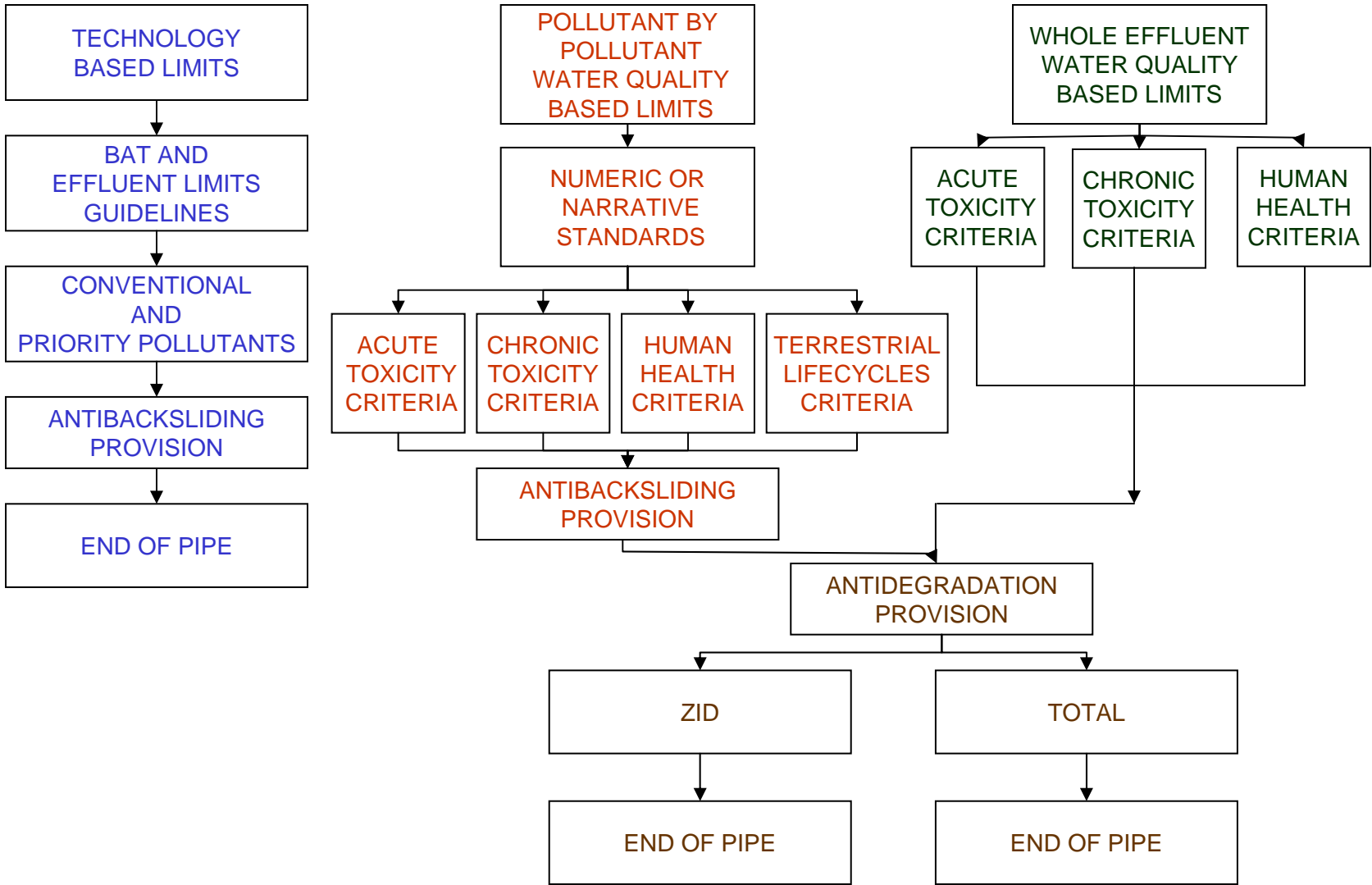


**NPDES Permitting,  
Mixing Zone and Water Quality  
Analyses**

Presented by **AquAeTer, Inc.**  
**Michael R. Corn, P.E.**

# Why Do We Need Mixing Zones?





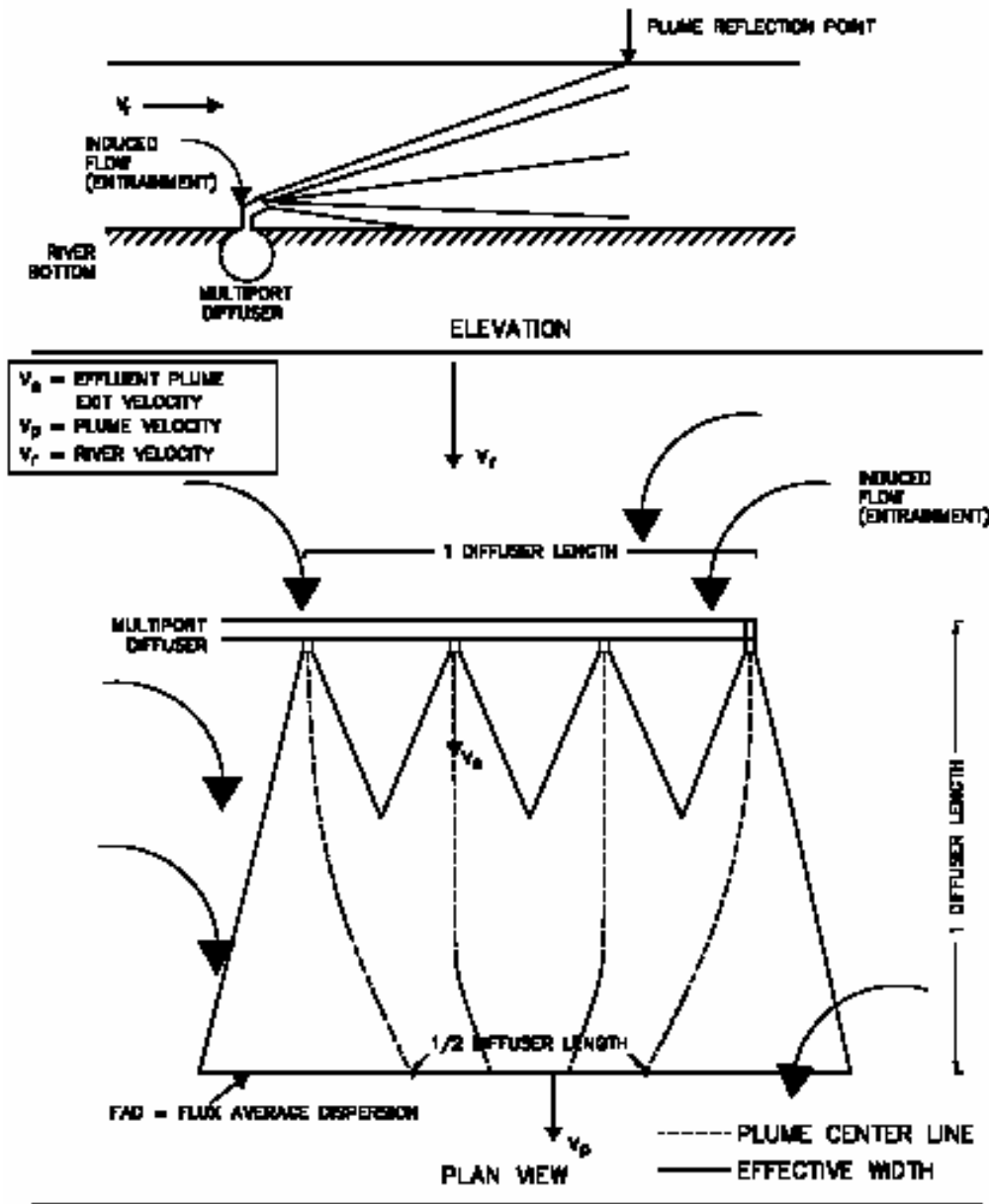
**FIGURE 2**  
 CLEAN WATER ACT OF 1987  
 WATER QUALITY-BASED TOXICS CONTROL

# Oregon Guidelines for Mixing Zones

- Shall be free of concentrations that cause acute toxicity. The Department may on a case by case basis establish a zone of immediate dilution if appropriate for other parameters (including acute and chronic toxicity)
- Shall be free of Nuisance materials
- Limits shall be described in the wastewater discharge permit.
- Avoid overlap with other mixing zones
- Not threaten public health
- Minimize adverse effects on other designated beneficial uses outside the mixing zone

