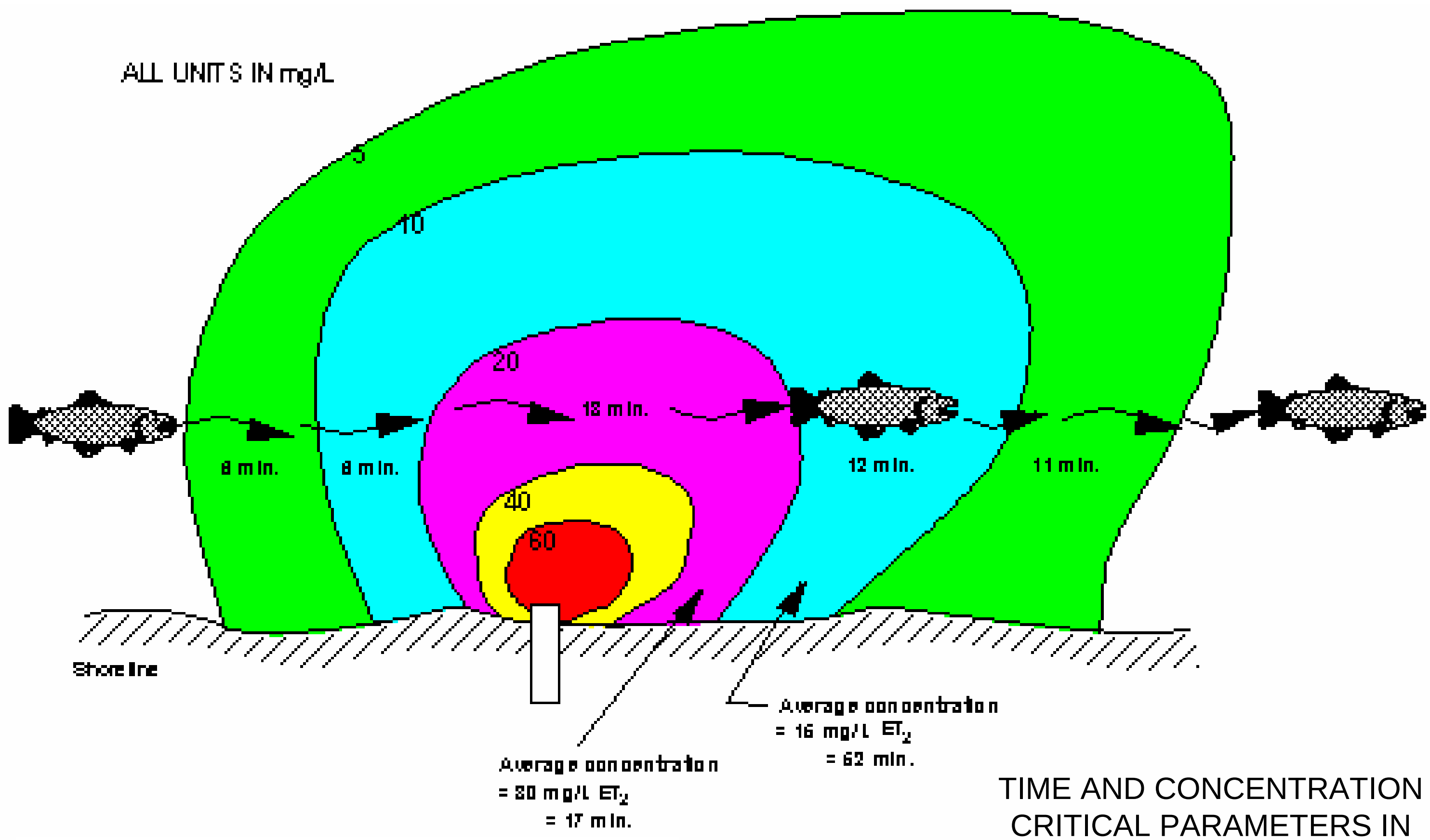
NPDES Permitting,

Mixing Zone and Water Quality Analyses

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

Why Do We Need Mixing Zones?



TIME AND CONCENTRATION CRITICAL PARAMETERS IN EXPOSURE SCENARIO

NATIONAL ACADEMY OF SCIENCES, WATER QUALITY COMMITTEE, 1972

HYPOTHETICAL EXPOSURE SCENARIO FOR FISH PASSING THROUGH A ZID

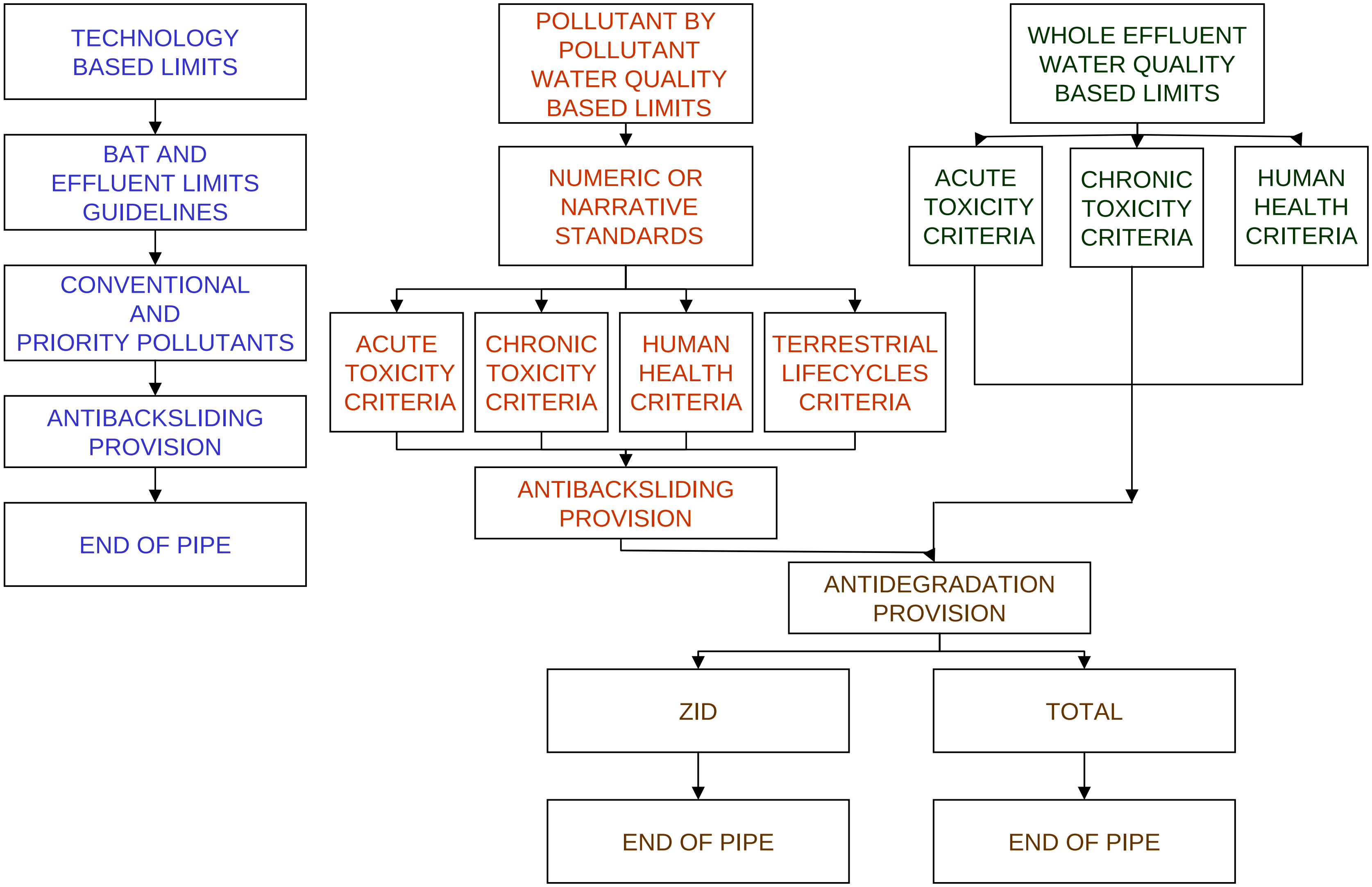
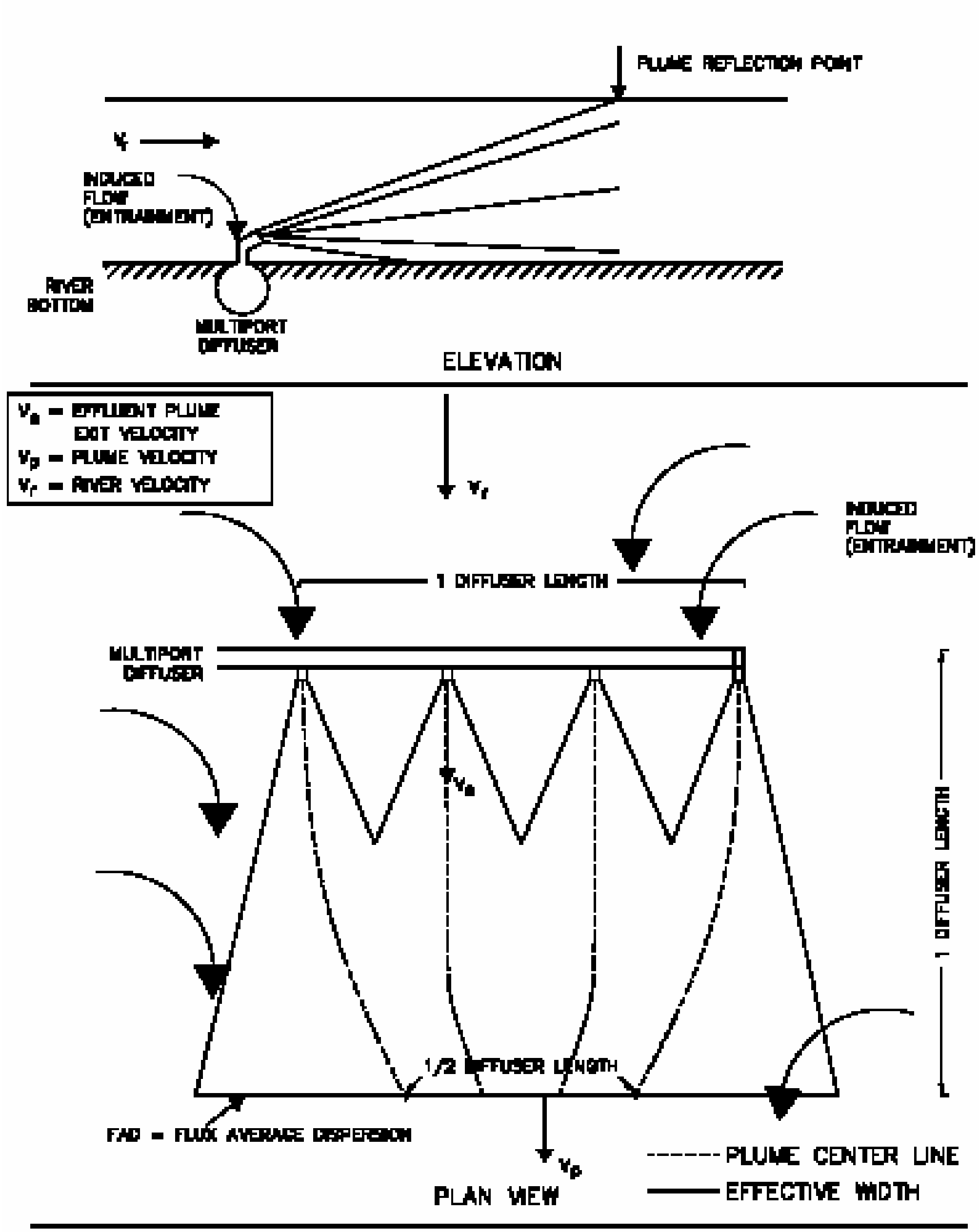


