Dredged Material Evaluation and Testing Part II – Upland Disposal

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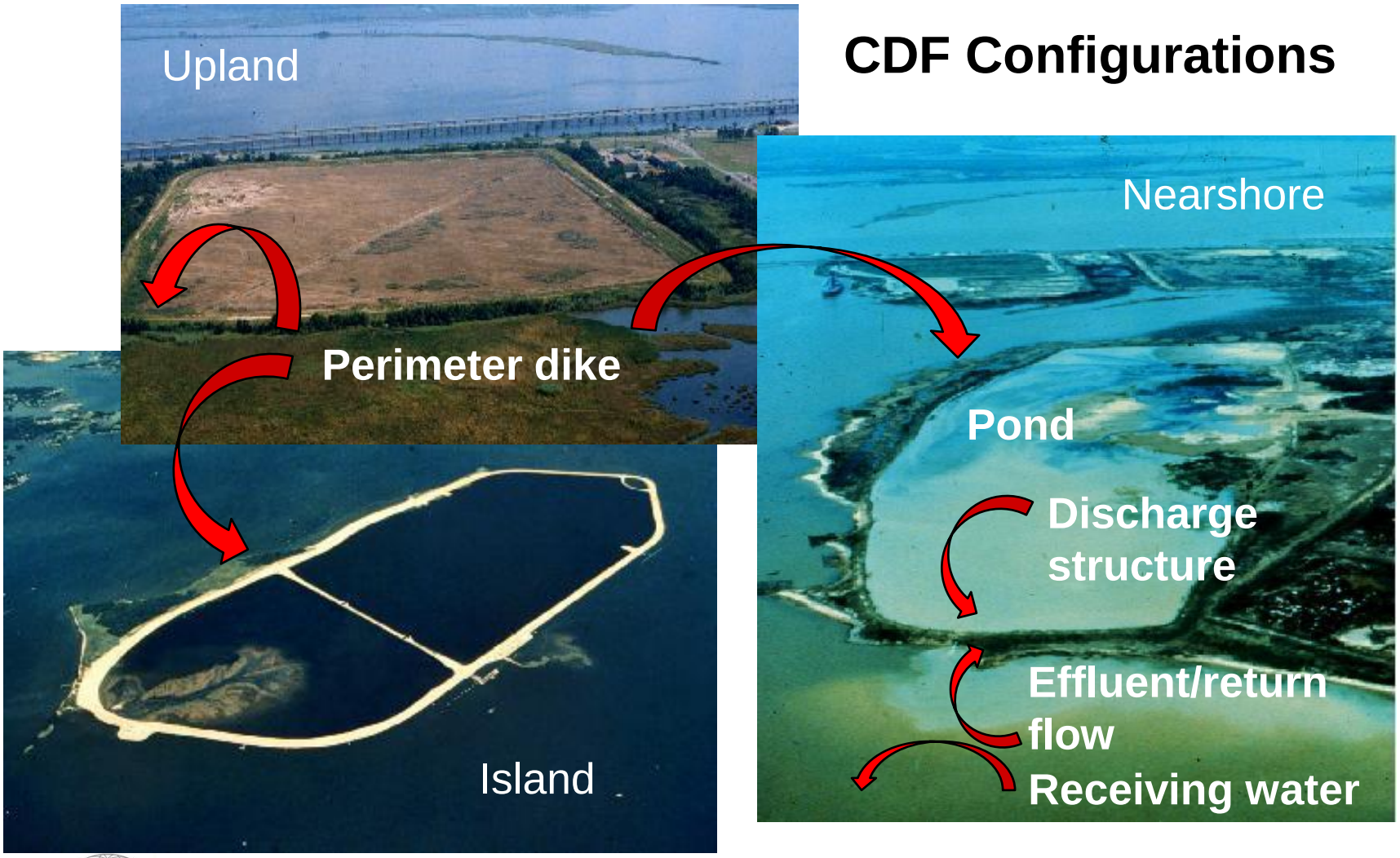
Topics

- Upland disposal defined
- Regulatory framework
- Technical evaluations
  - Purpose
- Disposal facilities
  - Testing and modeling tools
  - Conceptual design
- Environmental evaluation - 404 (b)(1)
  - Chemical testing and modeling
  - Tiered approach
  - Pathways

Upland = “Confined” Disposal

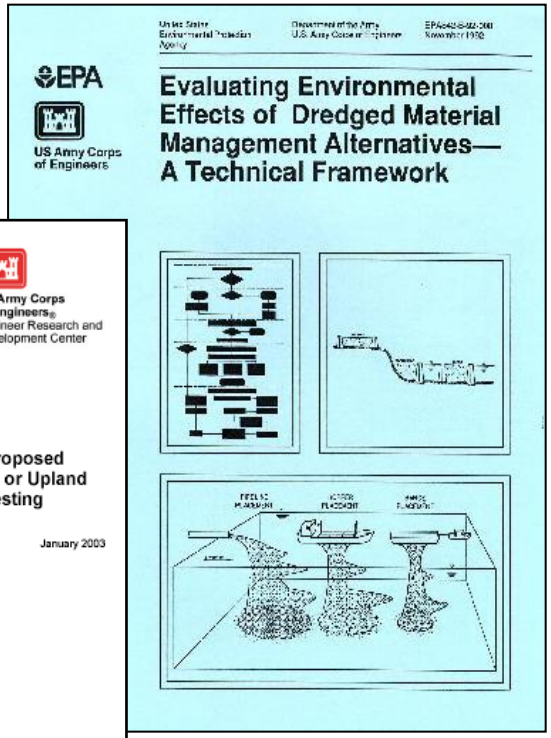


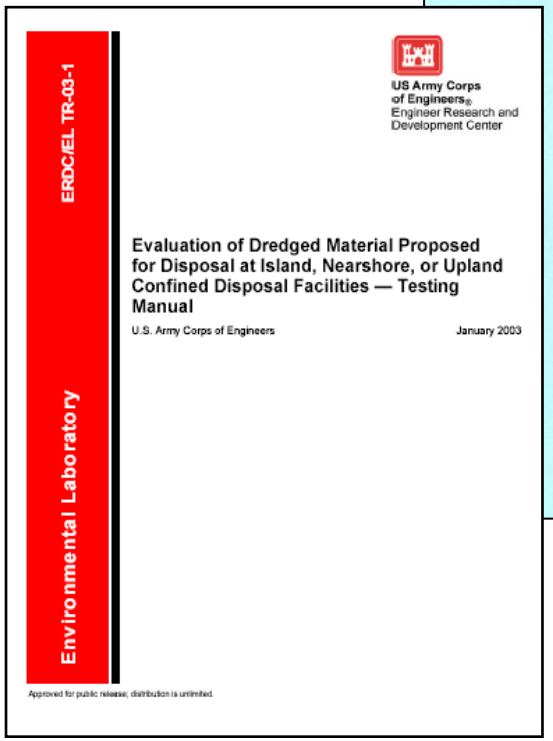
When do we use upland disposal?

- Open water infeasible
  - Logistically
  - Contaminant bioaccumulation/toxicity
- Associated benefits
  - Brownfields sites
- If best option
  - Cost
  - Availability
  - Environmental suitability

Governing Framework

- **Regulatory**
  - **Clean Water Act (CWA)**
- **Technical**
  - **USACE/EPA Technical Framework**
  - **Upland Testing Manual (UTM)**
    - **Previously incorporated in the Inland Testing Manual (ITM)**





Clean Water Act

- **Regulatory Section 404(b)(1)[a]**
  - **"…the term 'discharge of dredged material' … includes… the runoff or overflow from a contained land or water disposal area…" 33 CFR 323.2**
- **Requires return flow**
  - **Trigger for RCRA Subtitle C Exclusion[b]**
  - **BUT states can still choose to regulate DM as solid waste**

a) http://water.epa.gov/lawsregs/rulesregs/cwa/upload/CWA_Section404b1_Guidelines_40CFR230_July2010.pdf
b) Palermo and Wilson 2000

USEPA/USACE Technical Framework

- Guidance (not regulatory)
  - http://el.erdc.usace.army.mil/dots/pdfs/epa/tech-frame-rev04.pdf
- Articulates NEPA, CWA, MPRSA requirements
- Alternatives screening
  - Open water
  - Confined disposal
  - Beneficial use
- Environmental suitability

Upland Testing Manual

- Guidance (not regulatory)
  - http://el.erdc.usace.army.mil/dots/pdfs/trel03-1.pdf
- Concerned with contaminant exposures associated with CDFs
- Develop lines of evidence to support decision making
  - Alternatives analysis
  - Management requirements
  - Need for controls
  - Evaluation of risk, inform risk management

Evaluation and Testing Objectives

- **Physical requirements**
  - **Solids storage**
  - **Water management**
  - **Conceptual design**
- **Environmental impacts**
  - **Related to disposal[(a)]**