\*From “Water Pollution; Division 41; ‘Statewide Water Quality Management Plan; Beneficial Uses, Policies, Standards and Treatment Criteria for Oregon”

## 2. Conceptual Dispersion From a Multiport Diffuser



Provide rapid and immediate dispersion of effluents to prevent adverse effects to the receiving stream

### 3. Purpose of Mixing Zones

- Achieve Maximum Dispersion in Smallest Area
- Minimize Effects on Receiving Water
- Minimize Acute and Chronic Toxicity in Receiving Stream
- Meet Narrative Water Quality Standards
- Provide Maximum Protection for Receiving Stream
- Maintain Zone of Passage for Fish
- Meet ODEQ Narrative Mixing Zone Requirements
- Meet US EPA TSD Guidance

## Zone of Initial Dilution (ZID) - Acute

- ZID is part of Near Field Mixing
- Limited Impact Area
  - Still provides for upstream mixing in tidal situations
- Rapid and Immediate
- Based on Protective Concentrations for Short-term (1 Hour) Exposure (Daily Maximum Concentration)
- Critical time periods occur around low slack water and high slack water

# Zone of Initial Dilution (ZID) Cont'd

- Use EPA TSD Guidance
  - Use a high velocity diffuser  $\geq 10$ ft/sec to limit exposure to only a few minutes
  - Criterion Maximum Concentration (CMC) standards met:
    - 10% of distance from edge of outfall to edge of mixing zone in any spatial direction
    - Within 50 times the square root of the cross-sectional area of a single port in any spatial direction
    - Within distance of 5 times the local water depth in any spatial direction
    - Spatial is defined in the TSD as a discharge length scale or in the direction of flow. This is also mathematically defined along the centerline of the plume
- Hydraulically on the Order of 1 Diffuser Length (i.e., +/- 0.5 to 1.5 diffuser lengths, but dependent on ambient velocity). Cormix calculates the jet momentum zone to end at the 0.5 diffuser length



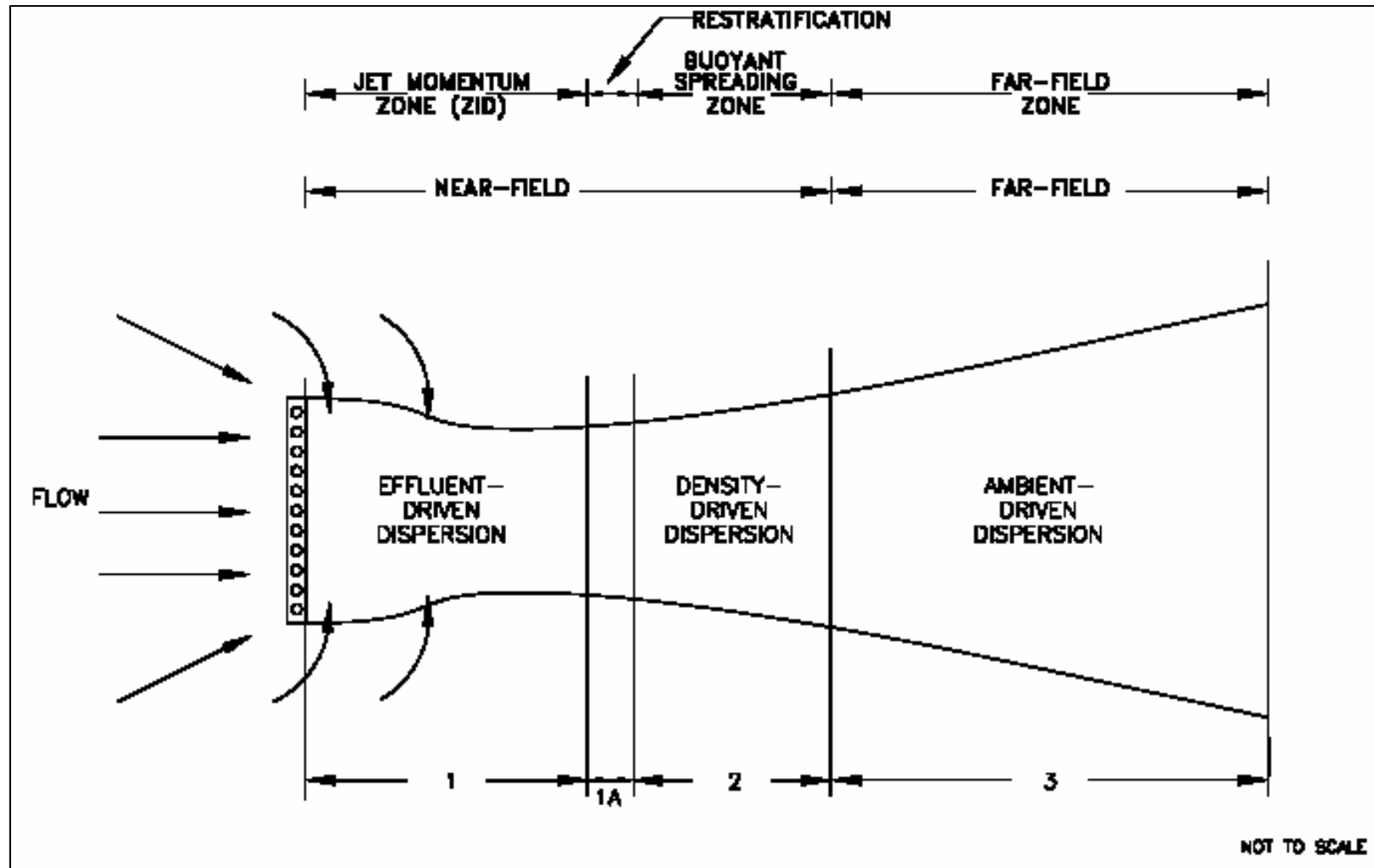
## Total Mixing Zone (Chronic)

- TMZ is Far-field
- Far-field extends until effluent totally mixed with receiving stream
- Criterion Continuous Concentration (CCC) to be met at edge of this zone
- Zone of free passage limits TMZ