FIGURE 2
CLEAN WATER ACT OF 1987
WATER QUALITY-BASED TOXICS CONTROL

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 >/= 10ft/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

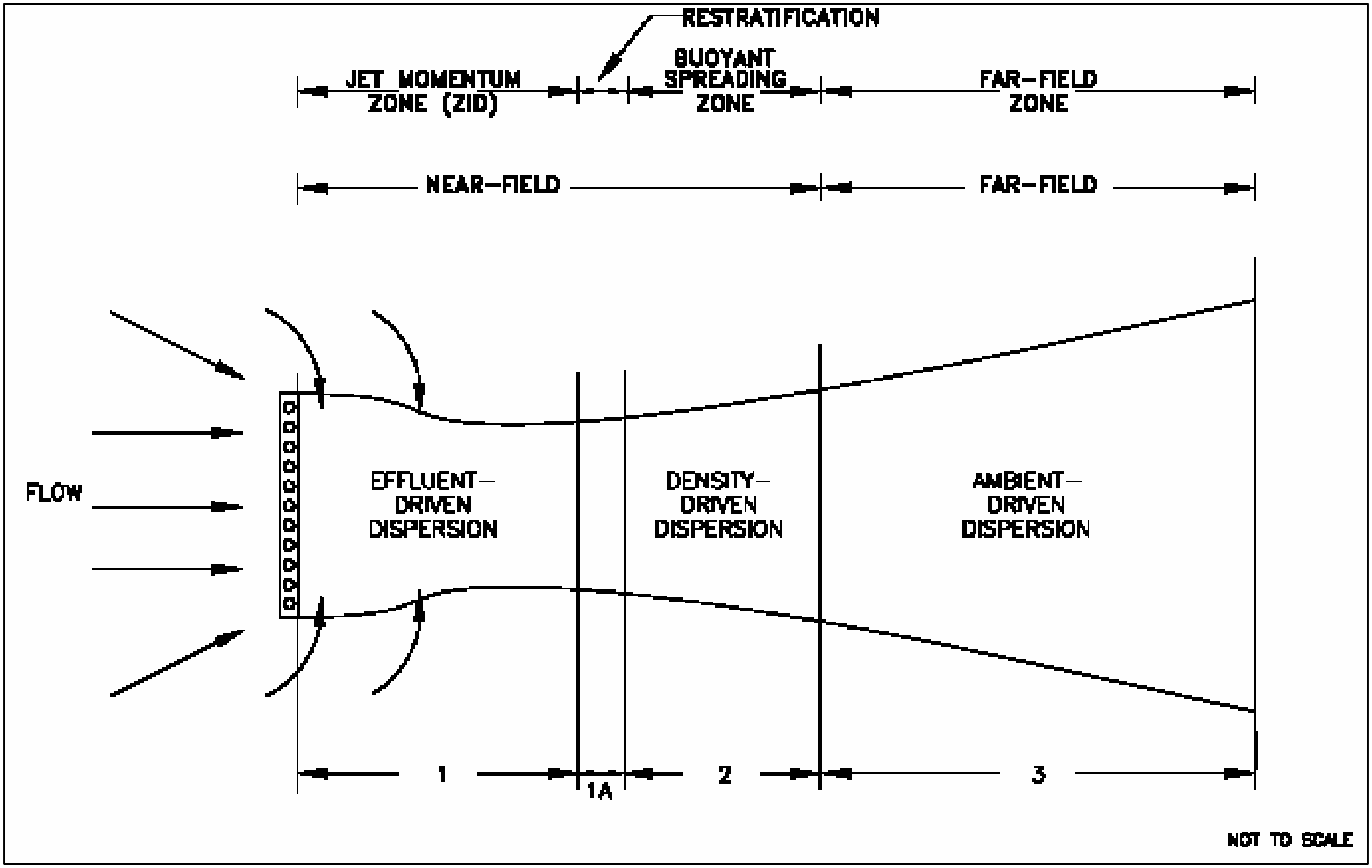
Total Mixing Zone (Chronic)

- 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?