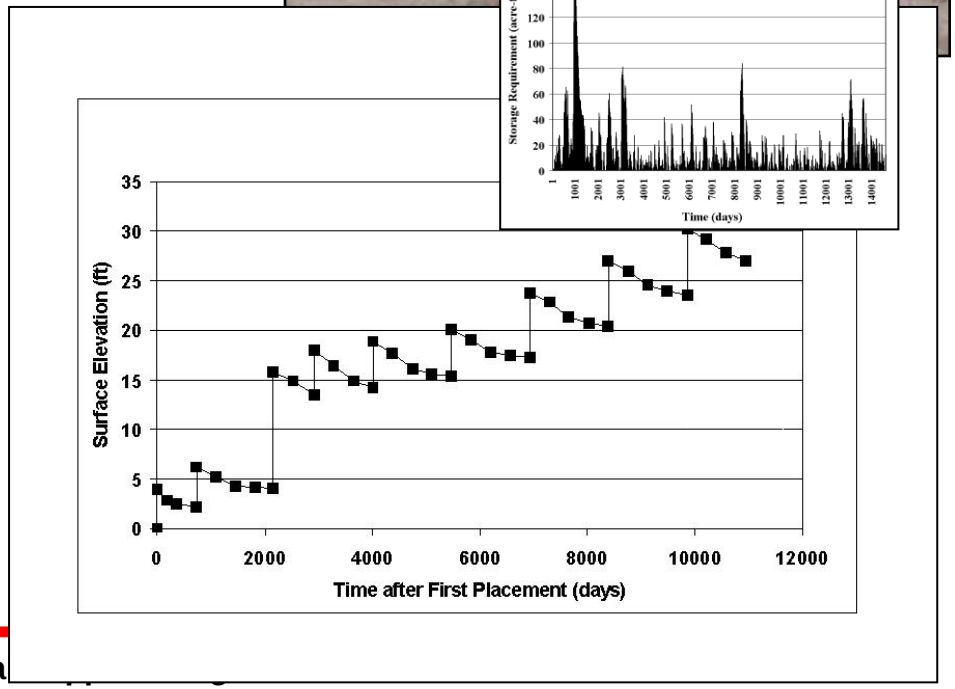
a) Re-suspension occurring during dredging is considered “de minimus” 33 CFR 323.2

CDF Conceptual Design

- **Design objectives**
  - Retain solids
  - Contain contaminants
  - Material recovery
- **Information/data required**
  - Sediment characteristics
  - Dredging plan
  - Dredging/offloading method
  - Prospective sites/borrow material
- **Supporting tests**
  - Column settling tests
  - Consolidation testing

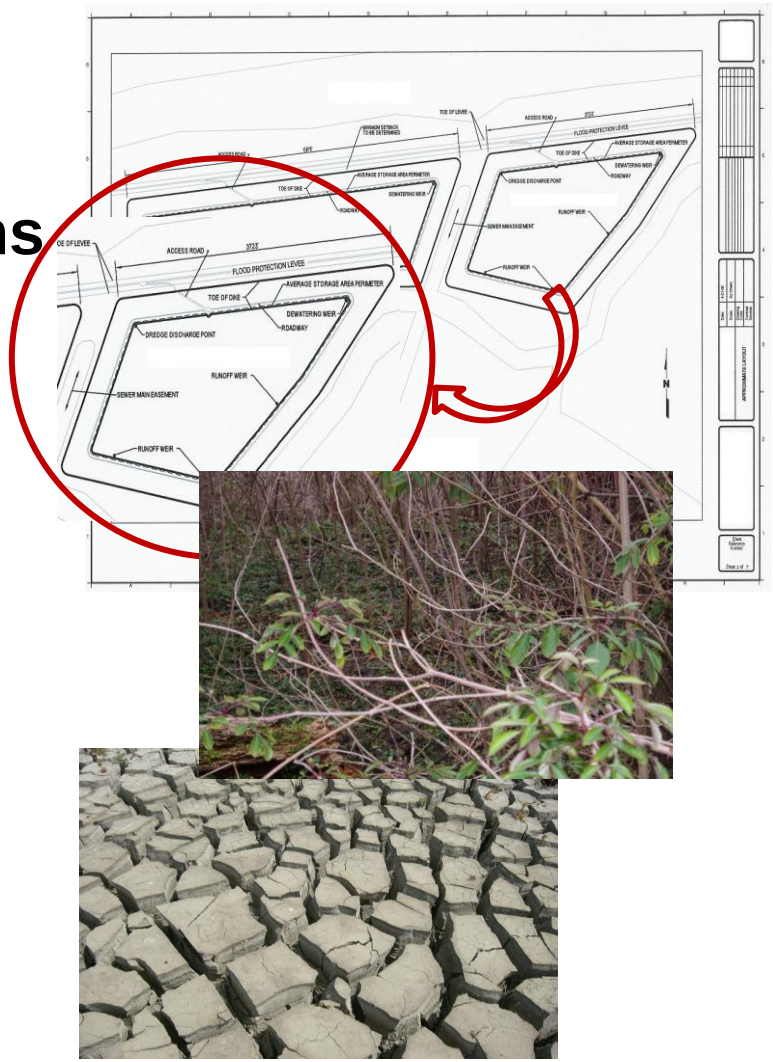
Capacity Requirements

- **Short term**
  - Storage & clarification area
  - Outlet weir length
  - Effluent suspended solids
  - SETTLE model
  - Data inputs
- **Long term**
  - Multiple placements
  - Consolidation
  - PSDDF model
  - Data inputs



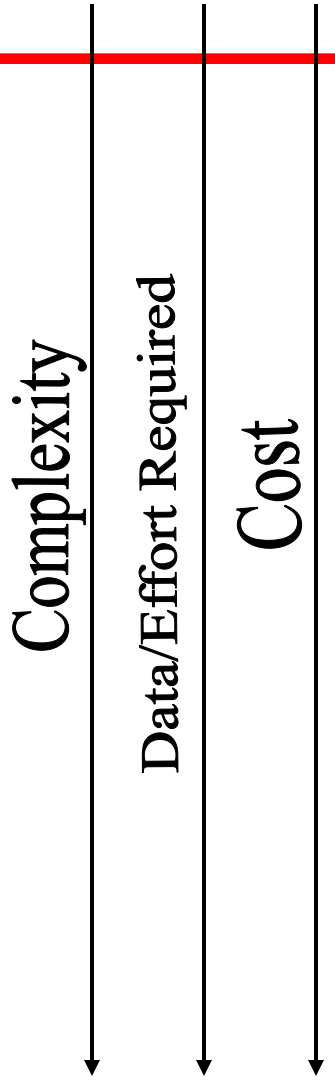
Design and Management

- Preliminary layout
- Detailed design
  - Construction specifications
  - Foundation treatments
  - Outlet structures
  - Water management plan
  - Site appurtenances
- CDF management plan
  - Maximize capacity
  - Accelerate dewatering
  - Manage vegetation, etc….