## 4. How is Mixing Zone Size Determined?

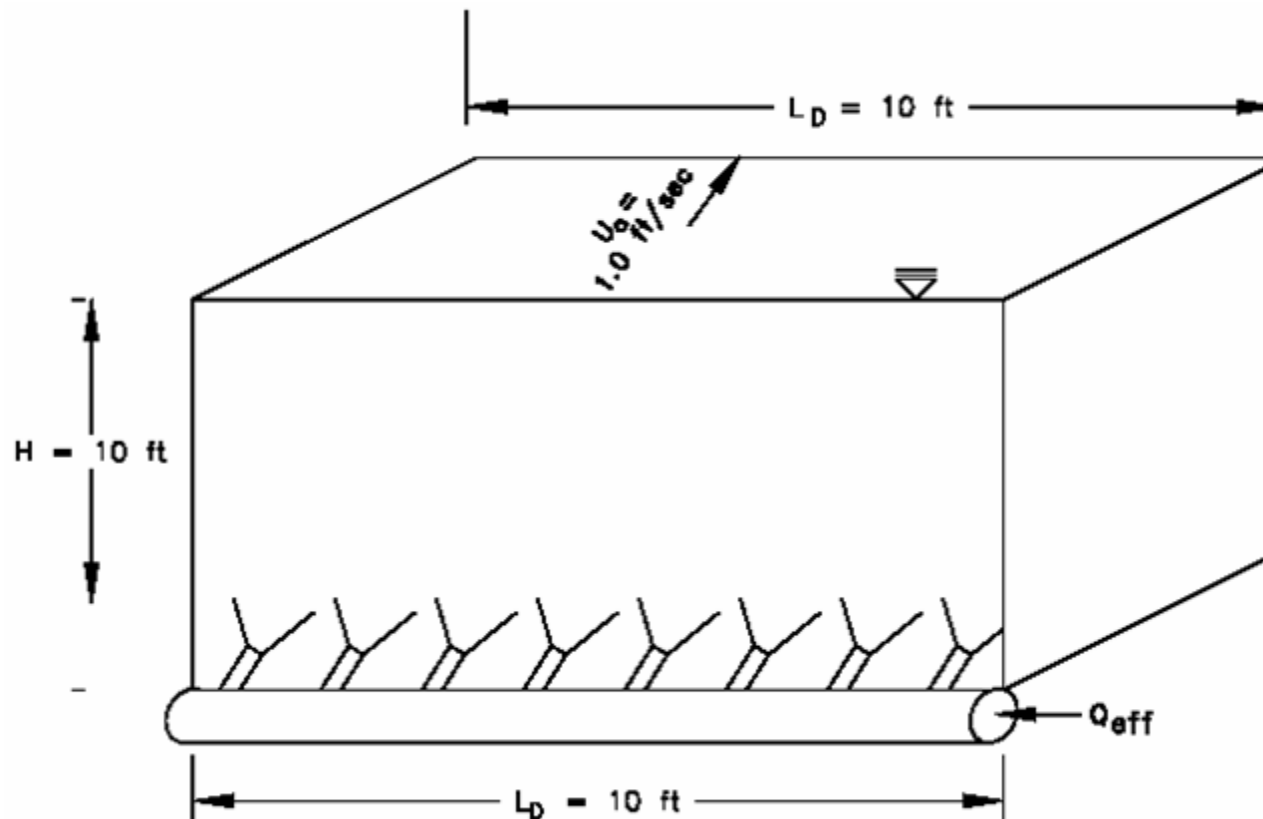
- Technical Support Document for Water Quality-based Toxics Control provides guidance (TSD)
- ZID is Limited to a downstream time of exposure length to a few minutes (~ 3 min)
- TMZ must allow free zone of passage

## 5. Hydraulic Mixing Zone Concepts



- To Define the Dispersion from Effluent Momentum and Ambient Diffusion

# Bulk Dispersion Analysis

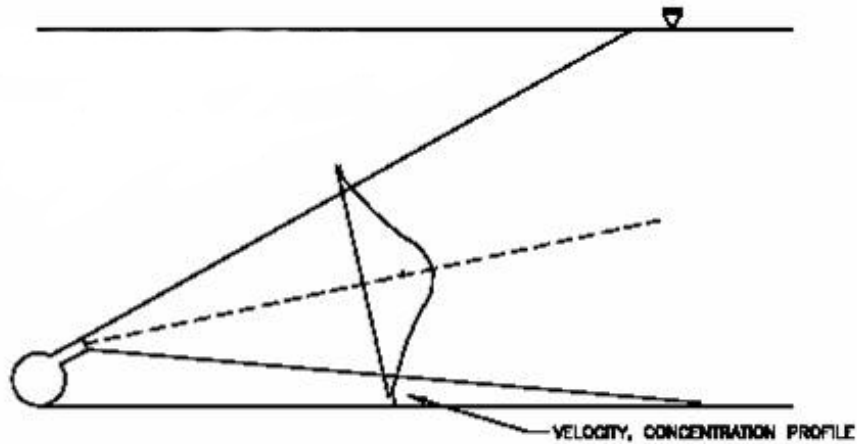


ESTIMATE OF DISPERSION =  $\frac{(U_0 \cdot H \cdot L_D) + Q_{\text{eff}}}{Q_{\text{eff}}} = \frac{(1.0 \text{ ft/sec} \cdot 10 \text{ ft} \cdot 10 \text{ ft}) + 5 \text{ cfs}}{5 \text{ cfs}} = \frac{105 \text{ cfs}}{5 \text{ cfs}} = 21:1$

NOT TO SCALE

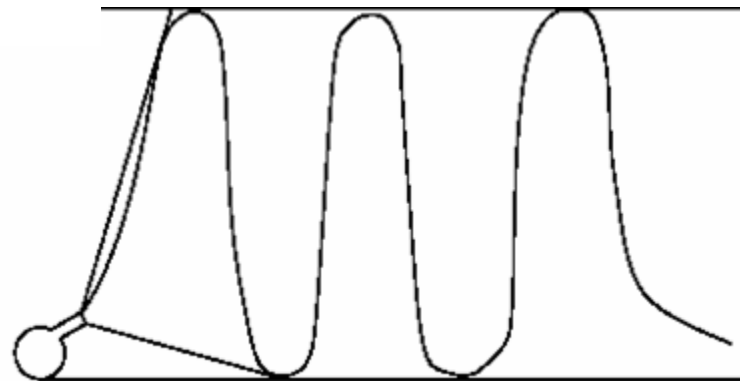
# Plume Stability Analysis

## STABLE (GAUSSIAN) PLUME



VELOCITY  
CONCENTRATION  
PROFILE

## UNSTABLE PLUME



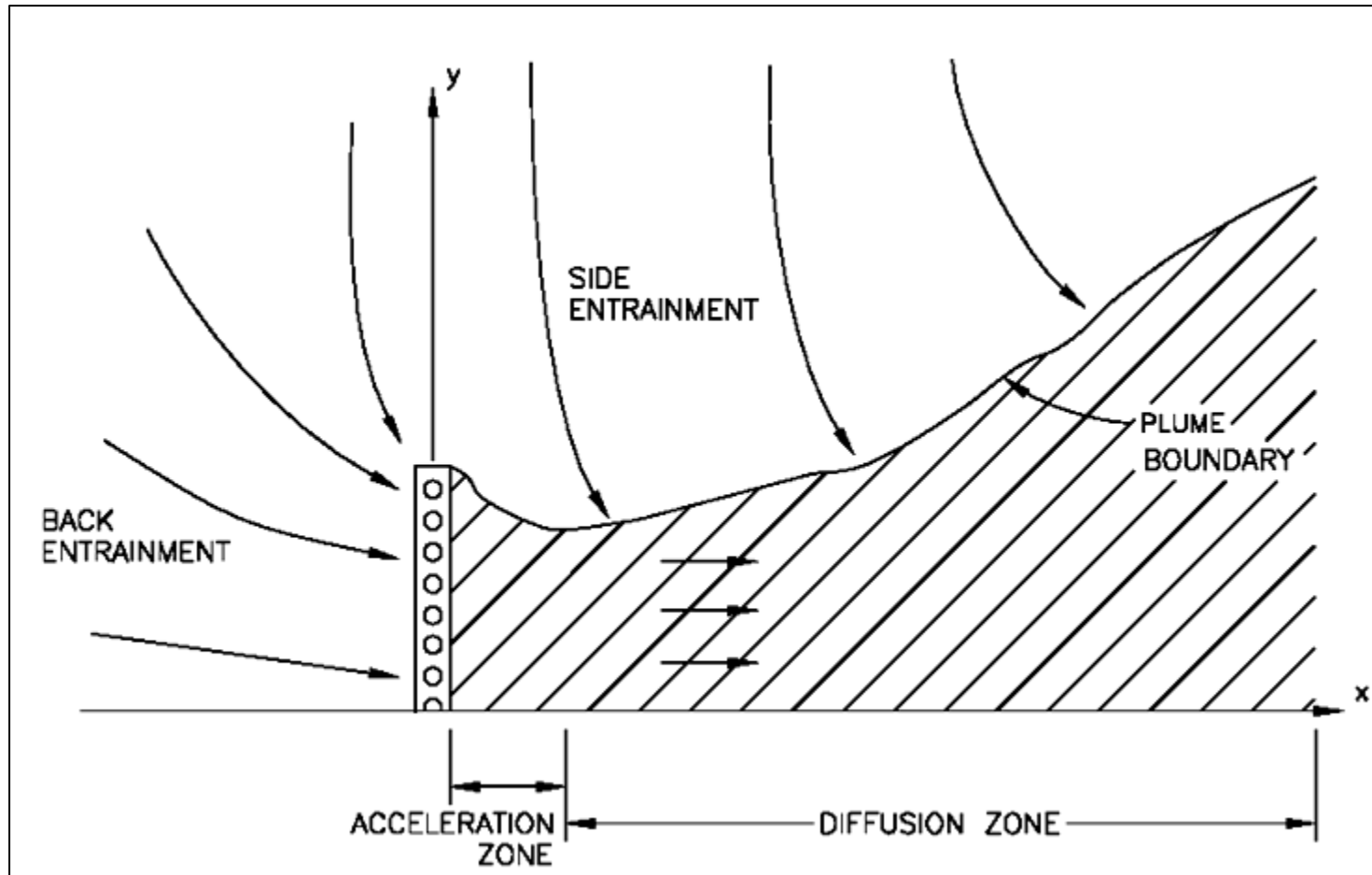
## Stable Plume Characteristics

- Propagates downstream in a well-defined conical fashion
- Grows in size until effluent is mixed top-to-bottom over the entire water column
- Similar to analogy of a garden hose discharging into a swimming pool