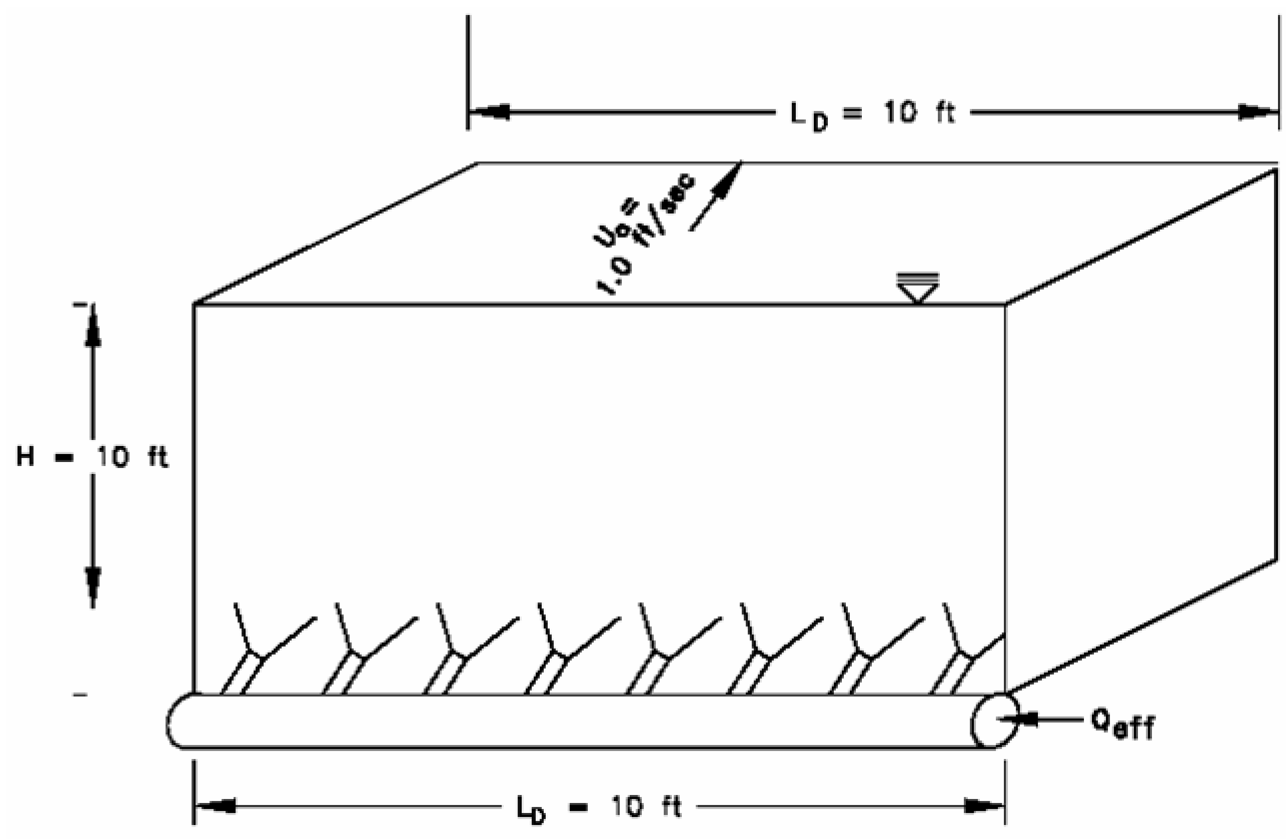
- Technical Support Document for Water Quality-based Toxics Control provides guidance (TSD)
- ZID is Limited to a downstream time of exposure length to a few minutes (~ 3 min)
- TMZ must allow free zone of passage

5. Hydraulic Mixing Zone Concepts



- To Define the Dispersion from Effluent Momentum and Ambient Diffusion

Bulk Dispersion Analysis

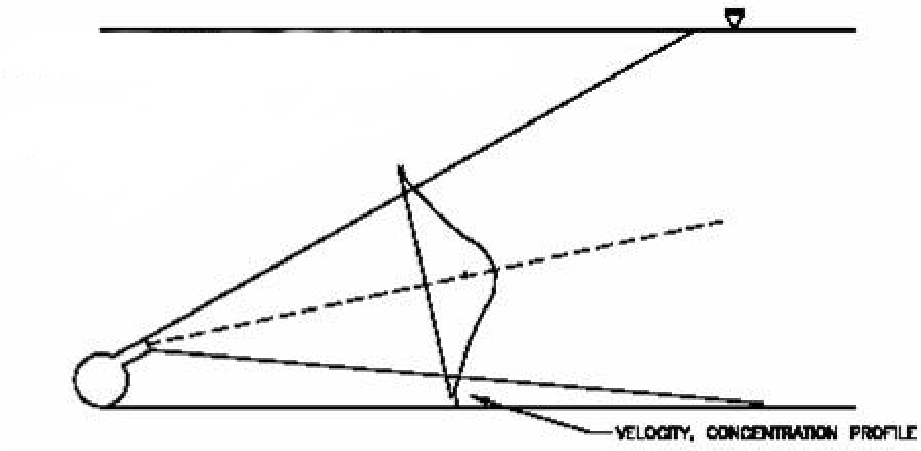


$$\text{ESTIMATE OF DISPERSION} = \frac{(U_o * H * L_D) + Q_{eff}}{Q_{eff}} = \frac{(1.0 \text{ ft/sec} * 10 \text{ ft} * 10 \text{ ft}) + 5 \text{ cfs}}{5 \text{ cfs}} = \frac{105 \text{ cfs}}{5 \text{ cfs}} = 21:1$$

