

# Training Range Environmental Evaluation and Characterization System (TREECS)

SERDP and ESTCP's Annual  
*Partners in Environmental Technology  
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*Billy E. Johnson, PhD, PE, D.WRE*

*Jeff Gerald, Zhonglong Zhang,  
Mark Dortch, and Andrew Simmons*



US Army Corps of Engineers  
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14. ABSTRACT

**Active military ranges contain munitions constituents (MC) and metal contamination that affect the usability and functionality of training facilities. Residues and disturbances from range operations can adversely impact the environment, including human and ecological health which require a variety of assessment tools to evaluate. Such impacts can also affect environmental compliance and range sustainment. Most Army live-fire training and testing ranges also have unique environments in which low-order and dud munitions may cause random and highly uncertain sources of MC contamination. Additionally, these ranges are under increased regulatory scrutiny, which in extreme cases has resulted in limitations being placed on training. The Training Range Environmental Evaluation and Characterization System (TREECS) has been developed by the Engineer Research and Development Center (ERDC) to assist Army analysts in managing ranges in such a manner that comply with environmental quality (EQ) objectives for toxic constituent stressors. The system hosts environmental characterization, risk management and evaluation tools and integrates the results for ease-of-use and reliability for MC. Specifically, the system automates conceptual model formulation and model parameter population across scales and pathways; formulates and couples first principle MC fate/transport/transformation-sequestration models with hydraulic models; and provides a single tool that bridges the gap between migration assessment and risk management and range sustainment. TREECS is currently being tested for use in the Army's Operational Range Assessment Program (ORAP). This presentation will discuss the overall TREECS framework and capabilities along with a case study demonstrating those capabilities.**

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## **TRAINING RANGE ENVIRONMENTAL EVALUATION AND CHARACTERIZATION SYSTEM (TREECS)**

DR. BILLY JOHNSON  
U.S. Army Engineer Research and Development Center  
Environmental Laboratory  
3909 Halls Ferry Road  
Vicksburg, MS 39180  
(601) 634-3714  
billy.e.johnson@usace.army.mil

Active military ranges contain munitions constituents (MC) and metal contamination that affect the usability and functionality of training facilities. Residues and disturbances from range operations can adversely impact the environment, including human and ecological health, which require a variety of assessment tools to evaluate. Such impacts can also affect environmental compliance and range sustainment. Most Army live-fire training and testing ranges also have unique environments in which low-order and dud munitions may cause random and highly uncertain sources of MC contamination. Additionally, these ranges are under increased regulatory scrutiny, which in extreme cases has resulted in limitations being placed on training. The Training Range Environmental Evaluation and Characterization System (TREECS) has been developed by the Engineer Research and Development Center (ERDC) to assist Army analysts in managing ranges in such a manner that comply with environmental quality (EQ) objectives for toxic constituent stressors. The system hosts environmental characterization, risk management and evaluation tools and integrates the results for ease-of-use and reliability for MC. Specifically, the system automates conceptual model formulation and model parameter population across scales and pathways; formulates and couples first principle MC fate/transport-transformation-sequestration models with hydraulic models; and provides a single tool that bridges the gap between migration assessment and risk management and range sustainment. TREECS is currently being tested for use in the Army's Operational Range Assessment Program (ORAP). This presentation will discuss the overall TREECS framework and capabilities along with a case study demonstrating those capabilities.

# ***TREECS Problem Statement***

- Residues and disturbances from range operations can impact the environment, including human and ecological health. Such impacts can impact environmental compliance and range sustainment.
- Army live fire training and test ranges have unique environments in which low-order and unexploded ordnance (dud munitions) are likely to cause random and highly uncertain sources of MC contamination.
- ***An assessment tool is needed to forecast if, when, and at what level MC concentrations in off-range media (groundwater, surface water, and sediment) may exceed protective health benchmarks.***



# ***TREECS Solution / Approach***

Training Range Environmental Evaluation and Characterization System (TREECS) is a client-based system that provides forecasts of Munitions Constituents (MC) fate on and off range based on munitions use on range.

## **Development Approach:**

Formulate and couple screening level MC fate/transport-transformation-sequestration models in an integrated framework for fast assessments with a minimal amount of user input.

## **Partners:**

PNNL, AEC, CHPPM, ITL, and EL

<http://el.erd.c.usace.army.mil/treecs/>



# ***TREecs Components***

- Framework for Tier 1 and 2 assessments
- Constituent databases
- Health Benchmark database
- Munitions database
- MC residual mass loading module based on munitions use
- GIS module
- Hydro-geo-characteristics toolkit (HGCT) for estimating input parameters
- Models for soil, surface water, vadose zone, and groundwater
- Simplified user input interfaces for models (GUIs)
- Viewers for results
- Sensitivity and uncertainty module for Tier 2 assessments



# TREecs Main Screen

TREecs - Training Range Environmental Evaluation and Characterization System

File References Web Data Tools Websites Options Help

Installation/AOI Description Tier Analysis Selection Site Conditions DoD Target Health Benchmarks Inputs Execute Uncertainty View Results