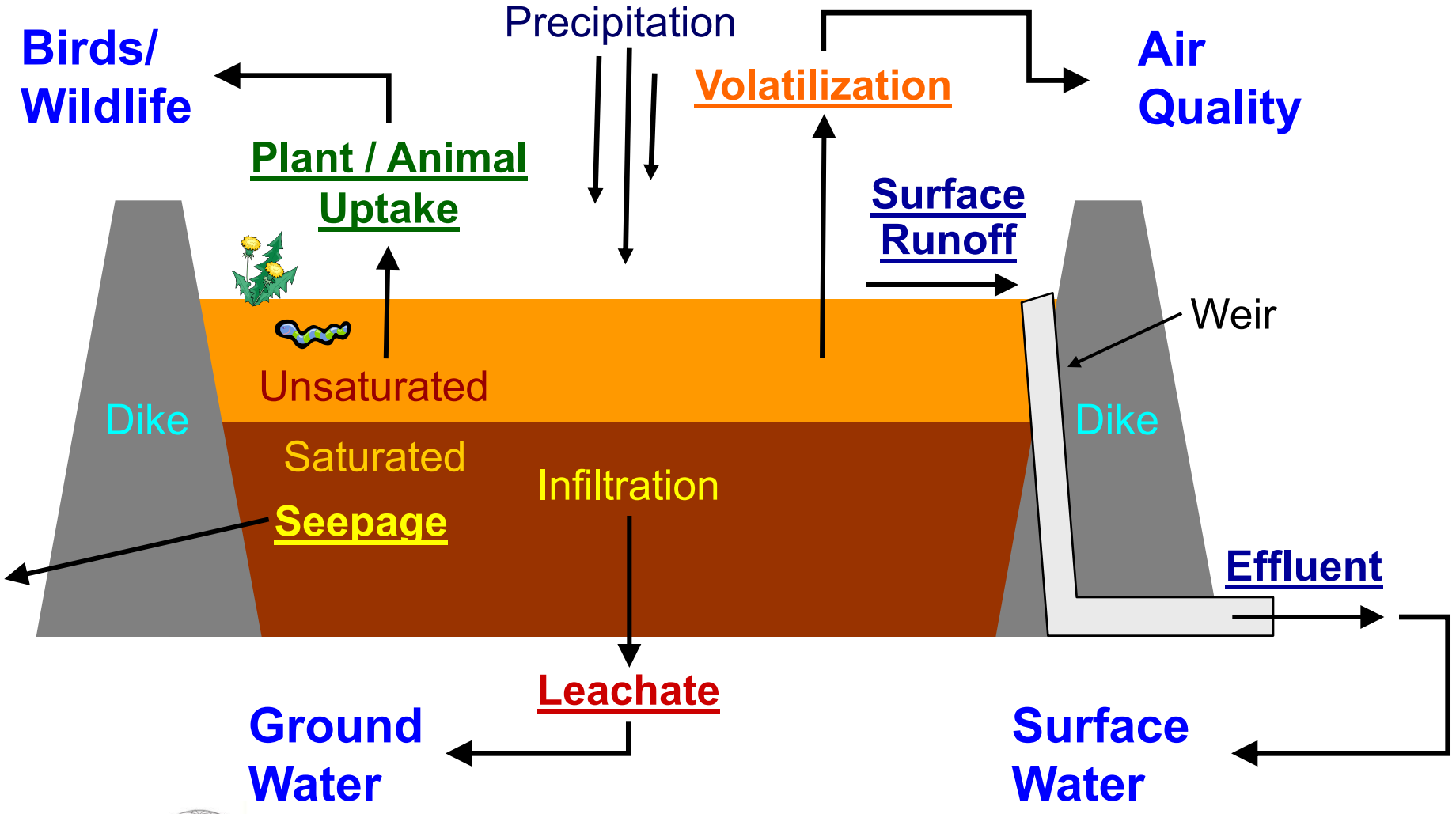


Environmental Evaluations – Tiered Approach

Tier I	Existing Info
Tier II	Screening Evaluations
Tier III	Effects-Based Testing and Evaluations
Tier IV	Case Specific Studies/ Risk Assessment



Conceptual Model - Contaminant Pathways



CDF Pathway End Points

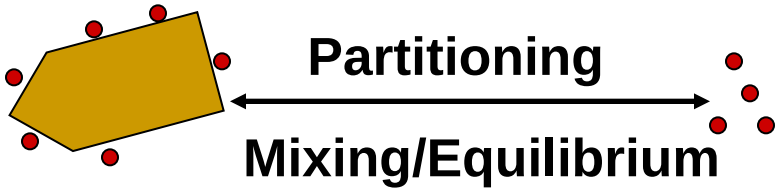
- **Effluent and Runoff**
  - **WQ Standards and/ or WC Toxicity after Mixing[(a)]**
- **Leachate**
  - **Applicable WQ Standards after Attenuation (groundwater or surface water typically)**
- **Volatiles**
  - **OSHA Human Exposure Standards after Dispersion**
  - **Health Based Air Concentration for Acceptable Risk**
- **Plant and Animal Uptake**
  - **Comparison of uptake to Reference Soil**
  - **Comparison to EcoSSL's**

a) where mixing zones are permitted by the State

Tier I – Existing Information

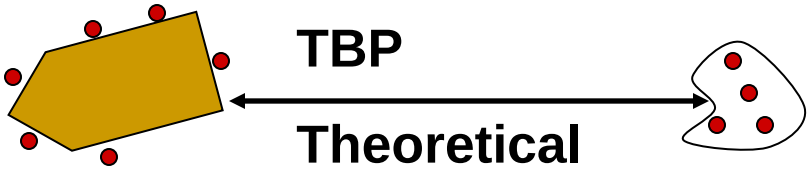
- **Establish Site-specific Pathways and Contaminants of Concern**
- **Compile**
  - **Available sediment and water chemistry**
  - **Sediment physical characterization**
  - **Area land uses**
  - **Municipal, industrial, surface water inputs**
  - **Project info (maintenance vs. new work)**
  - **Available data from other agencies – diversity studies, tissue sampling**
- **"Reason to believe"**
  - **Need for Tier II Pathway Evaluations – relevant pathways and contaminants**

Tier II – Screening Level Evaluations

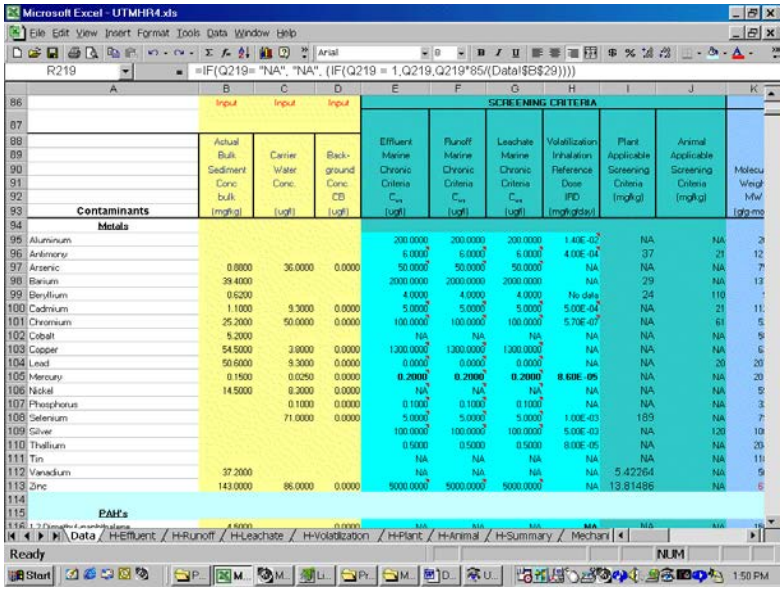


Effluent; Runoff; Leachate;

Volatiles (Henry's Law)



Animal Uptake



Plant Uptake - PUP

Diethylenetriamine-pentaacetic acid (DTPA) Extract

Tier II Outcomes

- **Definitive determination**
  - **WQC met with attainable dilutions/attenuation**
  - **Volatilization exposures acceptable**
  - **Plant and animal uptake levels acceptable**
- **Not definitive**
  - **Contaminants present have no WQC**
  - **Predicted dilution requirements high**
  - **Predicted exposures potentially unacceptable**
  - **Data or model inconsistency**

Resolve specific issues with Tier III Testing and Evaluations

Tier III Testing

- **Effects Based Testing and Evaluations**
  - **Physical "modeling" of contaminant exposure and effects**
  - **Key chemical and biological Tests**
    - **Effluent elutriate test (formerly modified elutriate)**
    - **Toxicity/bioaccumulation testing – sediment/effluent**
- **Modeling**
  - **Dilution requirements**
  - **Attainable mixing/dilution**

Tier III Outcomes

- **Definitive determination**
  - Toxicity/bioaccumulation not significant
  - No predicted WQC exceedances
  - Effective management controls, mixing/dilution
- **Not definitive**
  - Contaminants present have no WQC
  - Predicted dilution requirements high
  - Predicted exposures potentially unacceptable
  - Data or model inconsistency
- **Tier III test results provide data for Tier IV Risk Assessments**

Tier IV Case Specific Studies

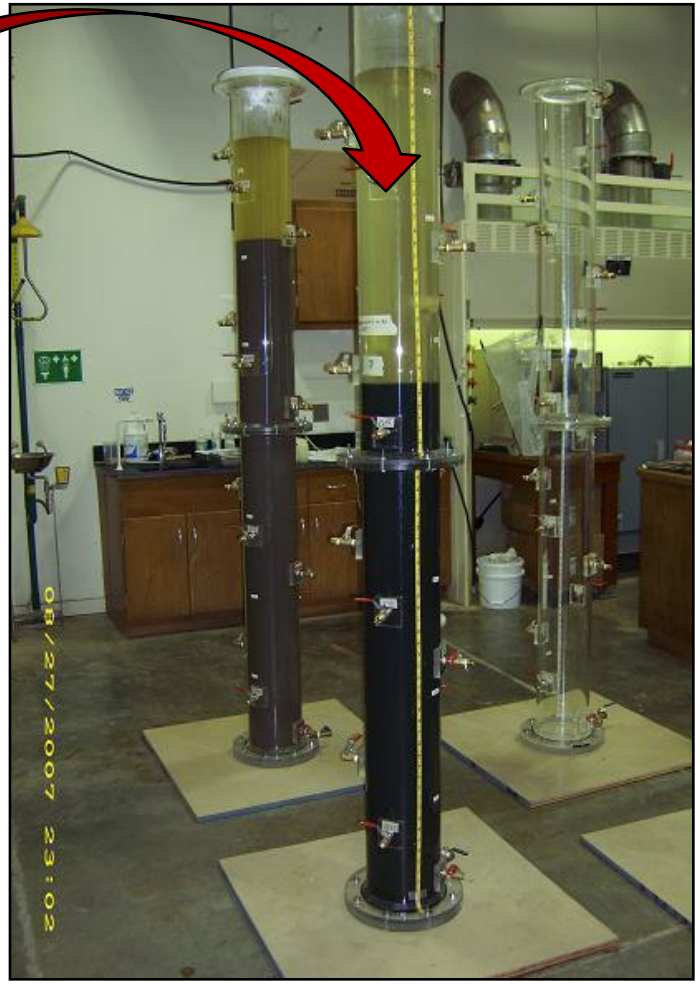
- Formal quantitative risk assessment
- Addresses specific, well-defined questions
- Rarely necessary for navigation dredging
- Unnecessary use of resources when
  - Merely a refinement of Tier III
  - Definitive determination unchanged
- Guidance
  - Cura, Wickwire, and McArlde (in preparation)
  - Other references PIANC 2010