NOT TO SCALE

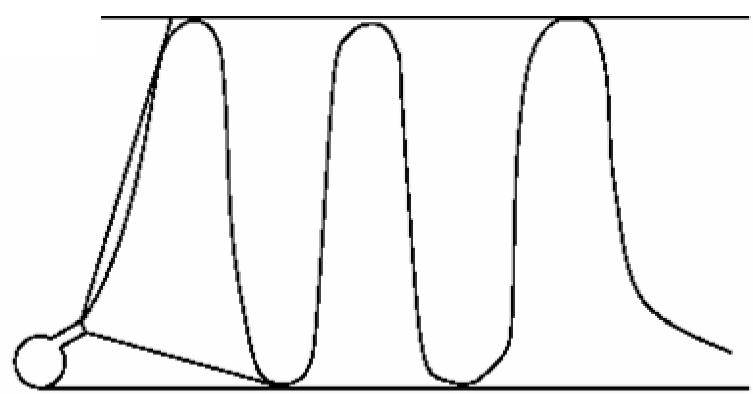
Plume Stability Analysis

STABLE (GAUSSIAN) PLUME



VELOCITY
CONCENTRATION
PROFILE

UNSTABLE PLUME



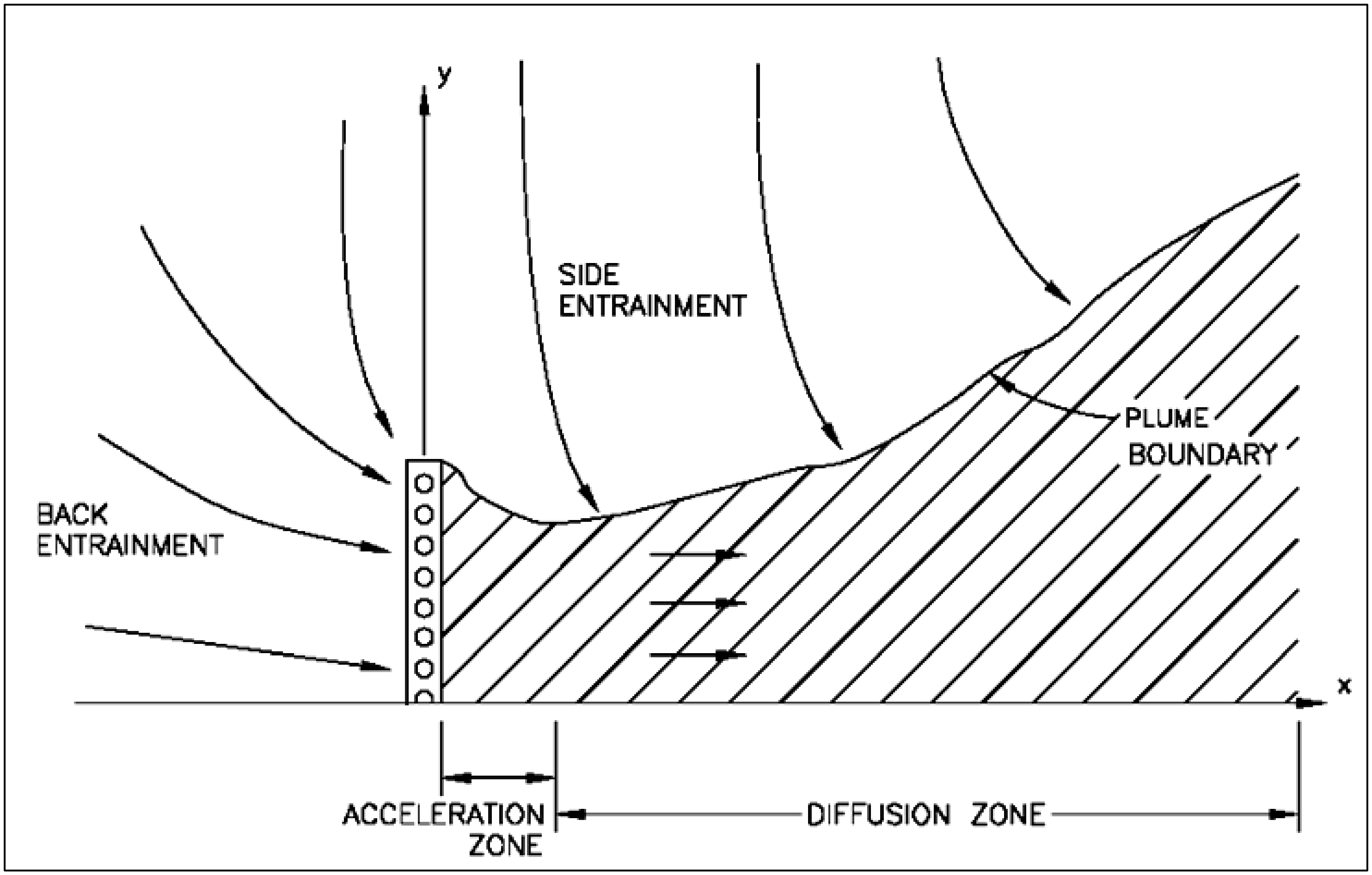
Stable Plume Characteristics

- 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

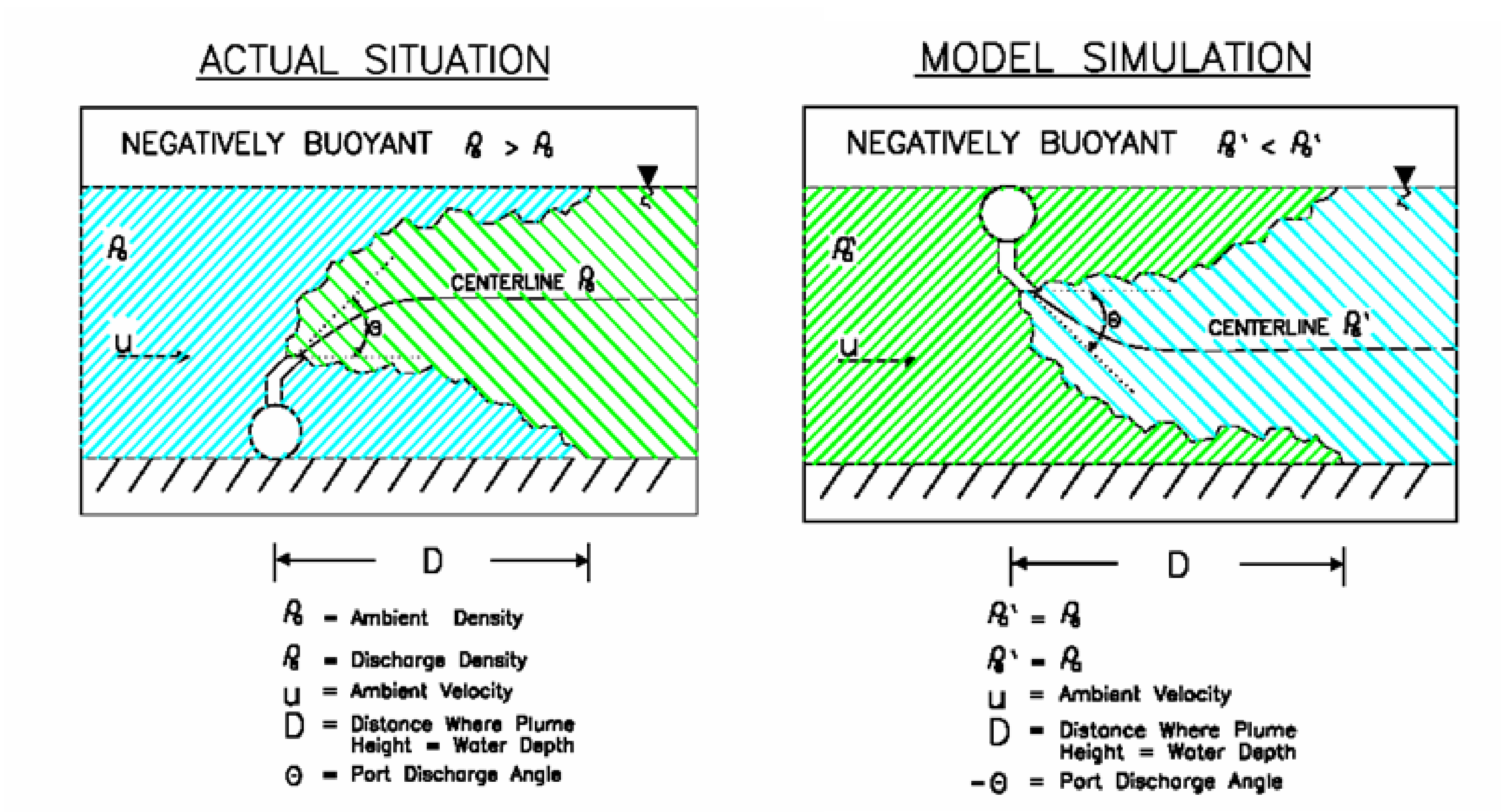
Unstable Plume Characteristics

- 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

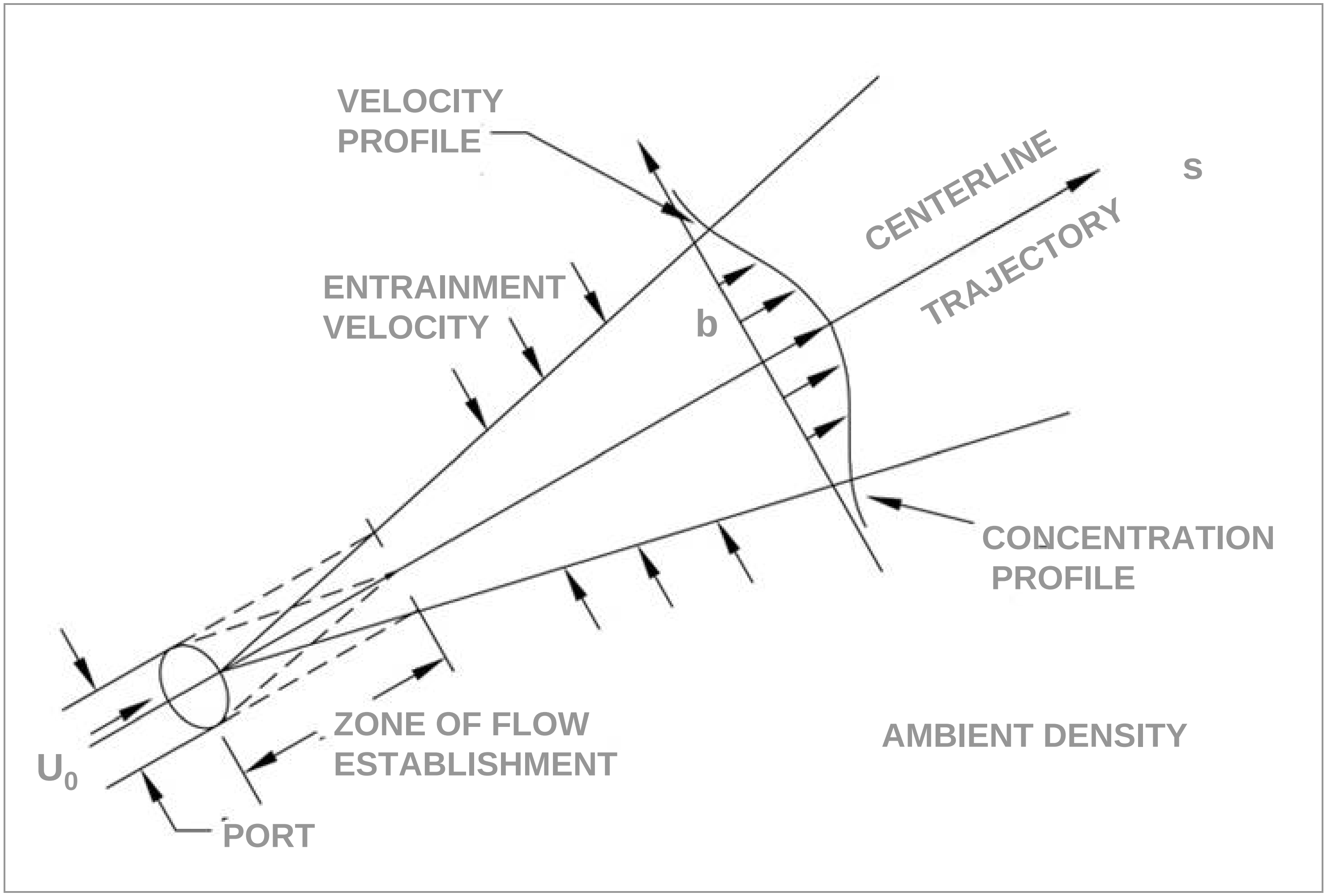
Entrainment of Water (1/2 Plume)