Installation name: Fort Benning, GA  AOI name: MyAoi

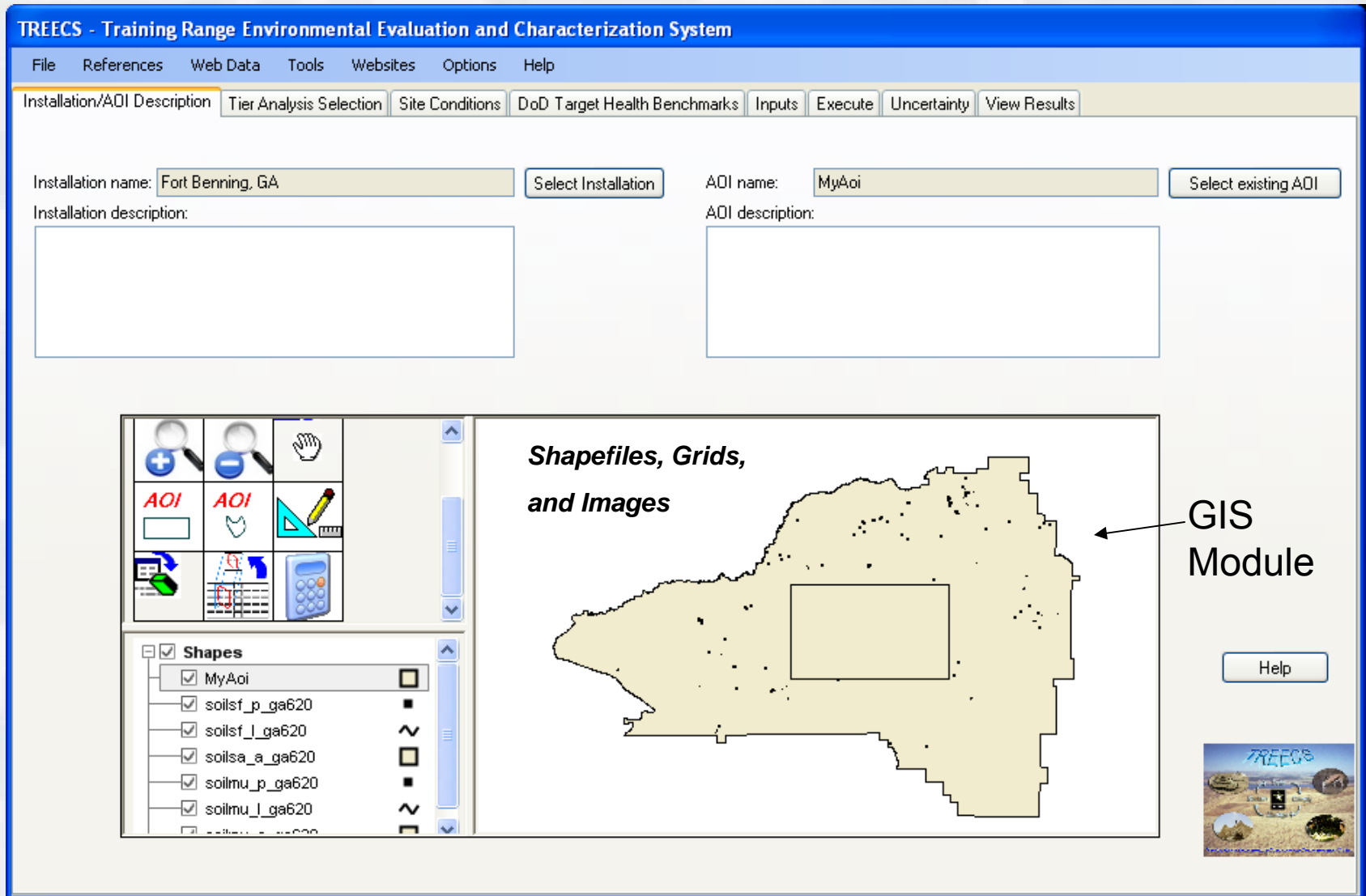
Installation description:

AOI description:

**Shapefiles, Grids, and Images**

GIS Module

Help



The screenshot displays the TREecs software interface. At the top is a blue title bar with the text 'TREecs - Training Range Environmental Evaluation and Characterization System'. Below this is a menu bar with 'File', 'References', 'Web Data', 'Tools', 'Websites', 'Options', and 'Help'. A secondary menu bar contains 'Installation/AOI Description', 'Tier Analysis Selection', 'Site Conditions', 'DoD Target Health Benchmarks', 'Inputs', 'Execute', 'Uncertainty', and 'View Results'. The main workspace is divided into several sections. On the left, there are two text input fields: 'Installation name: Fort Benning, GA' with a 'Select Installation' button, and 'Installation description:'. To the right of these are 'AOI name: MyAoi' with a 'Select existing AOI' button, and 'AOI description:'. Below the text fields is a large map area. The map shows a yellow-shaded area representing the AOI, with a white rectangular box inside it. The text 'Shapefiles, Grids, and Images' is overlaid on the map. To the left of the map is a toolbar with various icons for zooming, panning, and editing. Below the toolbar is a legend titled 'Shapes' with a list of items: 'MyAoi', 'soilsf\_p\_ga620', 'soilsf\_l\_ga620', 'soilsa\_a\_ga620', 'soilmu\_p\_ga620', and 'soilmu\_l\_ga620'. To the right of the map, an arrow points to the map area with the text 'GIS Module'. Below the arrow is a 'Help' button. At the bottom right of the map area is a small thumbnail image of the TREecs logo and a landscape scene.