Conceptual Design - Toolkit

- **Column settling test**
  - **DYECON**
    - **Hydraulic efficiency**
    - **Wier length**
  - **SETTLE**
    - **Storage and ponding requirements**
    - **Effluent SS predictions**
- **Consolidation tests**
  - **PSDDF**
    - **Long term volume changes**
    - **Effect of multiple lifts**

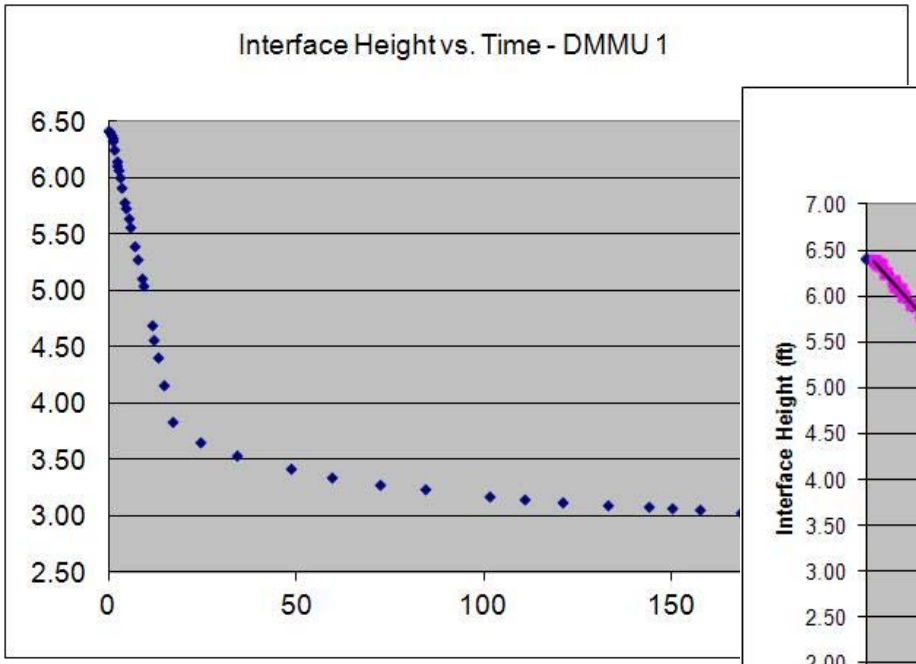
Column Settling Test

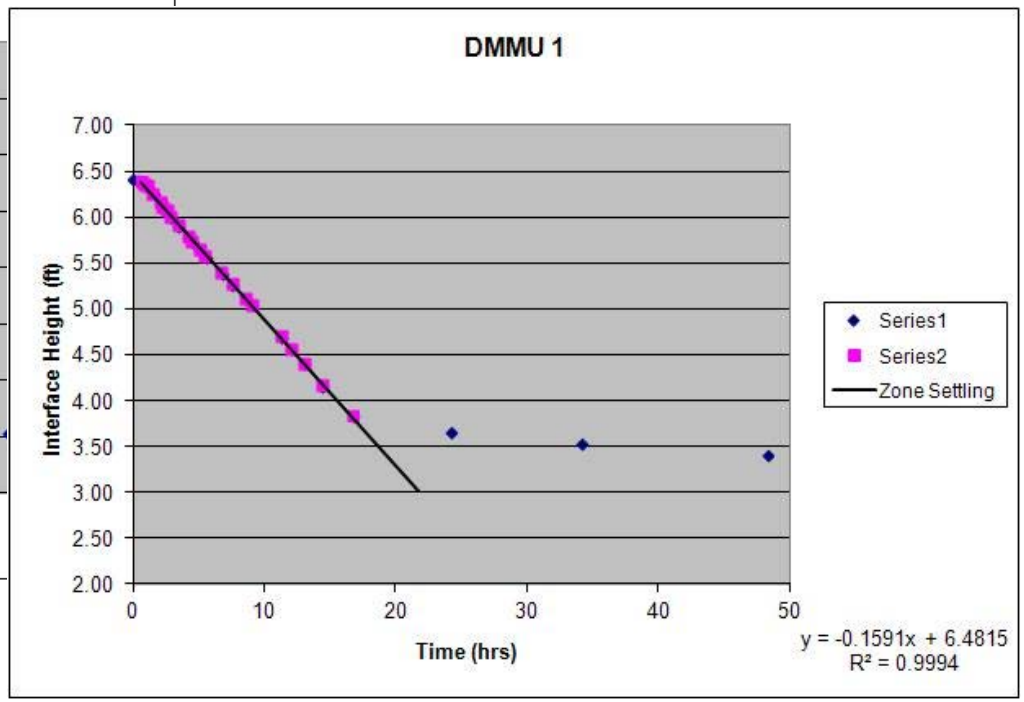
- **Fine sediment fraction**
  - **Default 150 g/l solids**
  - **Empirical %Fine +3x%Coarse**
- **Recommended sampling intervals ~1, 2, 4, 6, 12, 24, 48, 96 hr…15 days**
  - **If zone settling (rapid formation of interface) – supernatant (above the interface)TSS**
  - **If flocculent settling – TSS measured at all ports**



Column settling test data

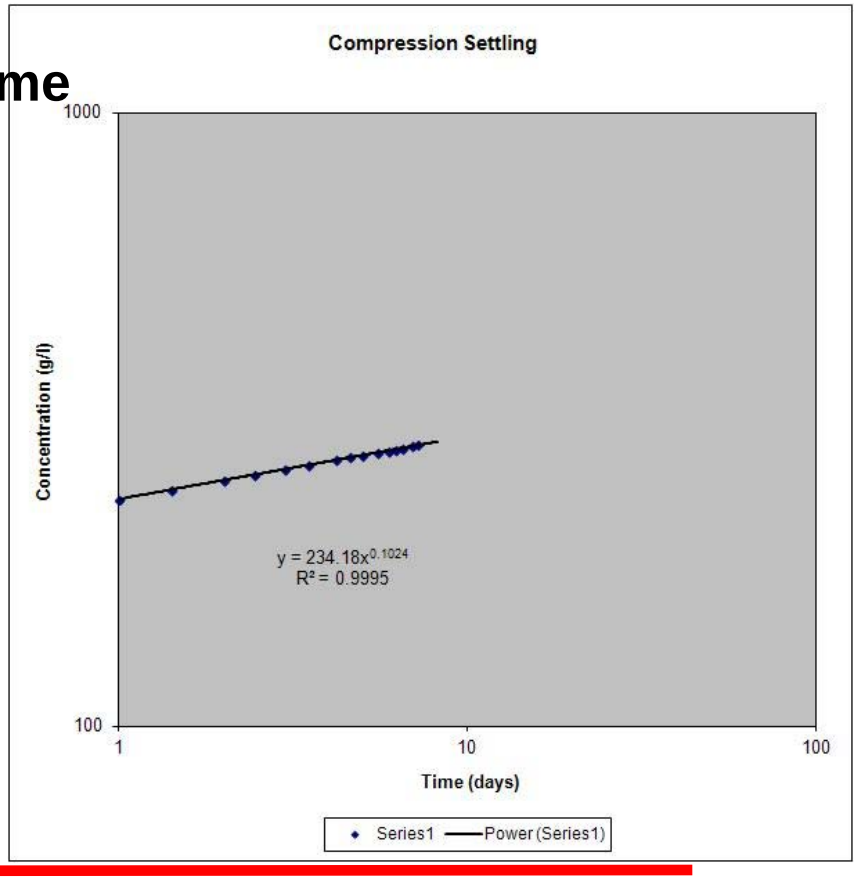
- **Zone settling**
  - **Basis for clarification requirements**
  - **Interface settling velocity – tangent**





Column settling test data

- **Flocculent settling**
  - **Basis for effluent TSS predictions**
    - **TSS measurements**
    - **Port height x sampling time**
- **Compression settling**
  - **Calculated solids concentration vs. time**
  - **Basis for storage requirements**



SETTLE

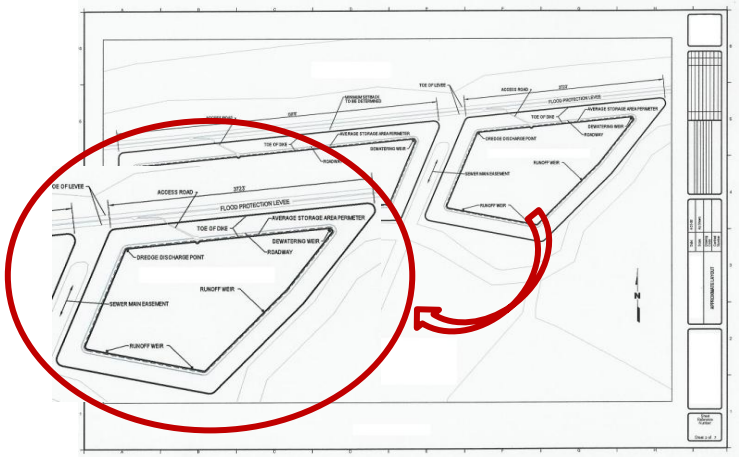
- **Sediment data**
  - **Input column settling test data**
    - **Compression settling**
    - **Zone settling**
    - **Flocculent settling**
  - **Sediment properties (partial list of input options)**
    - **Grain size (% less than 74 µm)**
    - **Specific gravity**
    - **In-situ solids concentration**
    - **Sand specific gravity**
    - **Settled sand solids concentration**