# Unstable Plume Characteristics

- Demonstrates a turbulent centerline trajectory
- Tends to mix top-to-bottom within a very short distance downstream from the diffuser
- Similar to analogy of a garden hose discharging into a small bucket

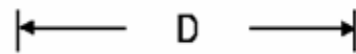
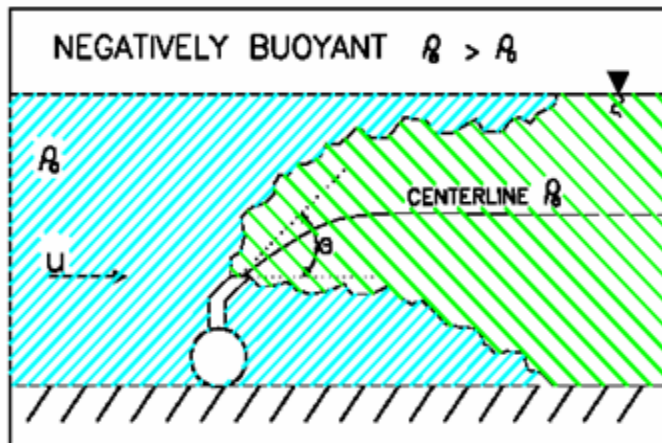
# Entrainment of Water (1/2 Plume)





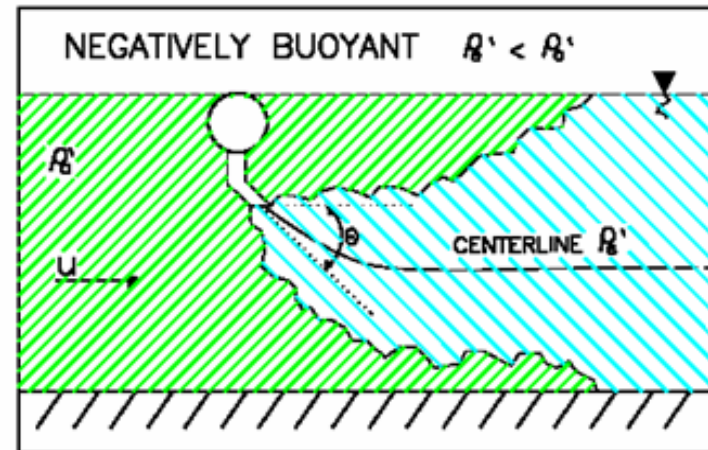
# Modeling Negatively Buoyant Plumes

ACTUAL SITUATION



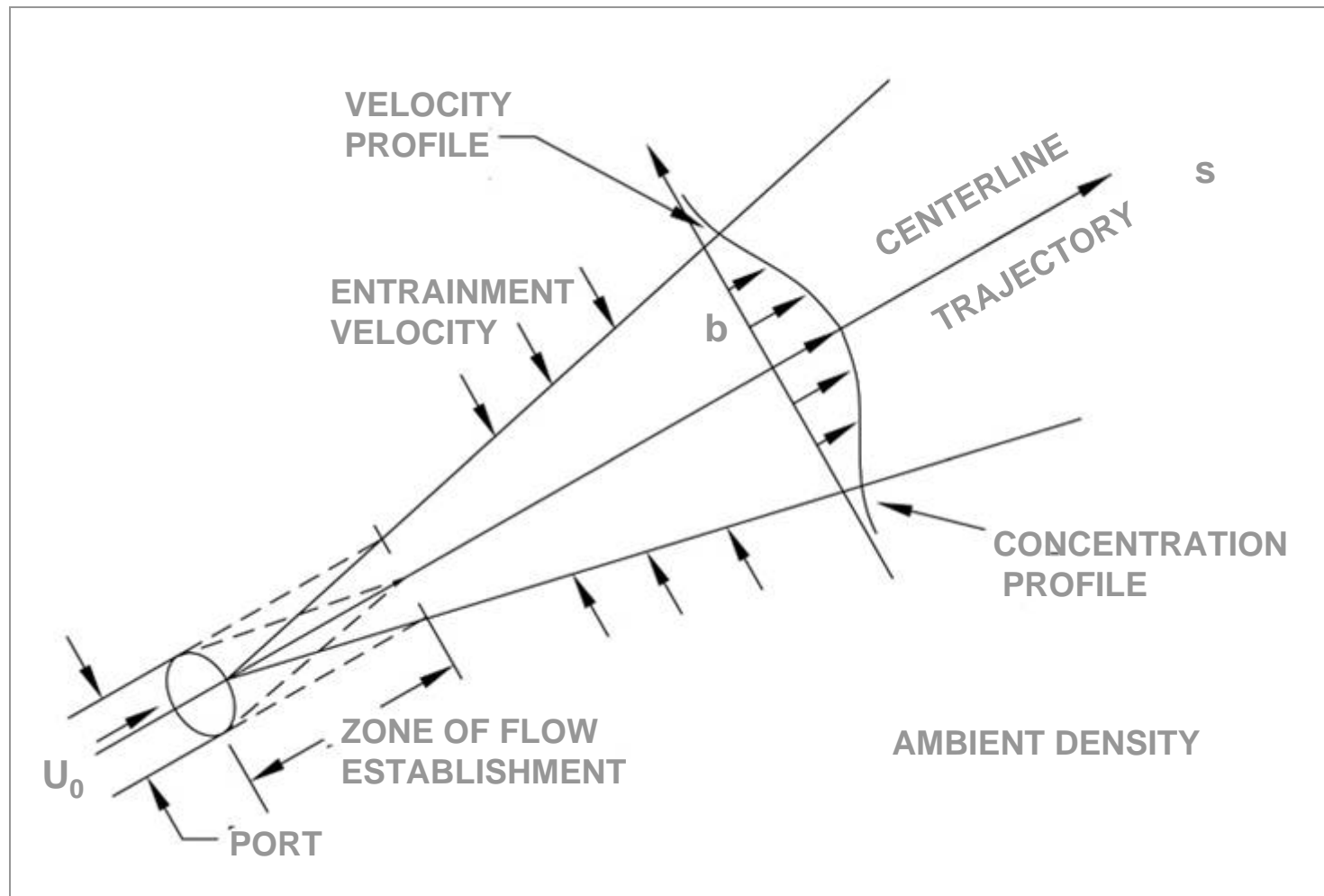
- $\rho_a$  = Ambient Density
- $\rho_d$  = Discharge Density
- $U$  = Ambient Velocity
- $D$  = Distance Where Plume Height = Water Depth
- $\theta$  = Port Discharge Angle

MODEL SIMULATION



- $\rho'_a = \rho_a$
- $\rho'_d = \rho_d$
- $U$  = Ambient Velocity
- $D$  = Distance Where Plume Height = Water Depth
- $-\theta$  = Port Discharge Angle