# GIS Functions/Tools



- For opening individual GIS files



- For saving individual GIS files



- For resampling a grid



- For zooming into an area in the workspace



- For zooming out of an area in the workspace



- For panning in the workspace

AOI



- For creating a rectangular AOI shapefile in the workspace

AOI



- For creating a polygon AOI shapefile in the workspace



- For measuring length and area in the workspace



- For converting a shapefile to a grid



- For extracting a subset of a grid



- For creating slope grid from DEM and performing simple arithmetic operations on a grid



# ***Hydro-Geo-Characteristics Toolkit (HGCT)***

- To aid the user in determining input variables required by TREECS models
  - ▶ Soil Properties
  - ▶ Soil erosion rate
  - ▶ Hydrology (infiltration, runoff, ET, etc.)
  - ▶ Darcy velocity
- Allows *point* (single value) and *spatially-varying* composite estimates
- Spatial option requires use of GIS module in TREECS or externally developed map files (grids)

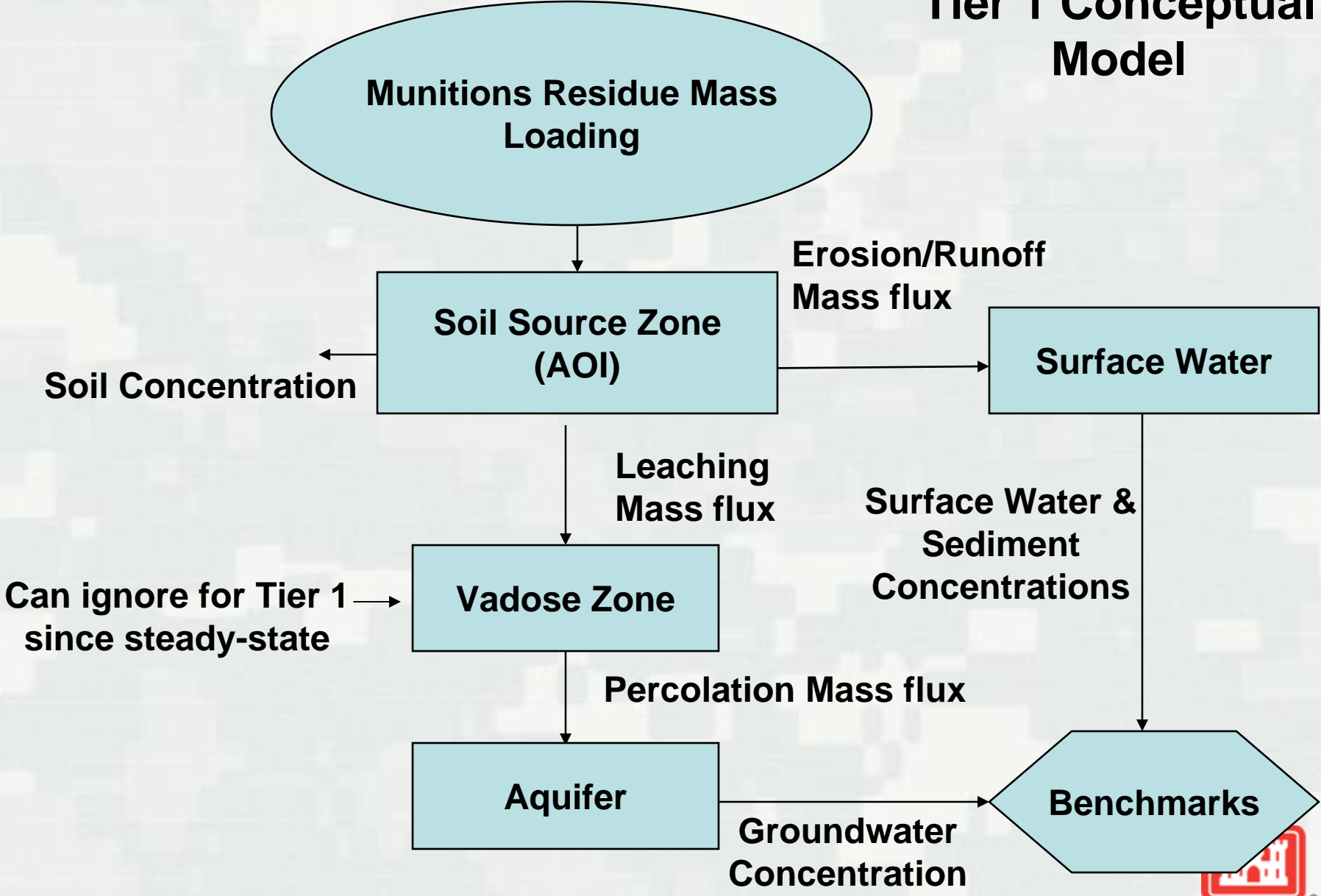


# ***Tiered Approach***

- Tier 1 (screening)
  - ▶ Steady-state, no degradation, worse case, highly conservative
  - ▶ Requires little data
  - ▶ Can be applied very quickly
  - ▶ Indicates whether a problem could ever potentially exist; if so, proceed to Tier 2
  