Modeling Negatively Buoyant Plumes



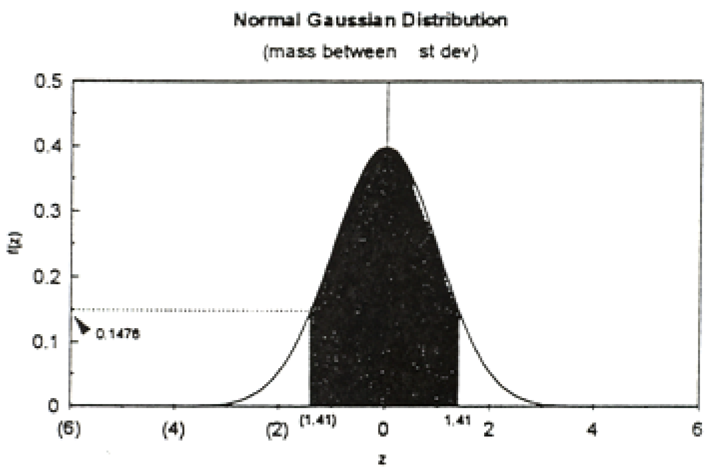
UDKHDEN Plume Analysis (Plan View)

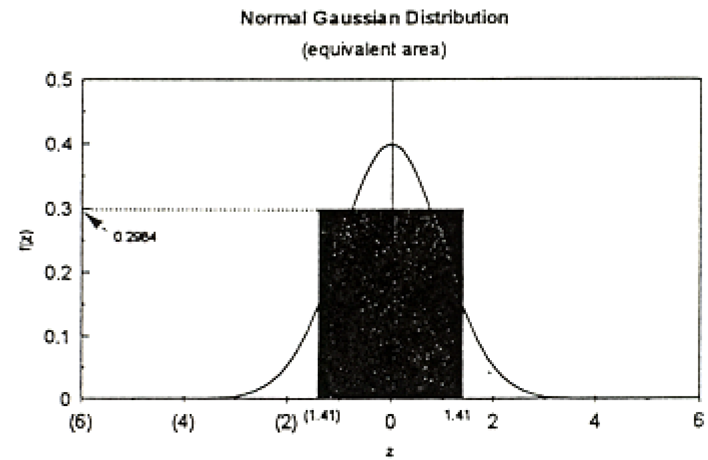


UDKHDEN Dispersion Model

- 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")