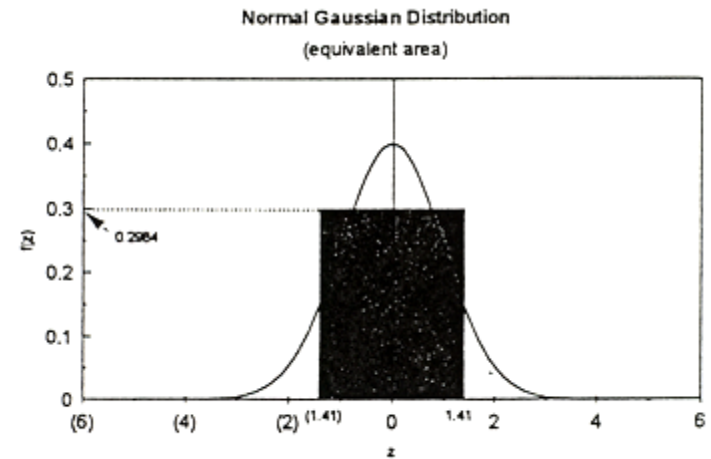
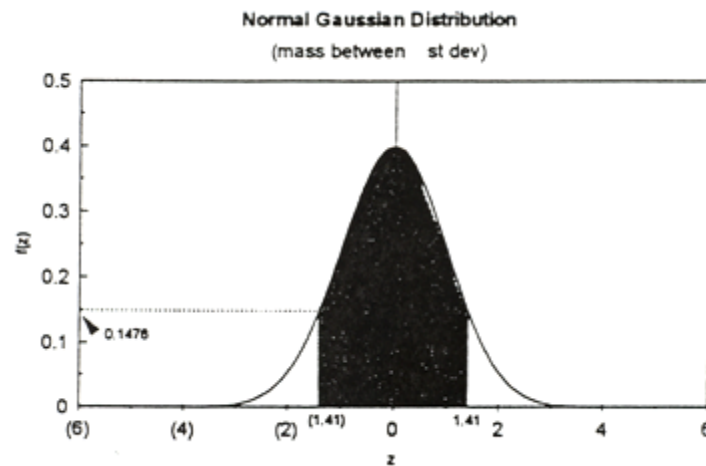
# UDKHDEN Plume Analysis (Plan View)



# UDKHDEN Dispersion Model

- Accounts for a zone of flow establishment
- Assumes an approximate Gaussian plume face in JMZ
- Mathematically develops the JMZ dispersion in three zones
  - Zone of Flow Establishment
  - Zone of Established Flow
  - Zone of Merging

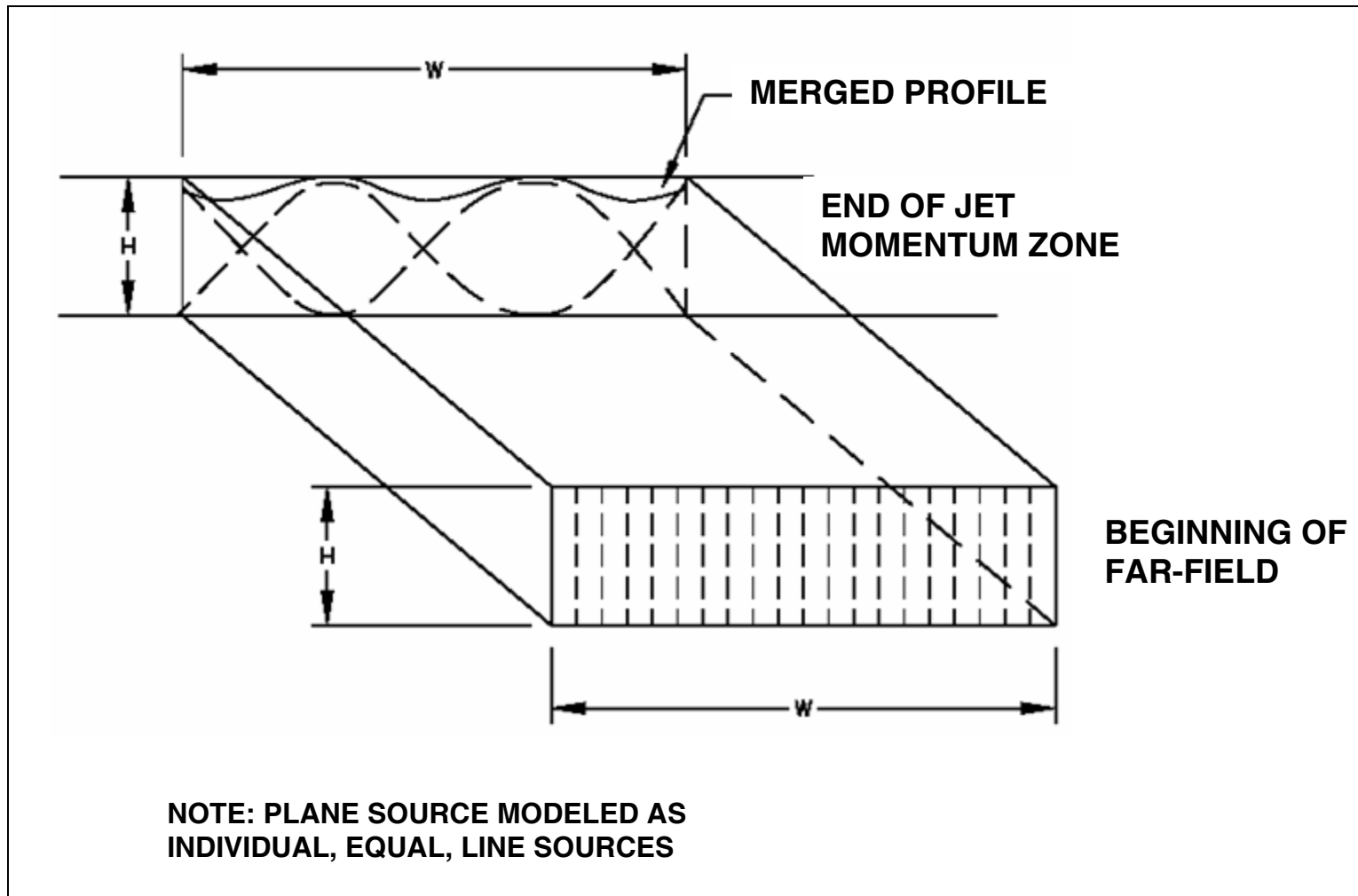
# Equivalent Areas (“FAD”)



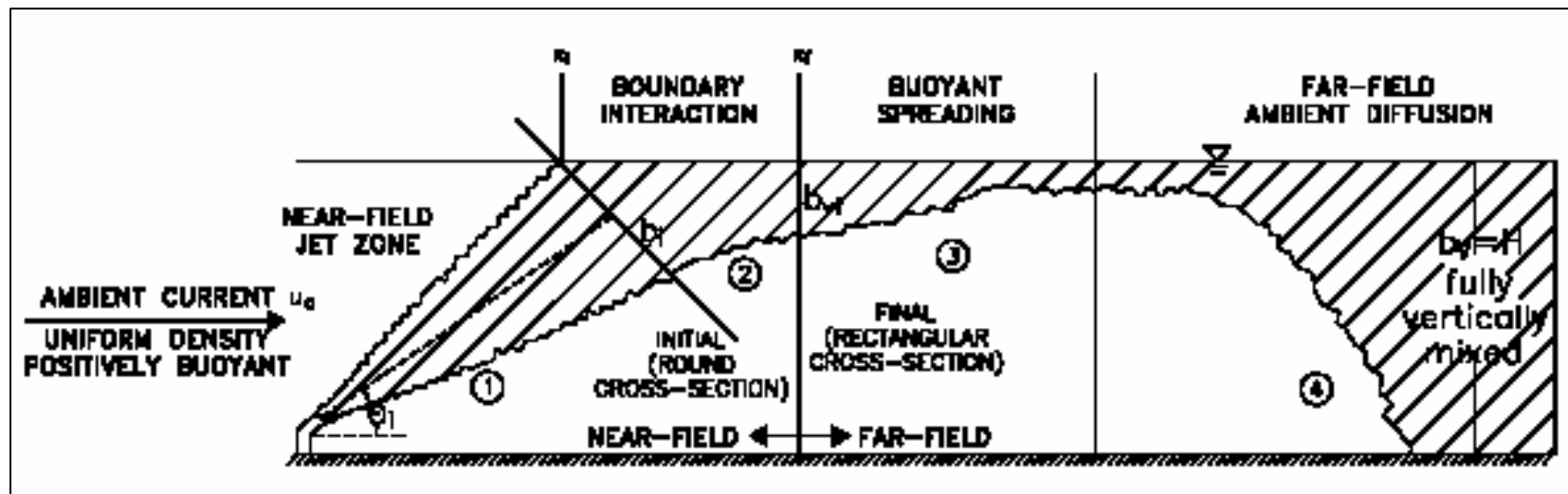
ZID-FAD = CENTERLINE DISPERSION / 0.7481 (+/- 1.41 SIGMA)