- Tier 2 (more comprehensive)
  - ▶ Time-varying, much more realistic and accurate
  - ▶ Requires more data
  - ▶ Requires more time to set up and apply, but still can be done relatively quickly
  - ▶ Can be used to determine when benchmark exceedence may occur
  - ▶ Useful for evaluating range management strategies



# Tier 1 Conceptual Model



# ***Tier 1 Model Primary Assumptions***

- Area of Interest (AOI) is homogeneous
- Constant loading of MC into impact area (could possibly add firing points later)
- Soil concentrations are at steady-state
- No decay/degradation or volatilization, except for surface water volatilization
- No losses between the AOI and receiving surface water



# *Tier 1 Modules*

- MC mass loading based on munitions use
- Constituent databases
- Benchmark database
- Hydro-geo-characteristics toolkit (HGCT) for estimating input parameters (covered in separate session)
- GIS module for viewing of spatial info and for use in developing gridded info for HGCT spatial (covered in separate session)
- Steady-state soil model
- MEPAS Aquifer model with inputs simplified for Tier 1
- RECOVERY surface water model with inputs simplified for Tier 1
- Viewers for results



# ***Constituent Database Module (Constituent Selection)***

- Available Databases
  - ▶ FRAMES
  - ▶ Risk Assessment Information System (RAIS)
  - ▶ Army Range Constituent Database
  - ▶ User Defined (build from Con DB editor tool starting with a copy of the FRAMES (FUI) DB)
- For selecting MC and their properties
- Contains physical/chemical properties for MC and other contaminants
- Can change property values within the TREECS application, but it does not change database value



# Constituent Selection

**Select Database**

Select the constituent database to use:

- FRAMES Constituent Database
- Amy Range Constituent Database
- Risk Assessment Information System (RAIS)
- User Defined Constituent Database

User-defined constituent database:  
C:\Program Files\TREECS\Databases\treec

**Select MC**

Available constituents (CASRN):

- 1,1 dichloroethylene (75354)
- vinylidene chloride (75354)
- 1,1,1,2-tetrachloroethane (630206)
- 1,1,1-trichloroethane (71556)
- methyl chloroform (71556)
- 1,1,2,2-tetrachloroethane (79345)

Search:

List by CASRN (name)

**View MC Properties**

Currently selected constituents (CASRN):

- rdx (121824)
- trt (118967)
- lead (7439921)
- copper (7440508)
- potassium perchlorate (7778747)

Can use a user defined database  
(Create under Tools)



# MC Residue Mass Loading Module (Operational Inputs)

**Constituent Selection** | **Operational Inputs**

Type of loading to be estimated:  
 Impact Zone  
 Firing Point

Select the munitions database to use:  
 Default munitions database  
 User defined munitions database

User defined munitions database:  
C:\Program Files\TREECS\Data  
[Browse for database] [Load/Reload Database]

Munitions master list:  
AP Hill B584 (NSN: 0001) (DODIC: B584)  
AP Hill L601 (NSN: 0002) (DODIC: L601)  
AP Hill L594 (NSN: 0003) (DODIC: L594)  
AP Hill H975 (NSN: 0004) (DODIC: H975)  
AP Hill D544 (NSN: 0005) (DODIC: D544)

Search: [ ] [Find/Find Next]

Munitions used at this site/range:  
AP Hill D544 (NSN: 0005) (DODIC: D544)  
AP Hill B546 (NSN: 0007) (DODIC: B546)  
AP Hill B470 (NSN: 0008) (DODIC: B470)  
AP Hill B542 (NSN: 0009) (DODIC: B542)  
AP Hill B103 (NSN: 0010) (DODIC: B103)

Munitions usage information:  
Munition: AP Hill D544 (NSN: 0005) (DODIC: D544)

Starting year of simulation: [ ]

Rounds fired per year: [861]  
Dud percentage: [0]  
Low order percentage: [2]  
High order percentage: [98]

Percentage of duds sympathetically detonated: [0]  
Sympathetic dud yield percentage: [100]  
Low order yield percentage: [50]  
High order yield percentage: [100]

Help

Constituent masses are summed across PEP, bulk, and inert material types and used as the total mass available at the impact or firing point. It is assumed that the fraction of summed constituent mass consumed in the yield is vaporized and is not available as residue.