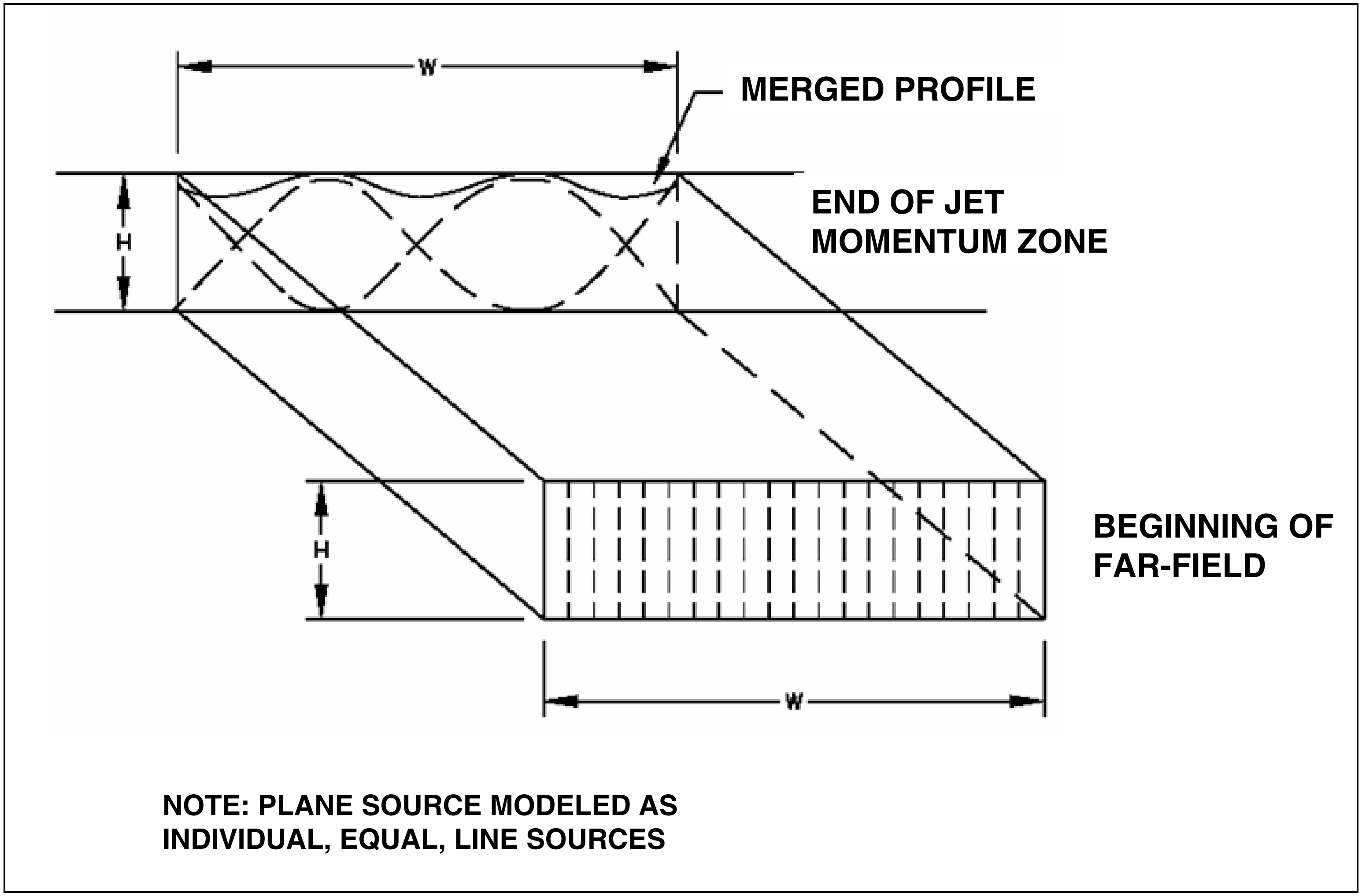




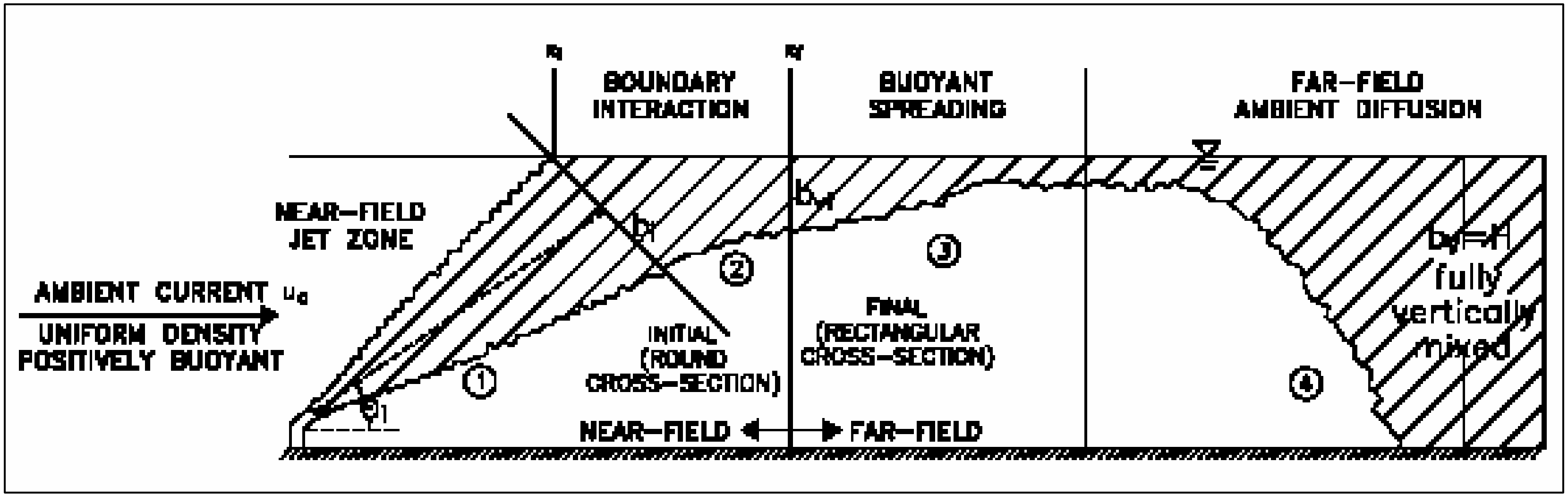
ZID-FAD = CENTERLINE DISPERSION / 0.7481 (+/- 1.41 SIGMA)