TMZ-FAD = CENTERLINE DISPERSION / 0.7909 (+/- 1.25 SIGMA)

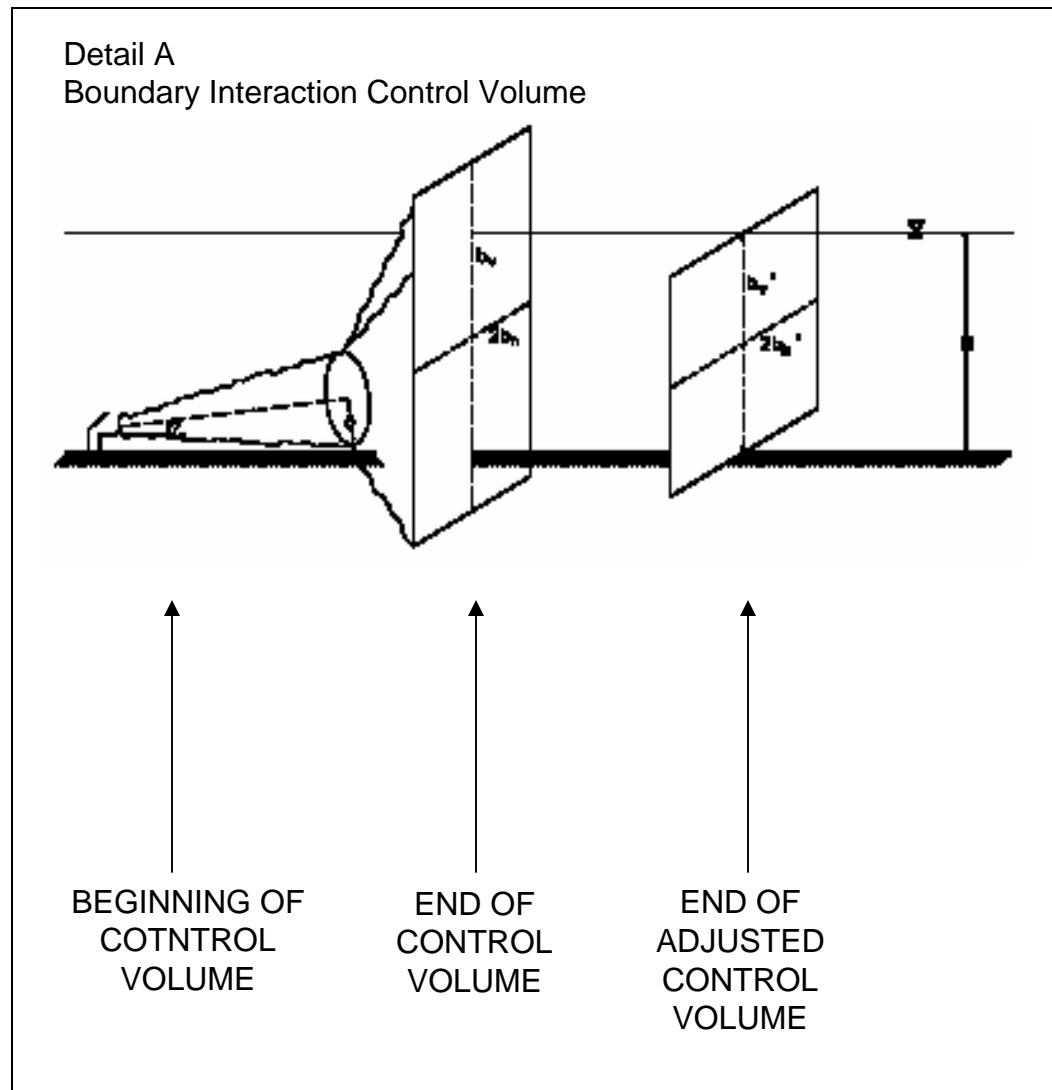
# Flux Concentration Modeled from UDKHDEN to BCV



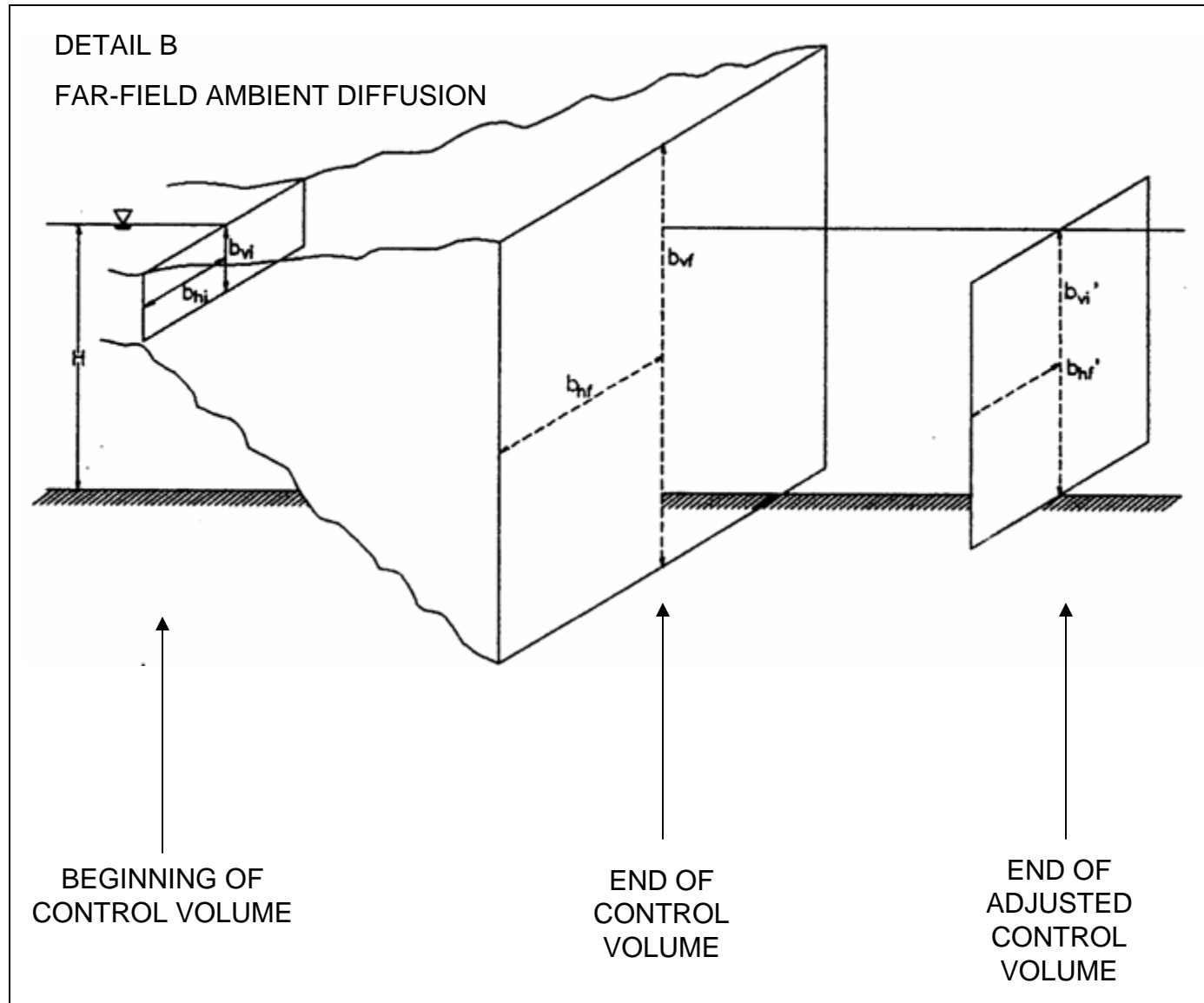
# CORMIX Schematic for Dispersion From a Diffuser