SETTLE (con't)

- **Production and operating assumptions (partial list of input options)**
  - **Dredge pipe diameter (in)**
  - **Average pipeline velocity (ft/s)**
  - **Dredge discharge solids concentration (g/l)**
  - **Hours/day operation**
  - **Days/week operation**

SETTLE (con't)

- **Disposal area configuration (representative, iterative assumptions)**
  - **Average dike height (ft)**
  - **Freeboard (ft)**
  - **Minimum ponded depth (ft)**
  - **Depth of withdrawal (ft)**
  - **Average storage area (acres)**
  - **Percent ponded at end of disposal (%%)**
  - **Hydraulic efficiency (%)**
  - **Maximum allowable effluent TSS (mg/l)**



SETTLE (con't)

- **SETTLE output (partial) – compression data**
  - Minimum area and storage volume
  - Minimum average depth or dike height
  - Max production/min disposal period
  - Max in-situ volume
- **SETTLE output (partial) – zone settling data**
  - Minimum ponded area
  - Maximum influent flow rate
- **SETTLE output (partial) – flocculent settling**
  - Minimum area, ponded area and volume
  - Mean residence time
  - Minimum pond depth
  - Maximum flow rate
  - Effluent suspended solids

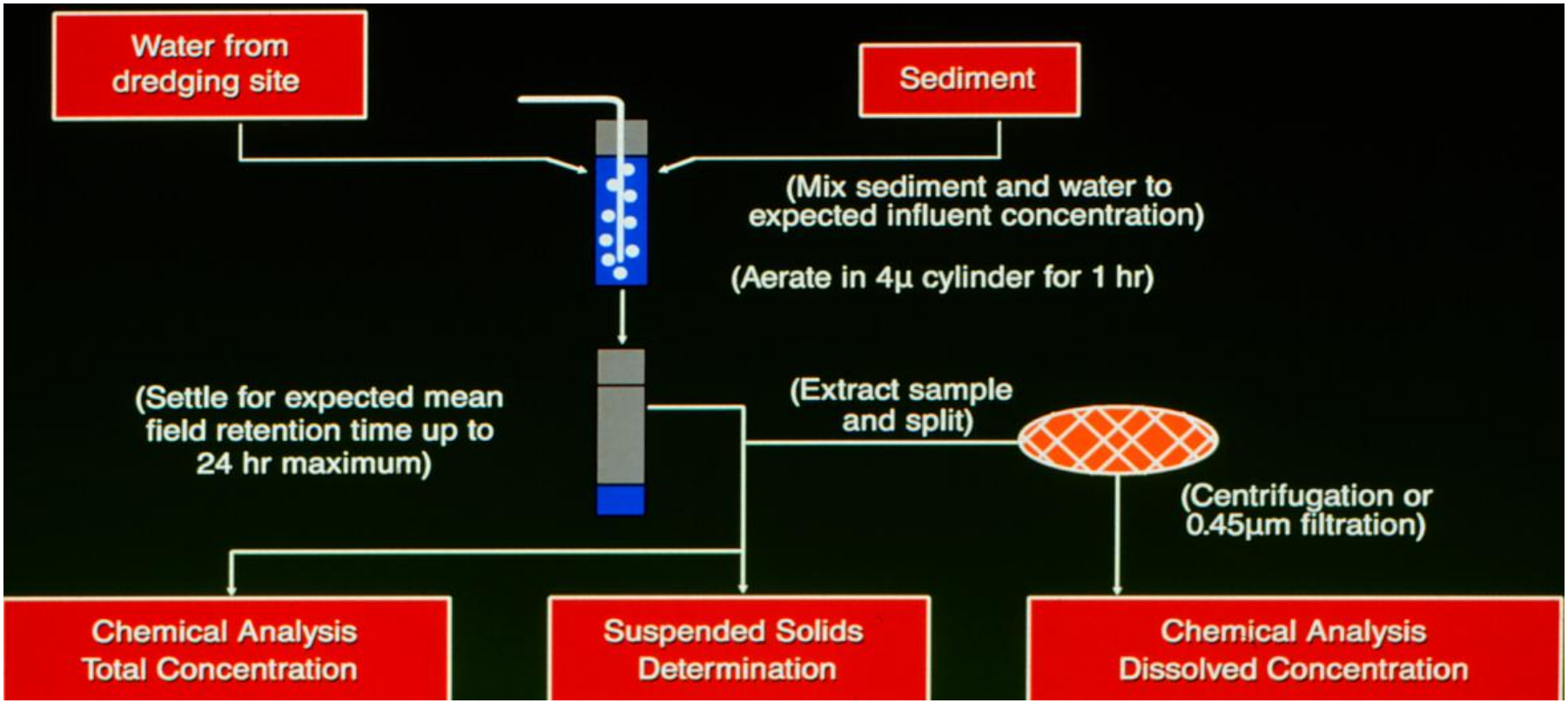
Partitioning Analysis

- **Predicted contaminant releases based on**
  - **Sediment chemical and physical properties**
  - **Carrier water properties**
  - **Contaminant properties (K_d , Henrys Law constant, etc.) for oxidized and unoxidized conditions**
  - **Influent slurry solids (g/l)**
  - **Receiving water properties and flow**
  - **Predicted effluent and runoff TSS**
  - **CDF geometry**
  - **Climatic conditions**
  - **Foundation soils**
  - **And other available parameters….**

Partitioning Analysis

- **Algorithms for all relevant pathways**
  - **Criteria comparisons**
- **Conservative**
  - **Generally over-predicts contaminant releases**
- **Predicted exceedances**
  - **Inform need for further testing**
  - **Refine contaminants of concern**
  - **Inform dredging/disposal plan**

Modified/Effluent Elutriate Test

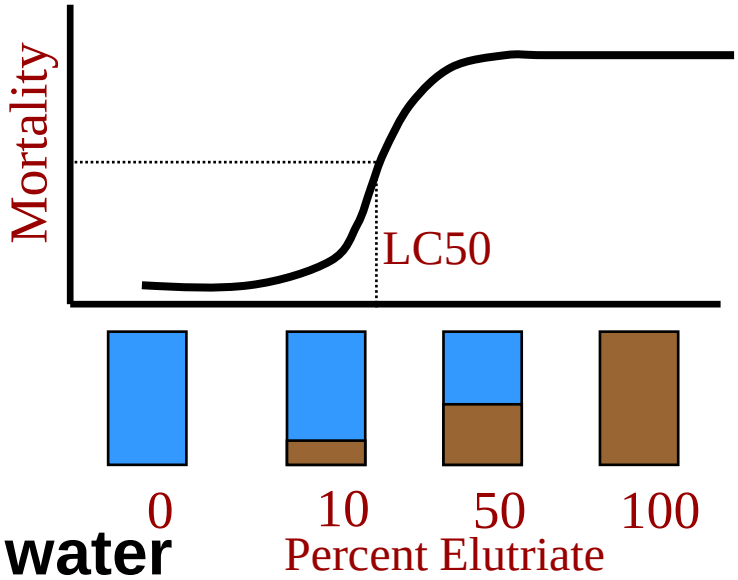


Effluent Toxicity Testing

- Evaluate toxicity of DM elutriate
- Conduct these tests if:
  - Tier I evaluation suggests the DM may contain contaminants that might result in adverse effects
  - Potential for synergistic interactions between chemicals identified in DM elutriate
  - No WQS for contaminants of concern
  - No factual determination has been made

Effluent Toxicity Testing

- Unfiltered supernatant after settling = 100% effluent
- Compare organism survival in dilution water and elutriate dilutions
  - At least 3 concentrations
  - Control survival > 90%
  - 5 replicates
  - 10 organisms/ replicate
  - 48- to 96-hour duration
  - Determine concentration resulting in 50% mortality (LC_{50})
- Compare mortality in dilution water and 100% elutriate
  - T-test if >10%
  - If not significant, elutriate meets LPC