Pulled from MIDAS Extract DB

Provided by user

Could add Firing Points

Can use a User Defined munitions database

Constant in Tier 1



# MC Residue Mass Loading

$$L_{i,k} = \sum_{j=1}^{j=n} \left\{ N_{j,k} M_{i,j} \left[ \frac{LO_{j,k} (100 - Y_{LOj,k}) + HO_{j,k} (100 - Y_{HOj,k}) + DUD_{j,k} SYM_{j,k} (100 - Y_{SYMj,k})}{100} \right] \right\}$$

$L_{i,k}$	= Loading for constituent I for year k, g/yr
$DUD_{j,k}$	= percent of duds for munitions item j for year k
$HO_{j,k}$	= percent of high order detonations for munitions item j for year k
$LO_{j,k}$	= percent of low order detonations for munitions item j for year k
$M_{i,j}$	= mass of constituent i in munitions item j delivered to impact area, g/item
$N_{j,k}$	= number of munitions item j fired for year k
n	= total number of munitions items used at AOI
$SYM_{j,k}$	= percent of sympathetic detonation of duds for munitions item j for year k
$Y_{HOj,k}$	= percent yield of munitions item j due to high order detonation for year k
$Y_{LOj,k}$	= percent yield of munitions item j due to low order detonation for year k
$Y_{SYMj,k}$	= percent yield of munitions item j due to sympathetic detonation for year k



# ***DoD Protective Health Benchmarks Database Construct***

- Media and end point
  - ▶ Soil: human and eco (grayed out since no values currently)
  - ▶ Groundwater: human
  - ▶ Surface water: eco and human
  - ▶ Surface water sediments: eco



# Benchmark Database Module

TRECS - Training Range Environmental Evaluation and Characterization System (T1APH\_SP.trp)

File References Web Data Tools Websites Options Help

Installation/AOI Description Tier Analysis Selection Site Conditions DoD Target Health Benchmarks Inputs Execute Uncertainty View Results

Select from the benchmark options below:

- DoD Target Health Benchmarks
- User-defined benchmark database

Can use the DoD DB or a User Defined DB

Constituent Name	Constituent CASRN	Media	Receptor	Value	Unit
RDX	121-82-4	surfacewater-mari...	Eco	5000	ug/L
RDX	121-82-4	sediment-marine	Eco	0.026	mg/kg
RDX	121-82-4	surfacewater-fresh	Eco	190	ug/L
RDX	121-82-4	sediment-fresh	Eco	0.026	mg/kg
RDX	121-82-4	surfacewater-fresh	Human	0.61	ug/L

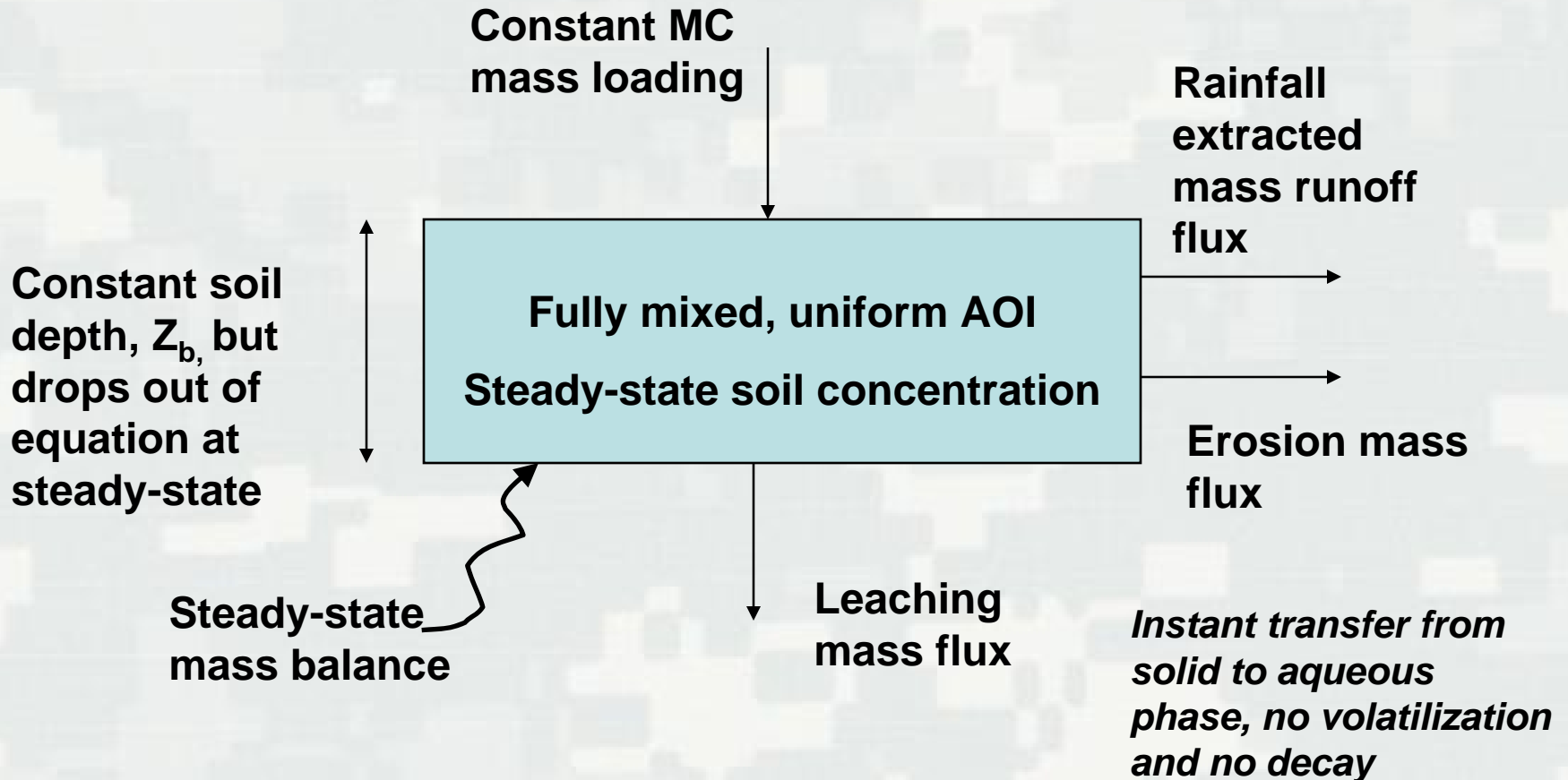
Ecological Surface Water/Sediment is marine (as opposed to freshwater)