# CORMIX Schematic for Near-field Dispersion



# CORMIX Schematic for Far-field Dispersion

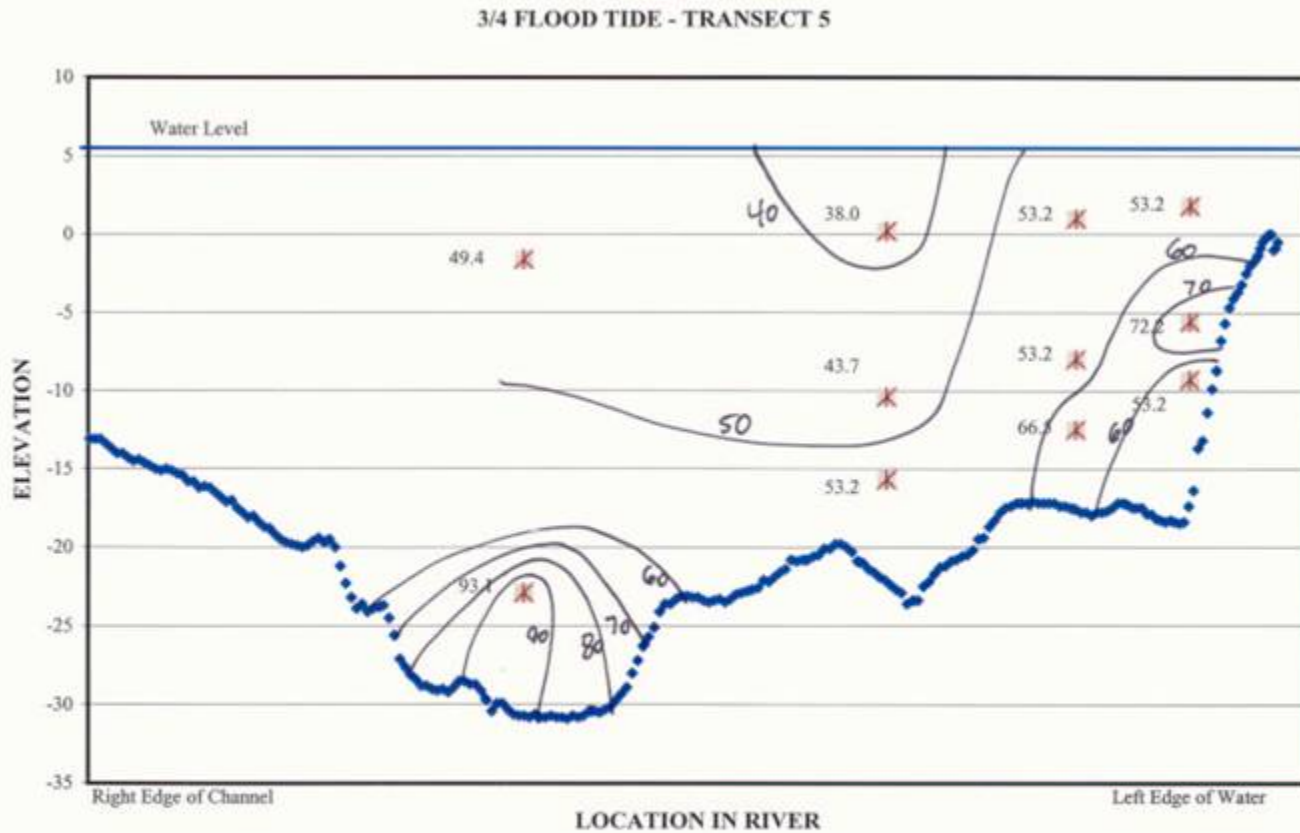




# Conducting a Field Tracer Study

- Bathymetry
- Effluent and Background Water Quality
- Tidal Stage and Velocity
- Dye Monitoring Over a Tidal Cycle
  - Monitor Water Column within the ODEQ specified ZID and the Hydraulic ZID
  - Monitor Surface within TMZ
- All equipment is used in conjunction with Global Positioning Satellite (GPS)

# Cross-section of Color



# Dye Dispersion



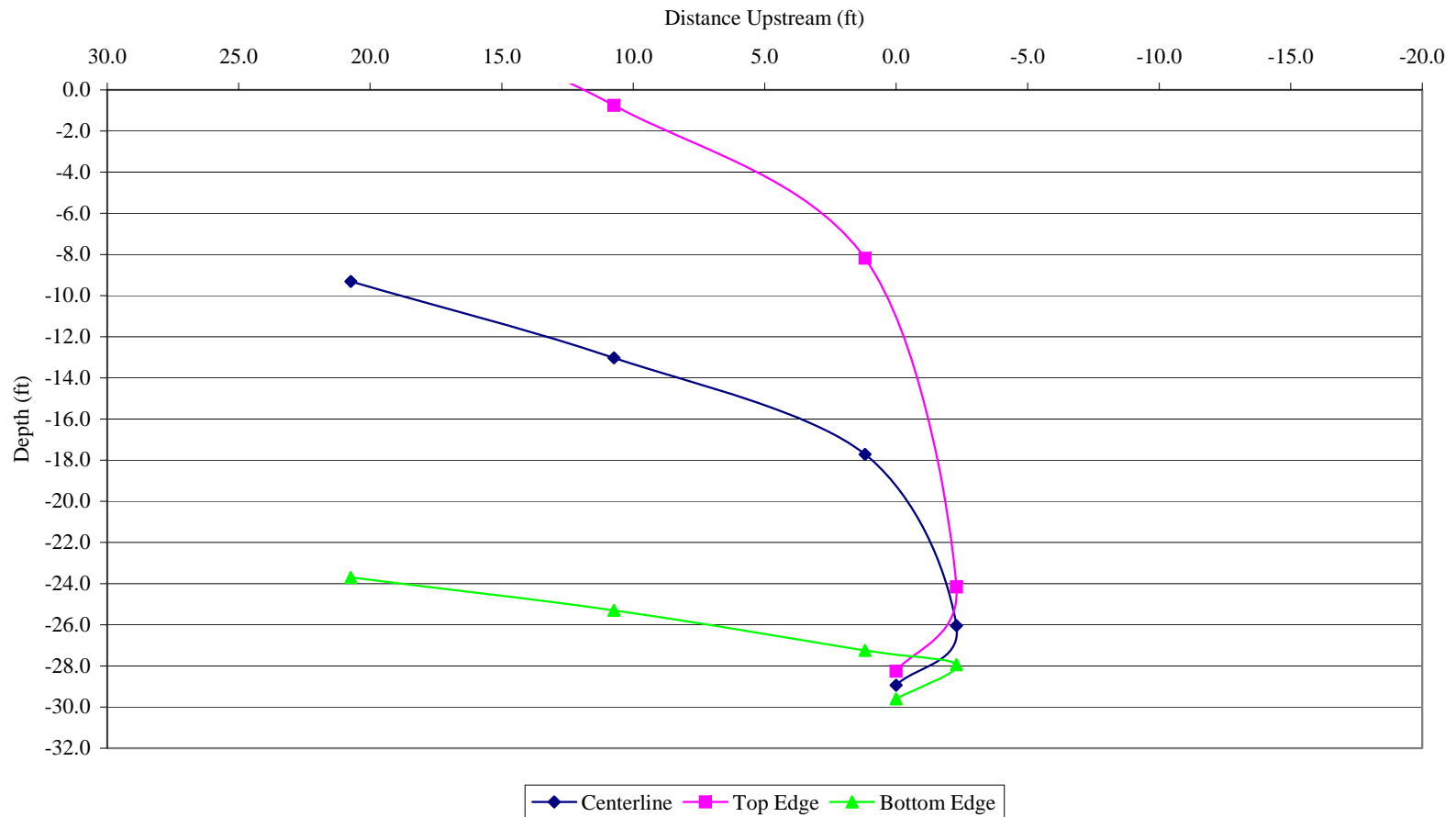
# Comparison of UDKHDEN Modeling To Field Results