Calculating Dilution Requirements

- **Dilution =Volume receiving water/Volume effluent required to meet WQC**
  - **Volume based[(a)]:**

$$D = \frac{\left(C_{eff} - C_{WQC}\right)}{\left(C_{WQC} - C_{rec}\right)}$$

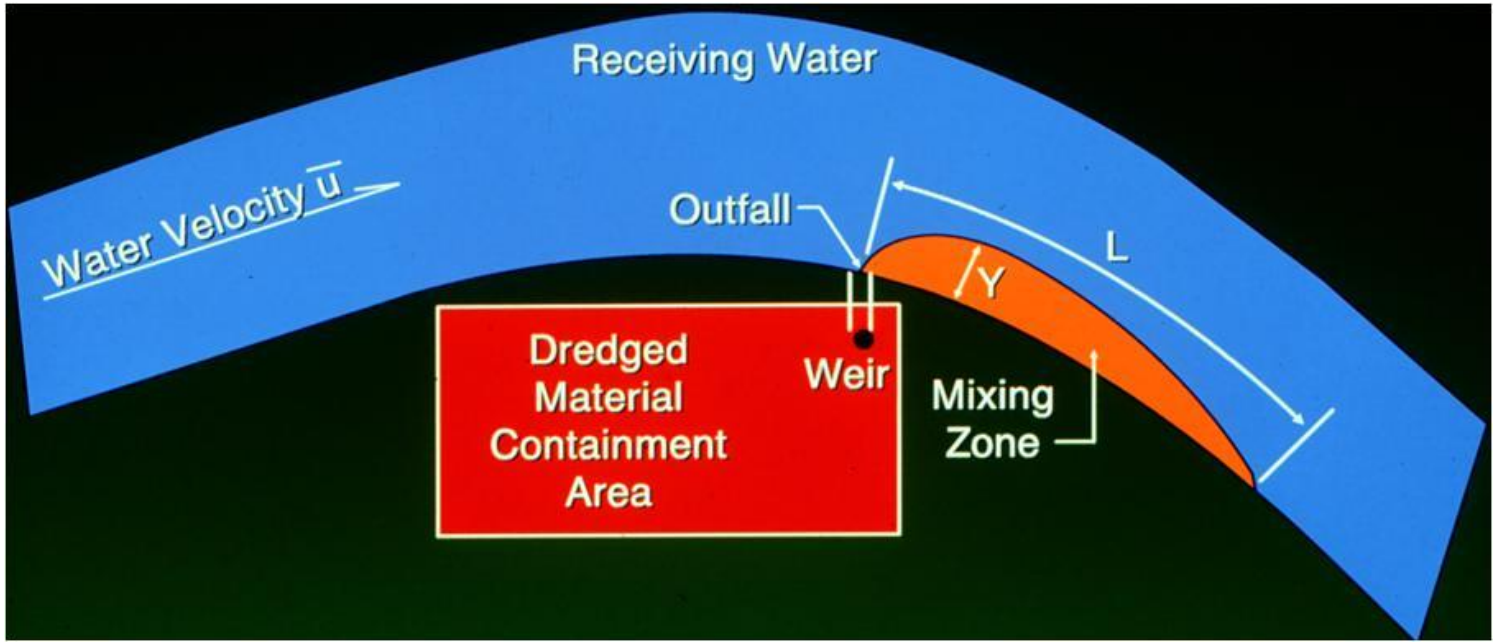
  - **Toxicity based[(b)]:**

$$D = \frac{\left(C_{100\%} - \frac{C_{LC50}}{AF}\right)}{\left(\frac{C_{LC50}}{AF} - C_{0\%}\right)}$$

    - **a) C_{eff} – effluent contaminant concentration, C_{WQC} – contaminant water quality criteria, C_{rec} – background contaminant concentration in receiving water**
    - **b) AF = application factor – converts acute exposure to chronic equivalent, $C_{100\%}$ - 100% elutriate, C_{LC50} – percent elutriate at 50% mortality, $C_{0\%}$ - zero% elutriate**

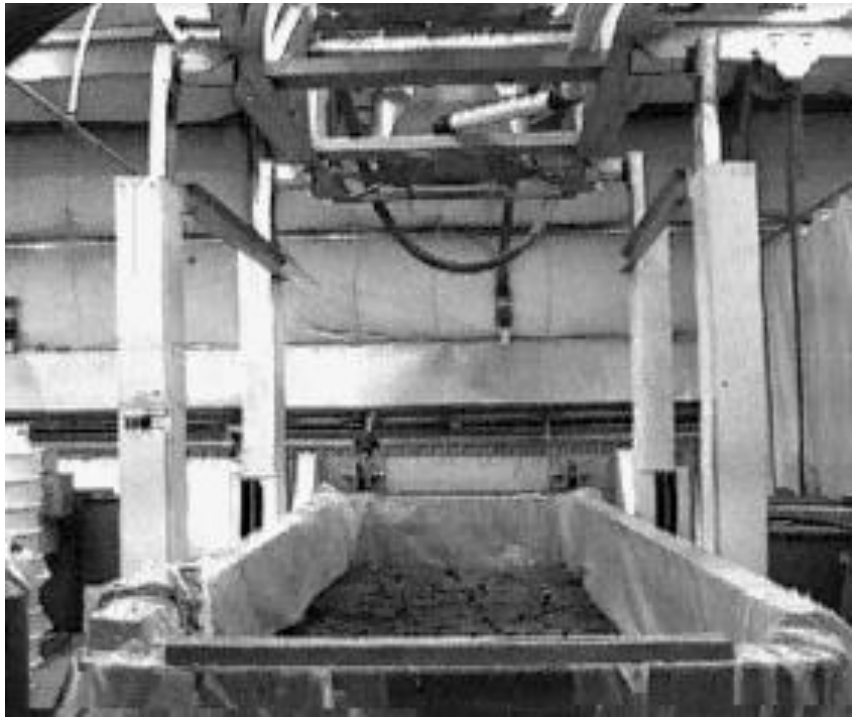
Calculating Dilution Requirements

- **Dilution available in mixing zone?**
  - **Mixing model – CDFATE, CORMIX**
  - **State specific definitions**
  - **Specified radius or % of receiving water flow**



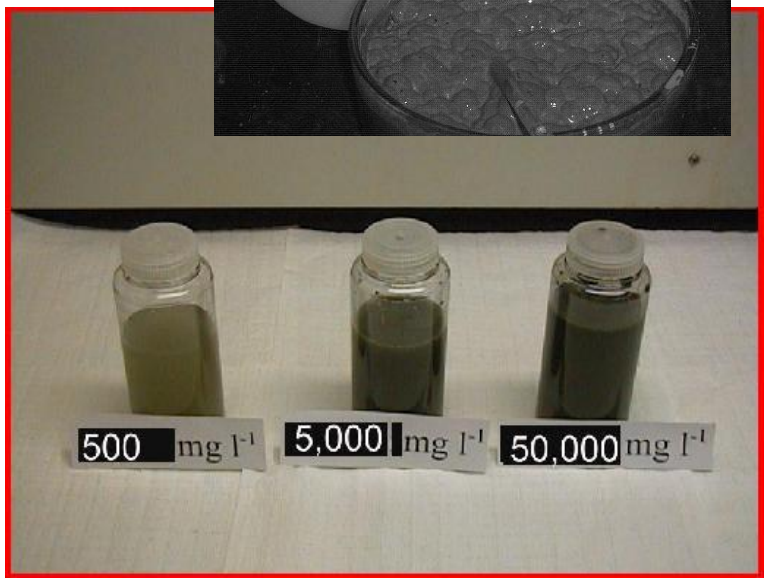
Simplified Laboratory Runoff Procedure

- **Replaces rainfall simulator for screening**
  - **Large sediment volume**
  - **Time intensive**
  - **$$$**
- **Laboratory extraction**
  - **Wet sediment**
  - **Dry/oxidized sediment**
- **Worst case exposure**



Simplified Laboratory Runoff Procedure

- **Dried sediment procedure**
  - Organic contaminants
  - 3 gal sediment
  - Common laboratory equipment
  - Dilute with DDI to desired TSS
  - Agitate for one hour
  - Analyze contaminant concentrations
    - Filtered for soluble
    - Unfiltered for total
    - Compare to WQC



Simplified Laboratory Runoff Procedure

- **Dried oxidized sediment**
  - **Metal contaminants**
  - **Air dry to less than 5% moisture, grind**
  - **Add H_2O_2 to increase sediment oxidation, dry, regrind**
  - **Conduct extractions, TSS at 50, 500, 5,000 mg l^{-1}**

Simplified Laboratory Runoff Procedure

- **Wet, unoxidized sediment**
  - **Applicable to all contaminants**
  - **Higher TSS**
    - **Wet sediment more easily eroded**
    - **Empirical evidence higher TSS runoff concentrations**
  - **Conduct extractions, TSS at 500, 5000, 50,000 mg l^{-1}**

Leachate Modeling

Sequential Batch Leach Test (SBLT)

“Pancake” Column Leach Test (PCLT)