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

Flux Concentration Modeled from UDKHDEN to BCV

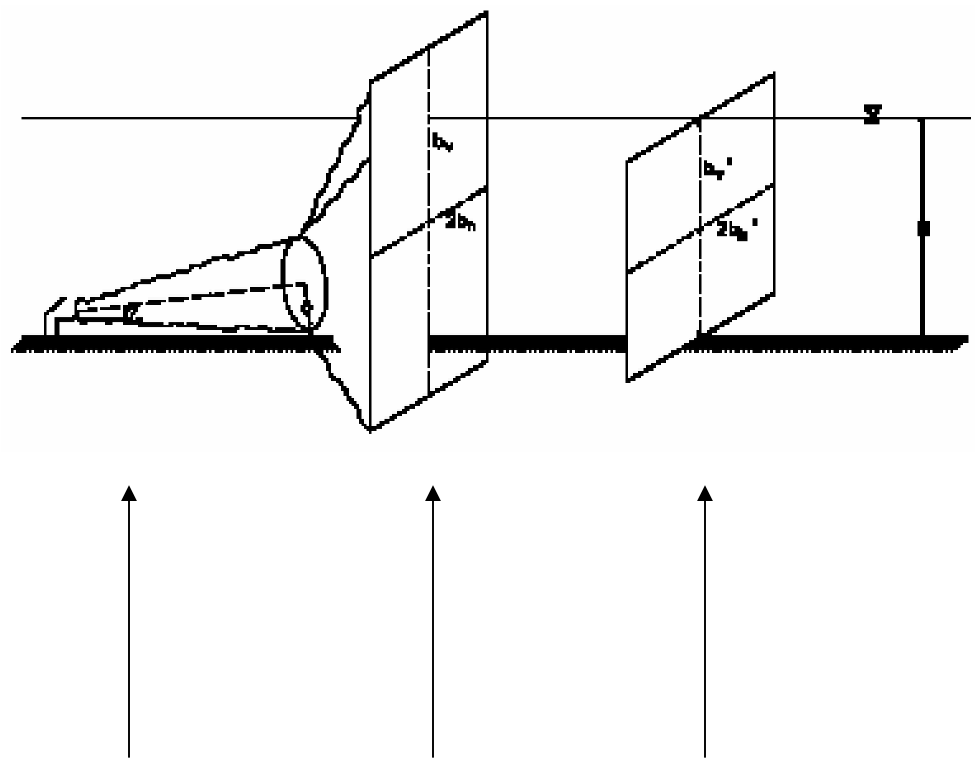


CORMIX Schematic for Dispersion From a Diffuser

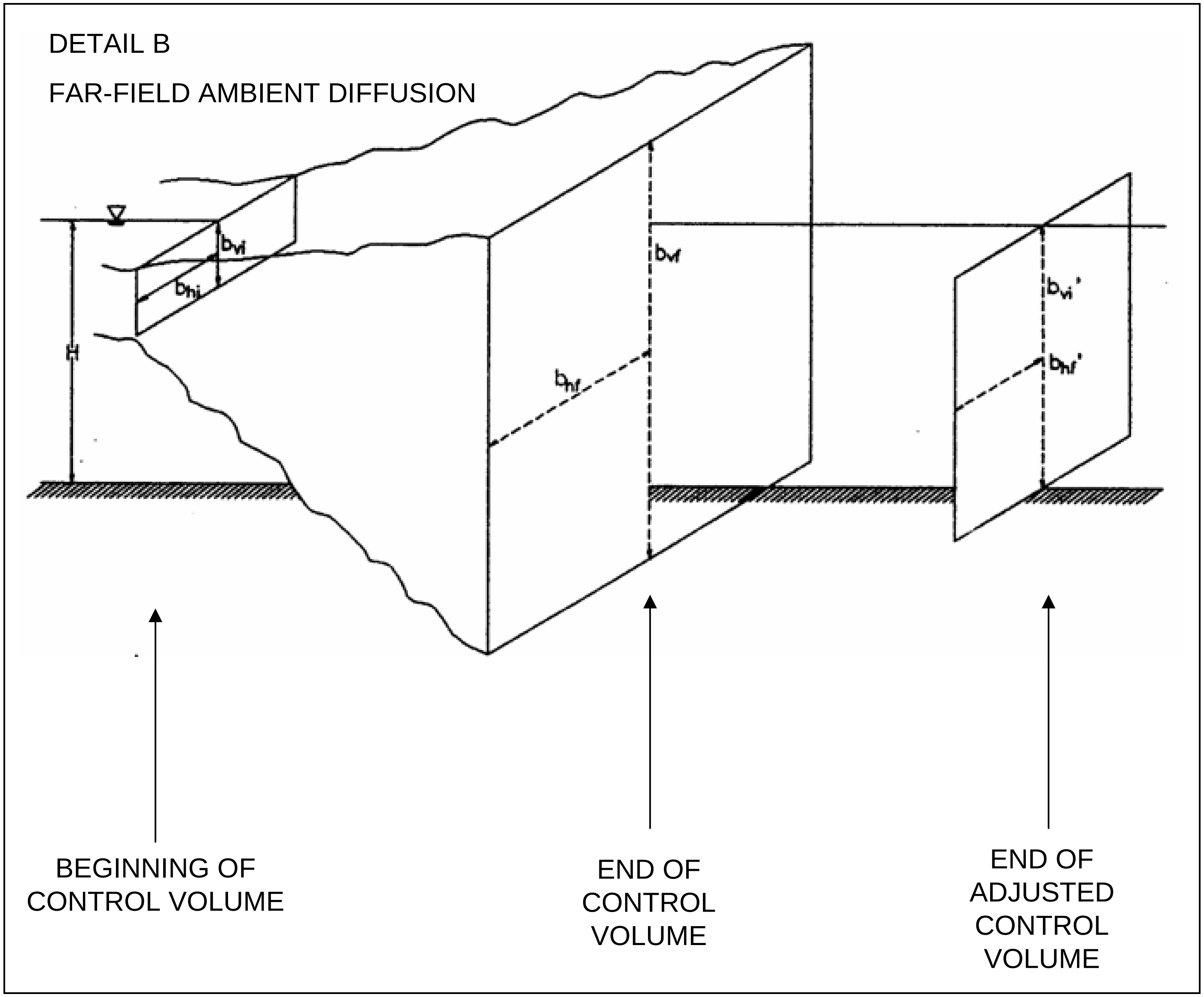


CORMIX Schematic for Near-field Dispersion

Detail A
Boundary Interaction Control Volume



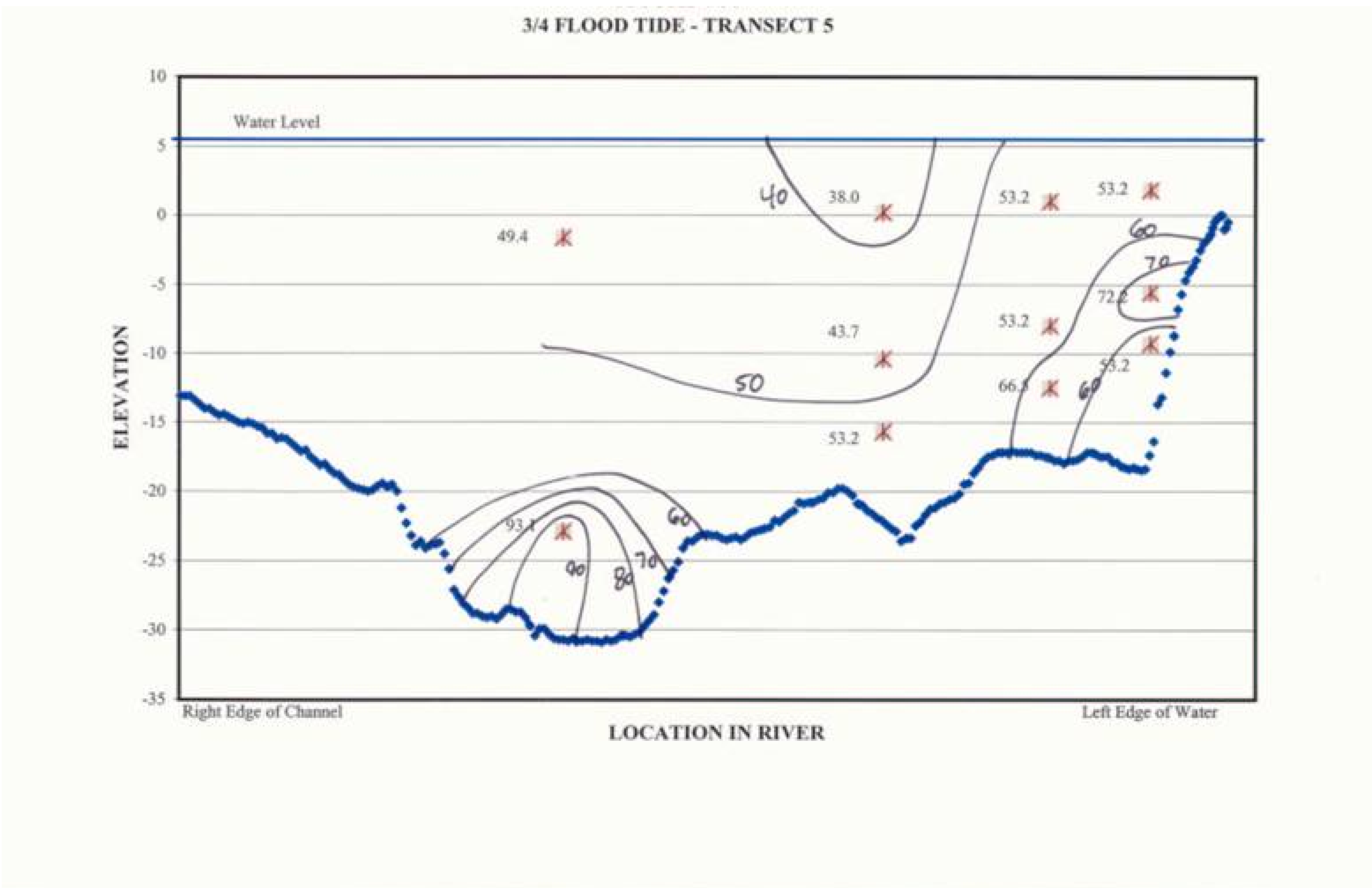
CORMIX Schematic for Far-field Dispersion