Sediment TOC:  fraction

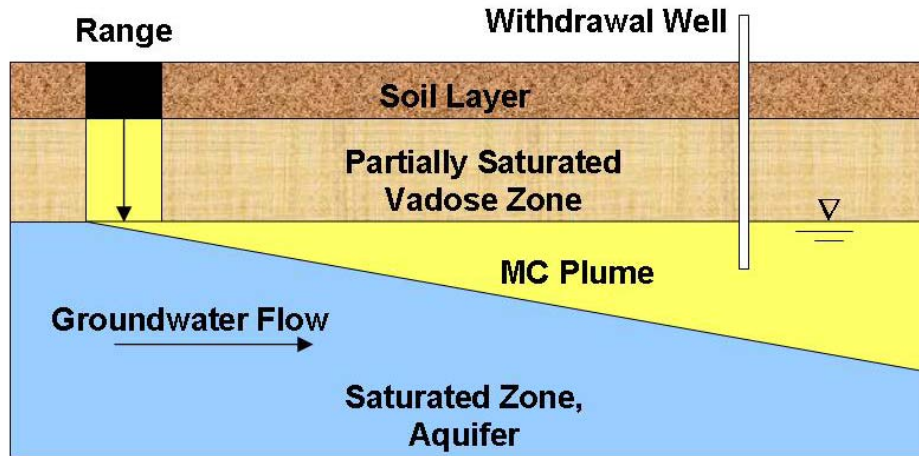
Soil TOC:  fraction



# Tier 1 Soil Model



# *Aquifer Model for Tier 1 – MEPAS Aquifer with less inputs (prescribed inputs)*

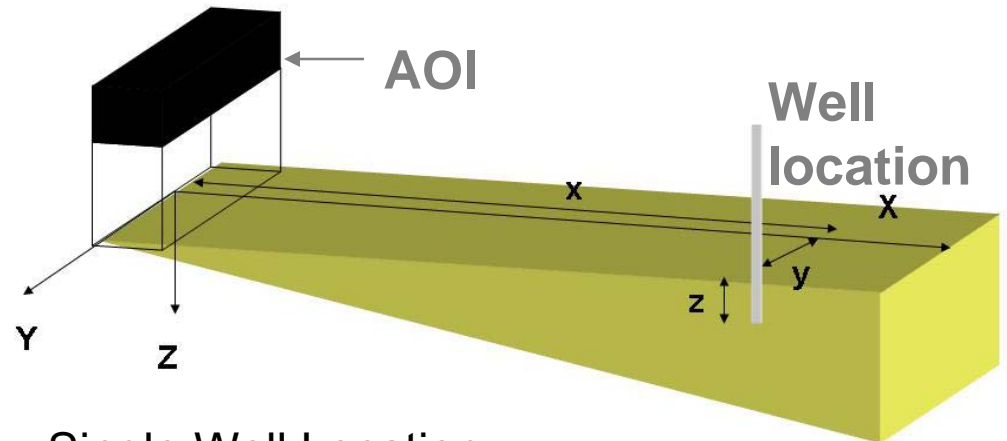


**Conceptual Model**

**Don't need to model vadose zone for steady-state**

**AOI length and width are input in Soil MUI**

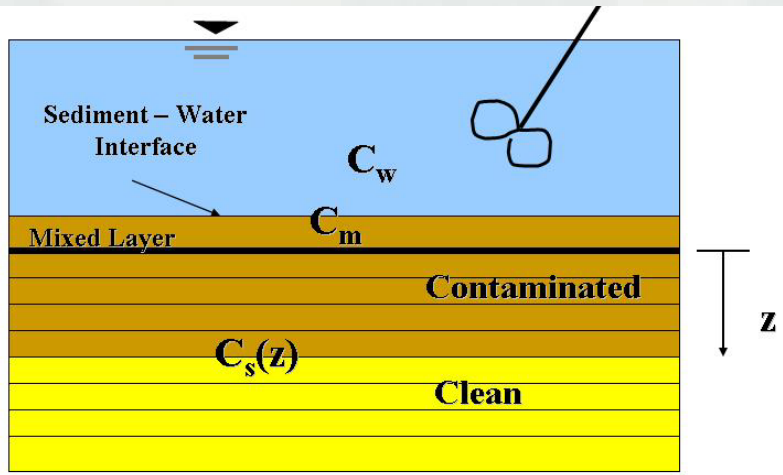
**MEPAS coordinates**



**Single Well Location**



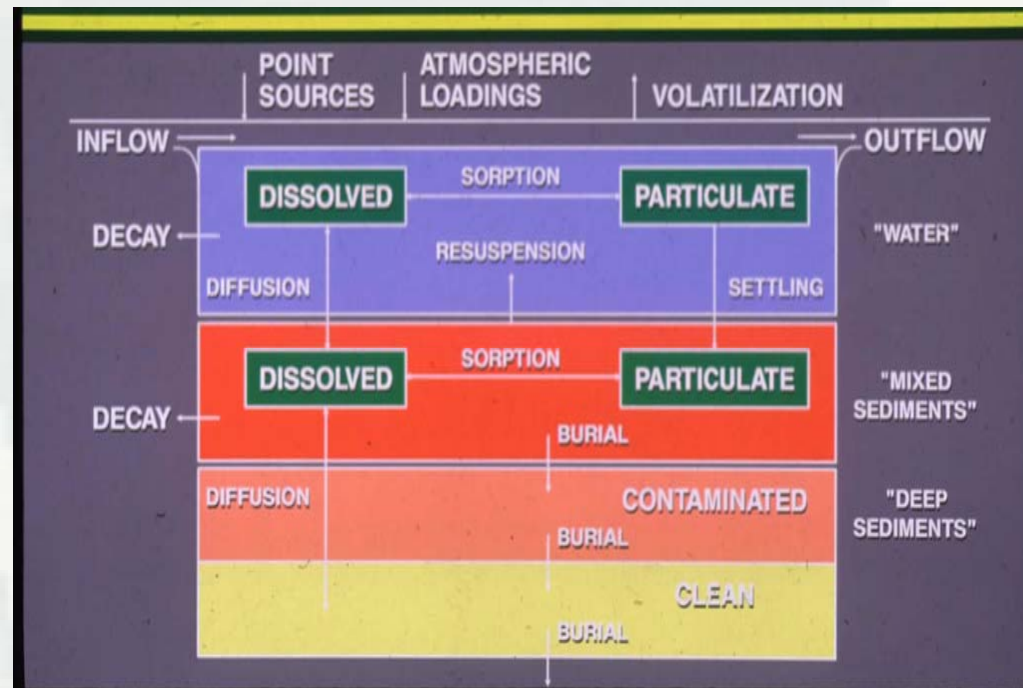
# Tier 1 Surface Water Model (RECOVERY with fewer inputs – prescribed inputs)



## Model conceptualization

MC runoff/erosion dumps directly into surface water, i.e., no routing or in-path storage

## Model fate processes



# Tier 2 Conceptual Model

Munitions Residue Mass Loading

Degradation and Volatilization

Soil Concentration

Soil Source Zone, AOI  
solid and non-solid phase mass

Erosion/Runoff mass flux

Surface Water

Interflow

Infiltration mass flux

Vadose Zone

Percolation mass flux

Groundwater mass flux to surface water

Surface water & sediment concentrations

Aquifer

Groundwater concentration

Benchmarks

Soil model includes dissolution kinetics



## ***Tier 2 Model Primary Assumptions***

- Area of Interest (AOI) is homogeneous
- Inputs and model responses are time-varying
- There can be fate losses, such as degradation (1<sup>st</sup> order)
- Sorption is linear, reversible equilibrium
- Solid and non-solid phase mass are tracked with dissolution
- No losses between the AOI and receiving surface water for runoff/erosion and interflow
- Steady-state hydrologic inputs (average annual conditions) like Tier 1
- Vadose transport is 1D vertical