Selection of Test Procedure

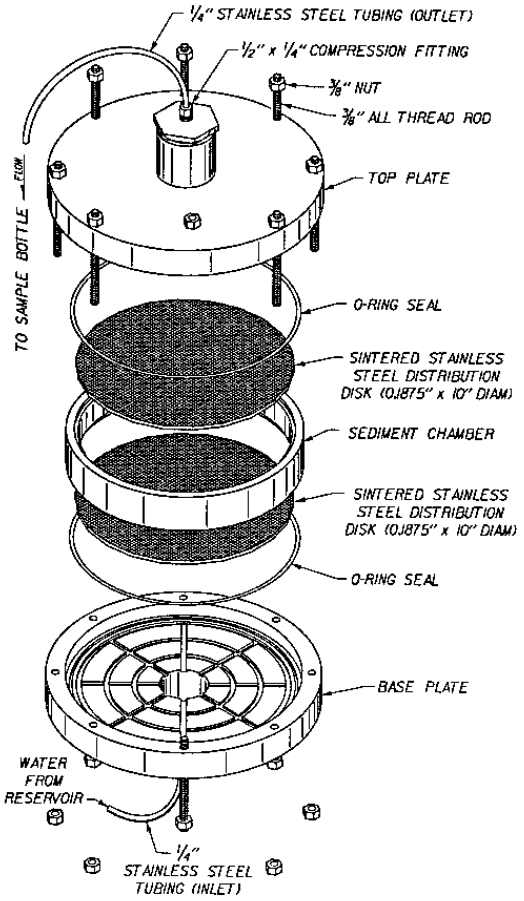
- **Freshwater Dredged Material**
  - **Batch testing**
  - **Generally yields well-behaved contaminant desorption isotherm or single point K_D**
- **Saline Dredged Material**
  - **Column Testing**
  - **Salt elution results in colloid release not well represented by batch test results**

Batch Test Procedure

- Load sediment in a 4:1 water-to- sediment ratio under anaerobic (nitrogen atmosphere) conditions
- Shake for 24 hours, centrifuge, and filter leachate
- Add water to sediment to make up that removed. Repeat steps 1 and 2
- Repeat procedure for at least four cycles

Column Test Procedure

- Thin layer column to maximize the number of pore volumes eluted
- Testing conducted in up-flow mode
- Elution of 30 pore volumes recommended
- More $$$ than batch testing

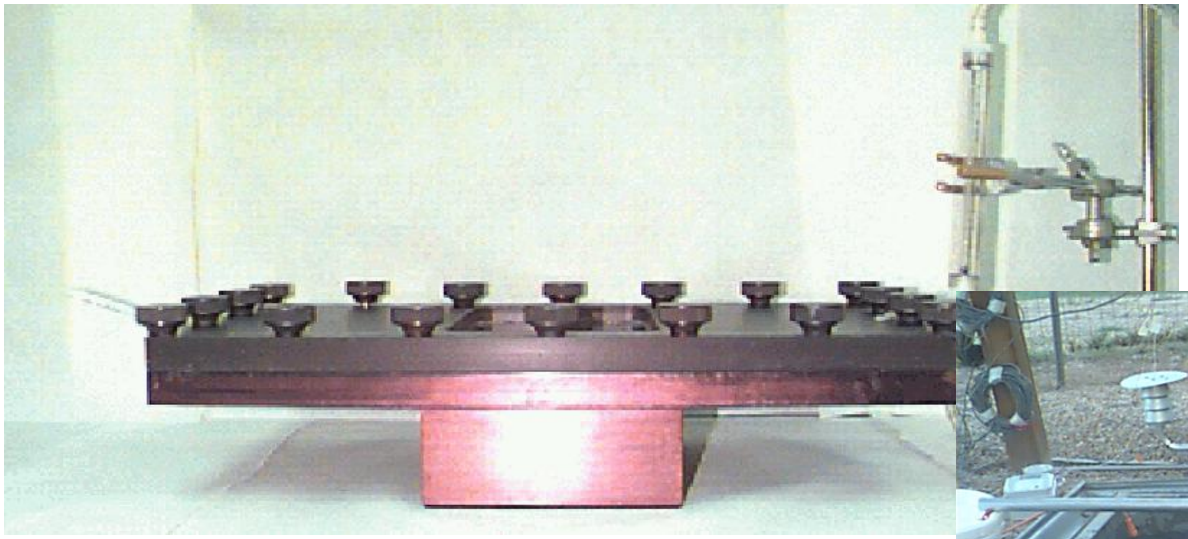


Leachate Modeling

- **Estimate leachate attenuation in vadose zone**
  - **Diffusion**
  - **Degradation**
  - **Volatilization**
  - **Irreversible exchange with solids**
- **Estimate dilution/mixing/transport in groundwater**
- **Estimate exposure concentration at point of compliance or at receptor**
  - **Compare to WQC - Groundwater, drinking water, or surface water criteria as appropriate to the site**