## Georgia-Pacific – Brunswick, Georgia

Tidal Period	Time (hr)	Udkhden Modeling		Field Results		
		Distance DS (ft)	Dispersion (:1)	Down Stream Dispersion (:1)	Up Stream Dispersion (:1)	At Diffuser Dispersion (:1)
Low Tide	10.00	37.6	15.1	29.2	28.9	38.8
1/4 Flood	11.55	3.1	22.9	29.5	26.7	25.9
1/2 Flood	13.10	22.2	37.8	32.5	28.7	35.6
3/4 Flood	14.65	12.0	34.1	34.5	30.7	11.4
High Tide	16.20	-15.6	10.1	39.8	25.9	9.7
1/4 Ebb	17.75	87.5	55.0	28.7	27.7	31.6
1/2 Ebb	19.30	107.5	62.3	31.3	47.7	30.5
3/4 Ebb	20.85	78.0	44.0	34.5	25.0	40.7
<b>Average</b>			<b>35.2</b>	<b>32.5</b>	<b>30.2</b>	<b>28.0</b>

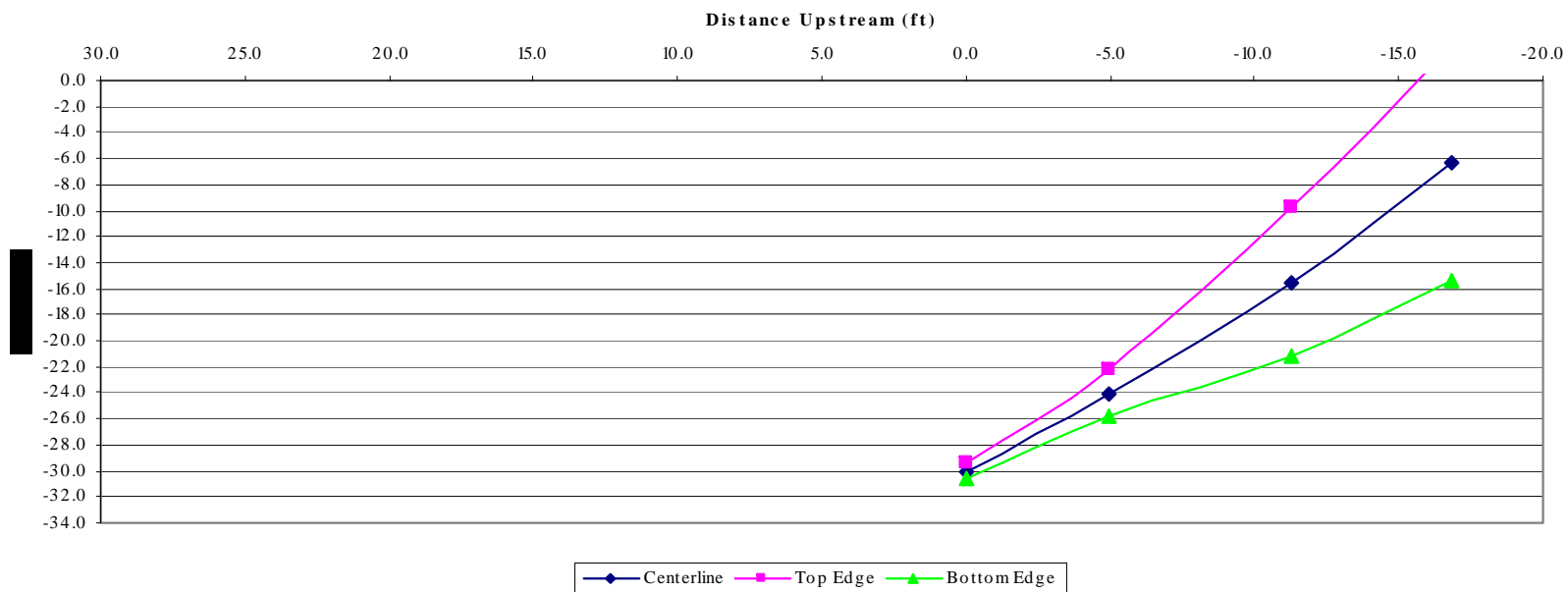
# GP Brunswick $\frac{3}{4}$ Flood Tide

Water Depth = 31.2 ft  
Velocity = -1.09 fps



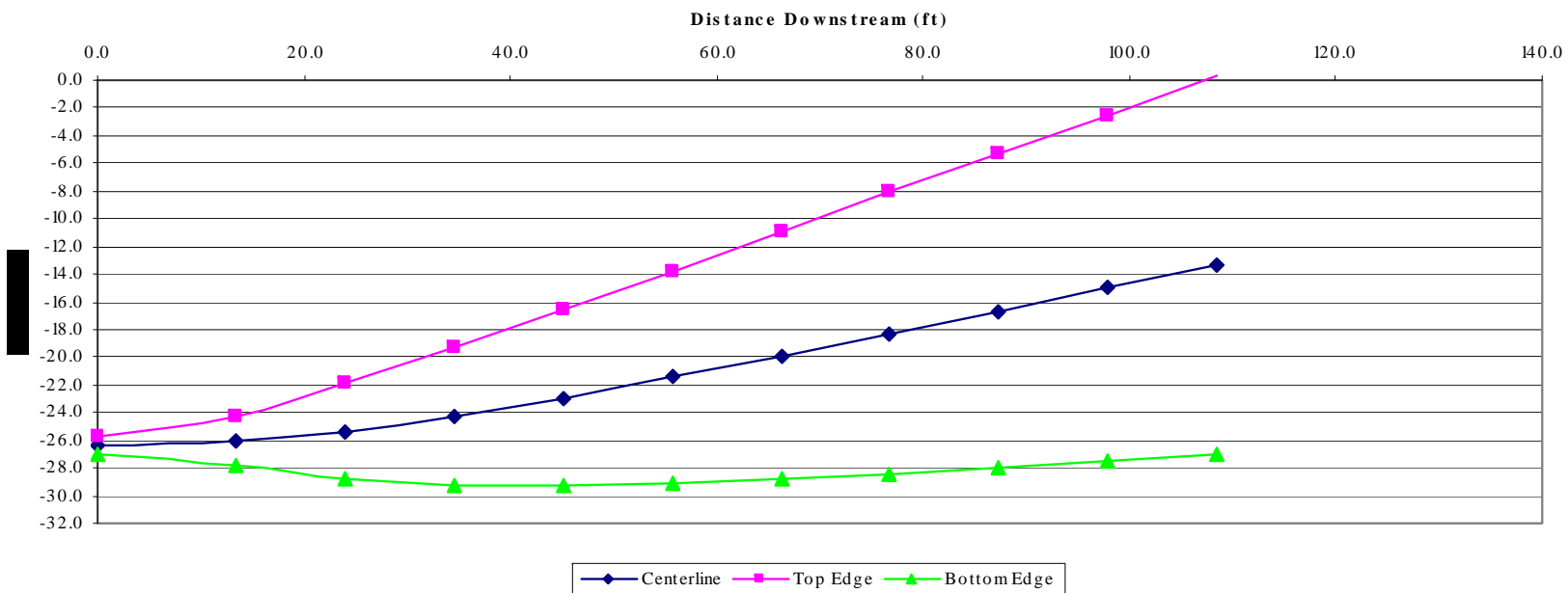
# GP Brunswick High Tide

Water Depth = 32.3 ft  
Velocity = 0.0 fps



# GP Brunswick 1/2 Ebb Tide

Water Depth = 28.6 ft  
Velocity = 1.51 fps



## 12. Calibration Procedure

- Models are typically within +/- 5% of actual measured values
- Re-entrainment based on dye studies are used to adjust to tidal conditions
- Re-entrainment can be mathematically projected



## 17. Biological Assessment

- Is toxicity caused by true toxicants or conversion of freshwater to saltwater?
- Benthological studies
  - Around diffuser
  - Background
- Fish collections or literature review
- Realize that freshwater is toxic to saltwater species

# Turtle River Estuary Bathymetry