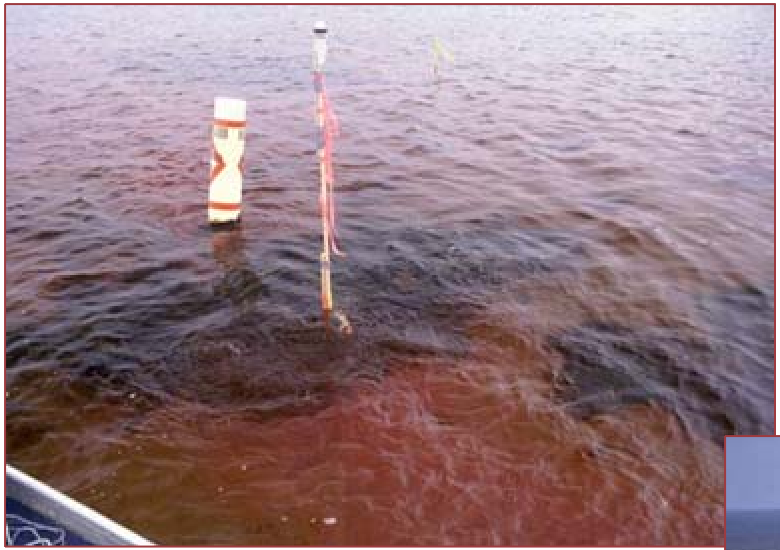
Conducting a Field Tracer Study

- 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

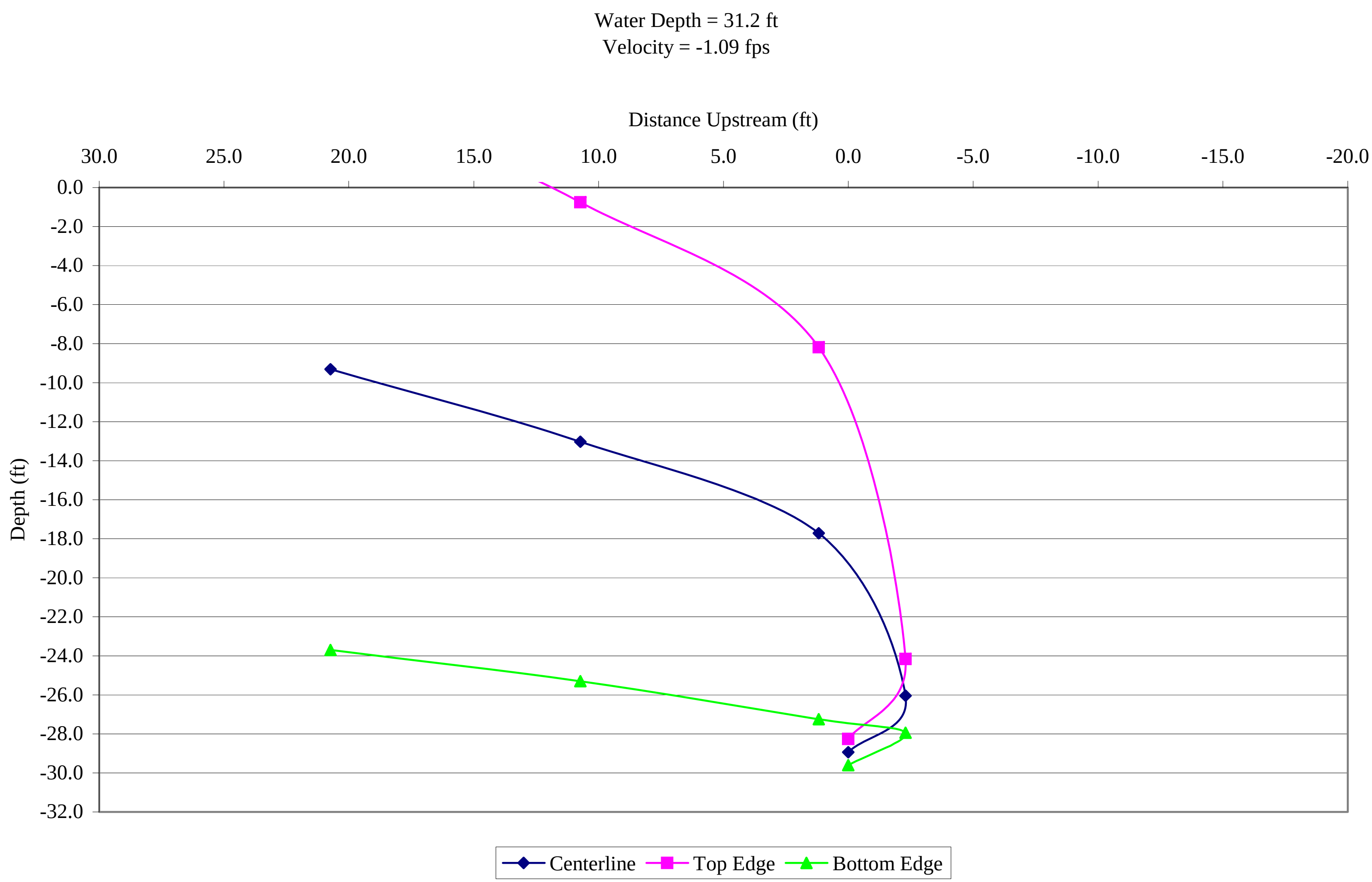


Comparison of UDKHDEN Modeling To Field Results

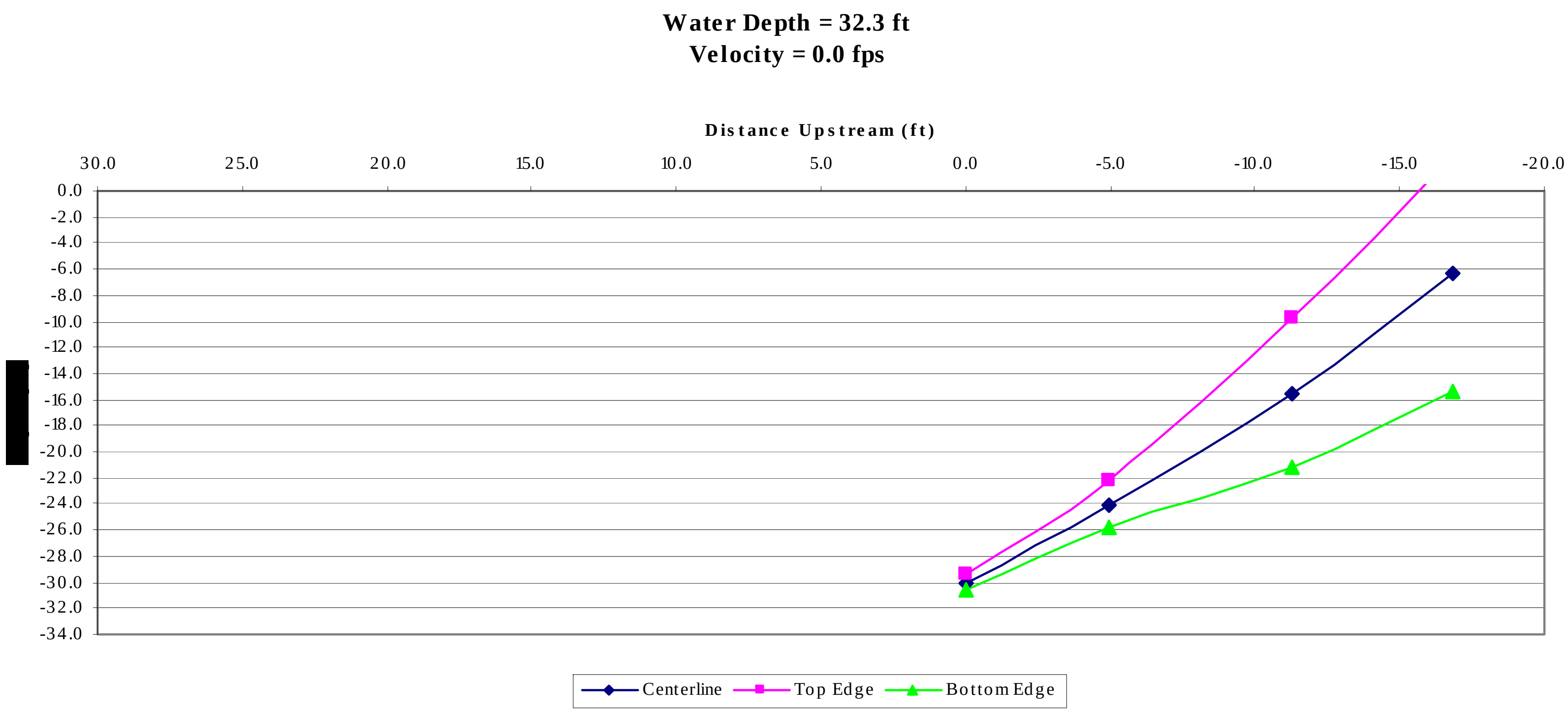
Georgia-Pacific – Brunswick, Georgia

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
Average			**35.2**	**32.5**	**30.2**	**28.0**

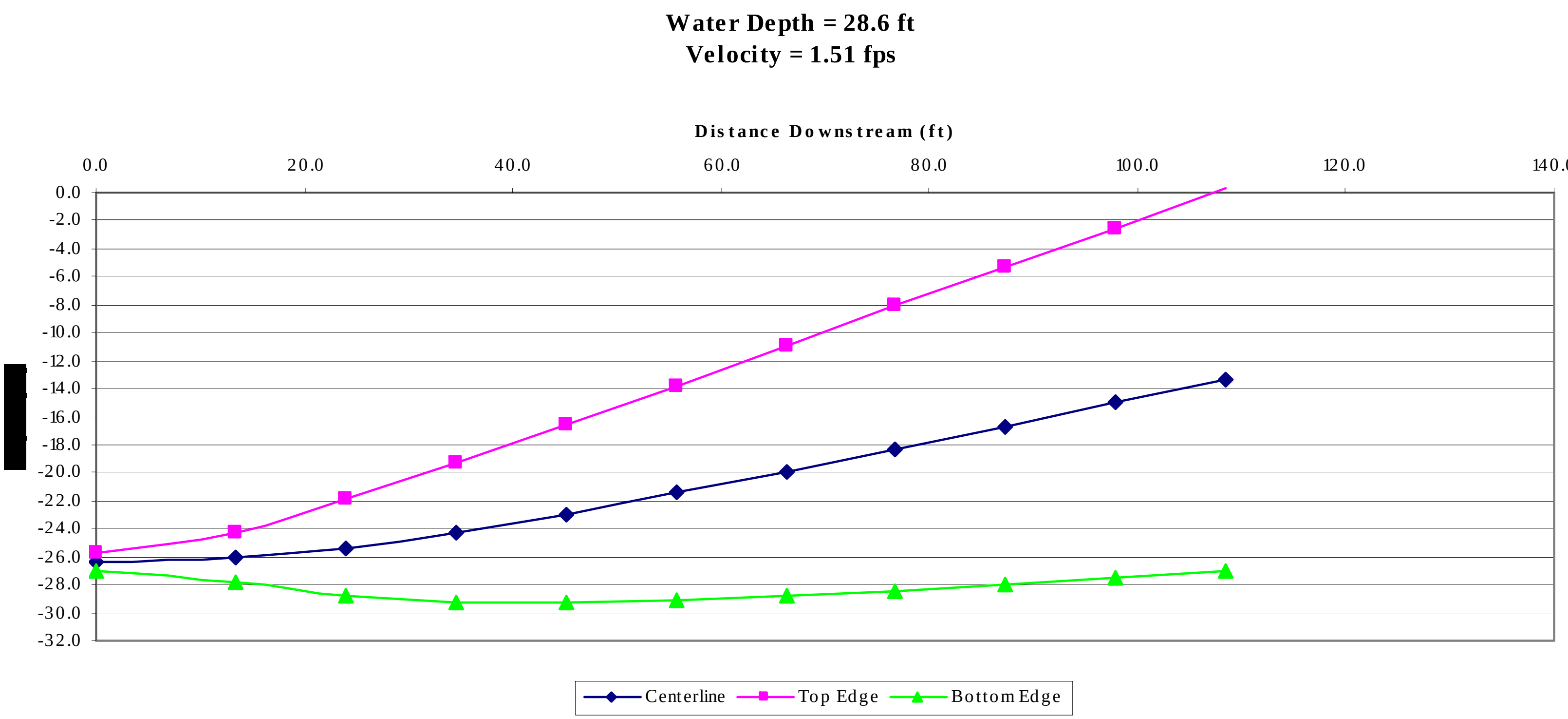
GP Brunswick ¾ Flood Tide



GP Brunswick High Tide



GP Brunswick ½ Ebb Tide



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