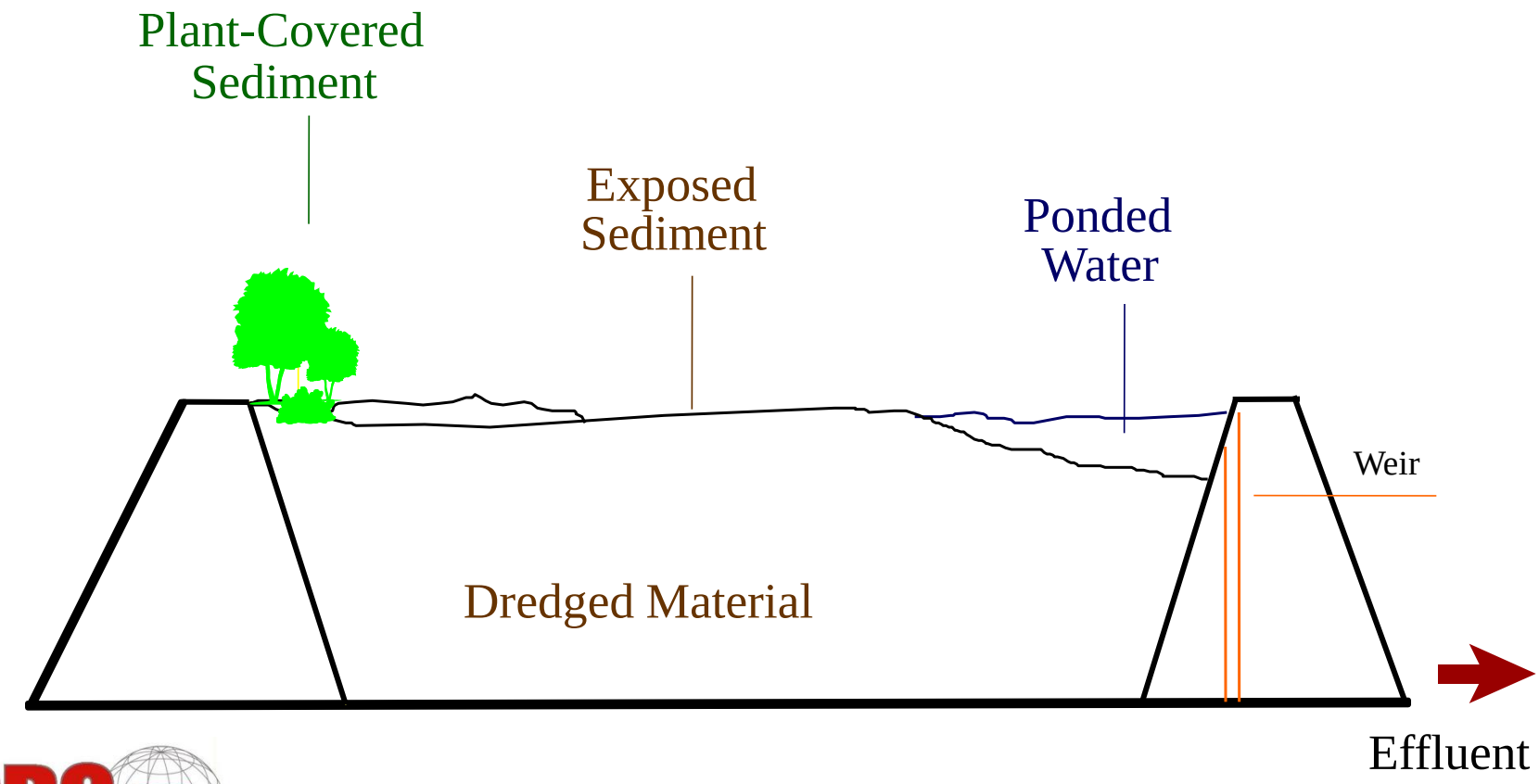
Volatilization Testing

Volatile Flux Chamber



Field Apparatus

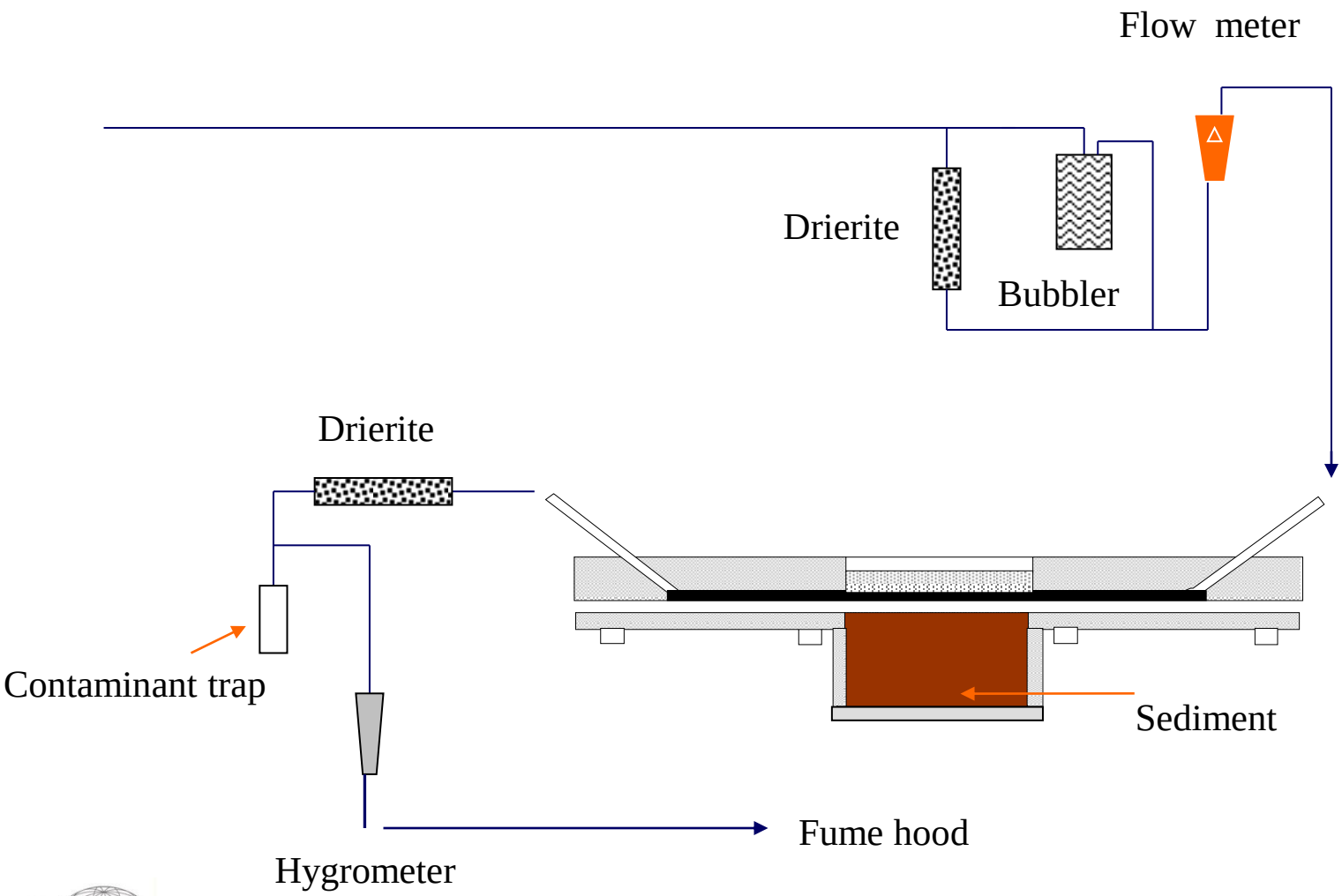
Volatile Emissions from Dredged Material



Volatilization Processes

- **Sediment Physical Characteristics**
  - **Moisture content, porosity, aging, oil and grease concentration**
- **Contaminant Chemical Properties**
  - **Henry's Law Constant, vapor pressure, sediment contaminant concentrations**
- **Environmental Variables**
  - **Relative air humidity, temperature**
  - **Mechanical movement (mixing) of the sediment**

Laboratory Experimental Design



Example Lab Sampling Protocol

- **Sampling times / intervals:**
  - **6, 24, 48, 72 hours, 5, 7, 10, and 14 days**
    - **Sample continuously (replace trap at each sample interval making sample intervals anywhere from 6 to 96 hours each)**
    - **Sampling length dependent on contaminant concentrations and analytical detection limits**
- **Experimental conditions:**
  - **Initiate experiment with field moist sediment and apply dry air over sediment surface (14-day experiment)**
  - **Apply humid air over sediment surface for 7 days**
  - **Rework sediment and repeat with dry air**

Test Protocol (Field)

- **Field Apparatus**
  - **Top portion identical to that of laboratory chamber**
  - **Bottom portion has central opening for sediment surface, with 2-inch-long side plates to seal the apparatus from the surrounding air**
- **Carrier Air –**
  - **“Outside” air is pulled through a trap (to assure uncontaminated air) and across sediment surface**
- **All other materials and sampling procedures identical to those in the laboratory**

Flux Calculations

- Contaminant flux is calculated by determining the total mass of material captured in a given time interval using the equation:

$$N_A(t) = \frac{\Delta m}{\Delta t A_c}$$

Δm = mass (ng) of compound collected on the trap in time Δt(hr)

A_c = area the sediment-air interface, cm^2

$N_A(t)$ is expressed in $ng/cm^2/hr$

Gaussian Dispersion Air Quality Model

Data Entry

Top of Form 1

Enter the Contaminant Emission Rate (Q):
0 milligrams/sec

Enter the Downwind Distance (X) from Origin:
0 meters

Enter the Crosswind Distance (Y) from Origin: (Typically, 0)
0 meters

Enter the Vertical Distance (Z) from Origin: (Typically, 0)
0 meters

Enter the Average Wind Velocity:
0 meters/sec

Enter the Effective Stack Height (H): (Always 0 for Ground Surface)
0 meters

Enter Atmospheric Stability Rating (A-F): (D is Neutral.)
Help

Calculate **or** Clear Data

Calculated Dispersion Coefficients

Calculated Sigma y:

Calculated Sigma z:

Air Quality Results

0 micrograms/cubic meter

- **Computes Contaminant concentration at a point (X, Y, Z) downwind from a source at an elevation H above the ground.**

Plant Uptake Evaluation

- DTPA extraction/PUP for metal uptake
- Plant bioassay to determine plant toxicity, uptake of inorganic and organic contaminants
- Compare to reference and available criteria
  - FDA Action Levels for foodstuffs
  - European/WHO recommended limitations in foodstuffs on animal feeds, leafy vegetables
  - USDA demonstrated effects levels - plant toxicity

DTPA Extraction Test

- **Chemical characterization of sediment**
  - **Acid-digest metals, pH, organic matter**
- **DTPA extraction of wet and dry sediment to predict plant extractable metals**
- **Results are input into the Plant Uptake Program (PUP)**
  - **Estimates total plant uptake of metals**
    - **(tissue concentration x plant biomass)**
  - **Compares predicted results of test sediment to reference sediment**

Typical Upland Plant Bioassay

Animal Uptake Evaluation

- **Earthworm bioassay**
  - **Toxicity (7 day)**
  - **Bioaccumulation (28 day)**
  - **Salinity <10 ppt**
  - **Analyze for COCs**
  - **Compare to reference & controls**
- **Sediment comparisons**
  - **Reference soils**
  - **FDA- type action levels**

Questions?


DOTS Website
http://www.wes.army.mil/el/dots
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References

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- US Army Corps of Engineers 2003. "Evaluation of Dredged Material Proposed for Disposal at Island, Nearshore, or Upland Confined Disposal Facilities — Testing Manual", ERDC/EL TR-03-1, Engineer Research and Development Center, Vicksburg, MS.
- Palermo and Wilson 2000. "Corps Of Engineers Role In Contaminated Sediment Management And Remediation", proceedings of *Contaminated Sediments: Science, Law and Politics*, the 8th Section Fall Meeting, American Bar Associate, Section of Environment, Energy, and Resources, New Orleans, Louisiana, September 20-24, 2000, U.S. Army Engineer

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- Engineer Manual 1110-2-5027 Confined Disposal of Dredged Material
  - http://www.usace.army.mil/inet/usace-docs/eng-manuals/em1110-2-5027/toc.htm

Models and Documentation Links

- **Dredged material disposal management models site on EL website**
- http://el.erdc.usace.army.mil/products.cfm?Topic=model&Type=drgmat
- **Model documentation links**
- **SETTLE – CDF storage/ponding requirements/TSS predicito**
- http://el.erdc.usace.army.mil/elmodels/pdf/ee-06-18.pdf
- **DYECON – CDF hydraulic efficiency**
- http://el.erdc.usace.army.mil/elmodels/pdf/ee-06-17.pdf
- **CDFATE – Mixing zone computations**
- http://el.erdc.usace.army.mil/elmodels/pdf/cdfate.pdf
- **CORMIX – Mixing evaluations**
- http://www.cormix.info/
- **PSDDF – Consolidation of dredged material**
- See reference list for model documentation
- **PUP – Plant uptake**
- http://el.erdc.usace.army.mil/elmodels/pdf/ee-04-12.pdf

Models and Documentation Links

- **Model documentation links**
- **HELPQ – leachate evaluations**
- **http://el.erdc.usace.army.mil/elmodels/pdf/help3use.pdf**
- **AERMOD (AMS/EPA Regulatory Model (AERMOD) – air emissions modeling**
- **http://www.epa.gov/scram001/7thconf/aermod/aermodugb.pdf**