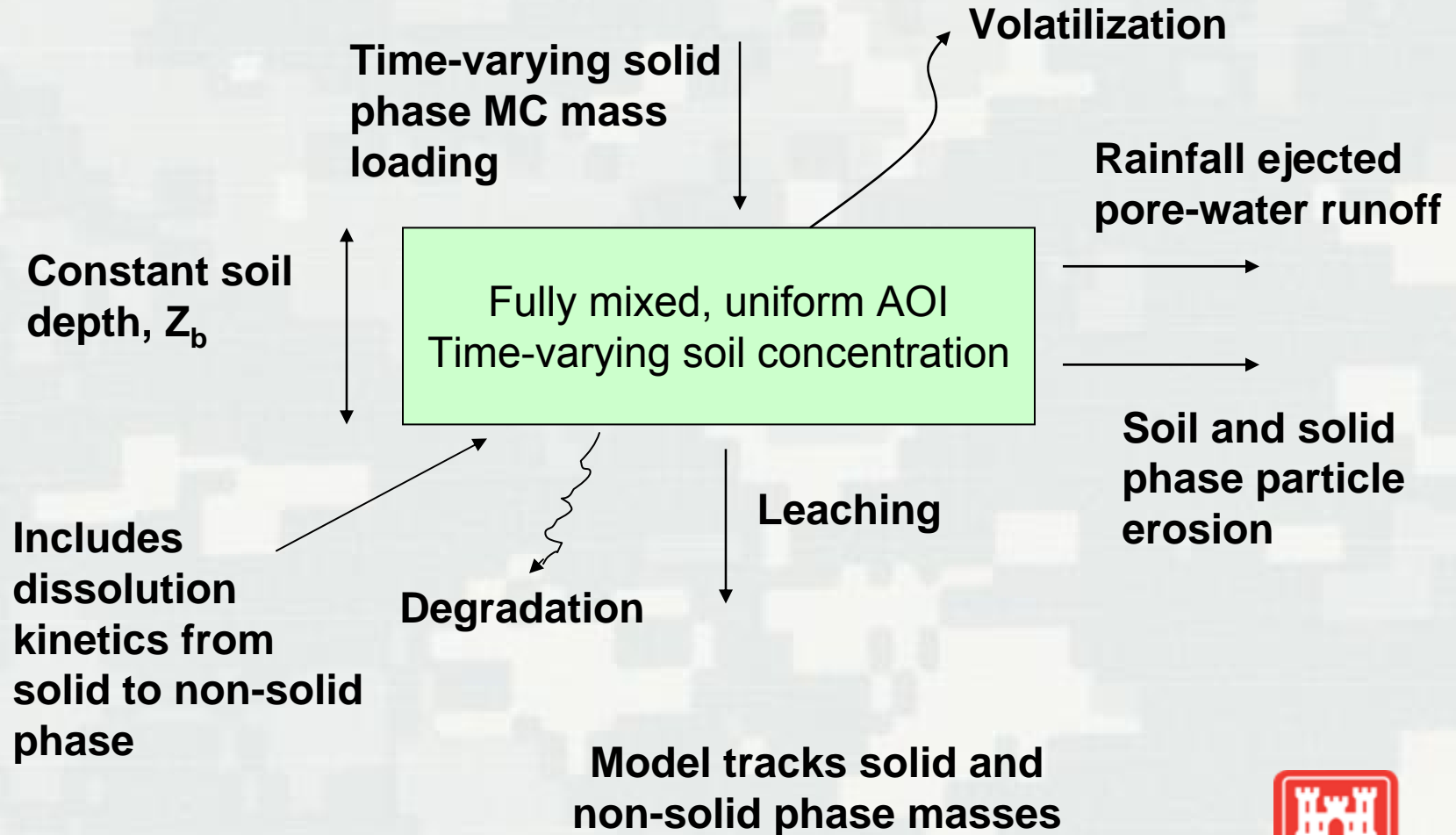


# *Tier 2 Modules*

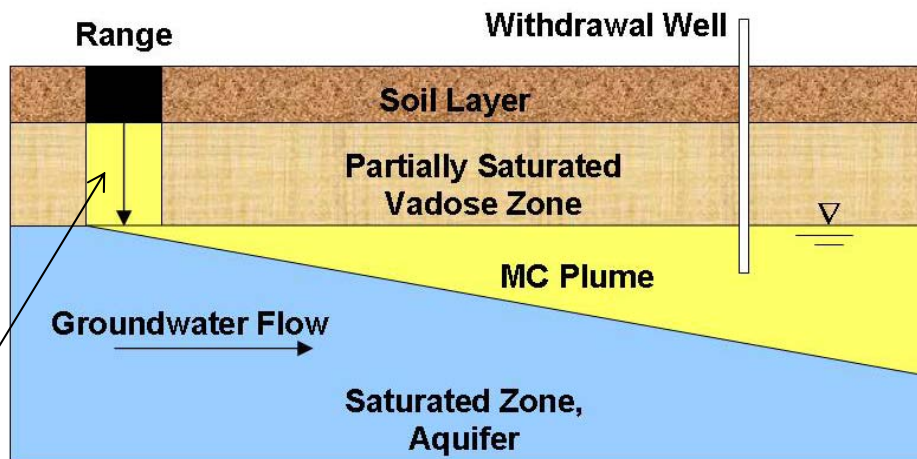
- Same as Tier 1 except for the following additions:
  - ▶ Tier 2 soil model is used instead of Tier 1 soil model
  - ▶ MEPAS Vadose Zone model and flux viewer
  - ▶ Contaminant Model for Streams (CMS); user must choose whether to use CMS or RECOVERY for surface water and sediments (default is RECOVERY)
  - ▶ Sensitivity and Uncertainty (S/U) based on Monte Carlo simulation with Latin Hypercube sampling
  - ▶ S/U viewers
  - ▶ Plus-SG Operator: allows aquifer discharge to surface water; transparent to user other than having to specify the aquifer discharge rate to surface water



# Tier 2 Soil Model



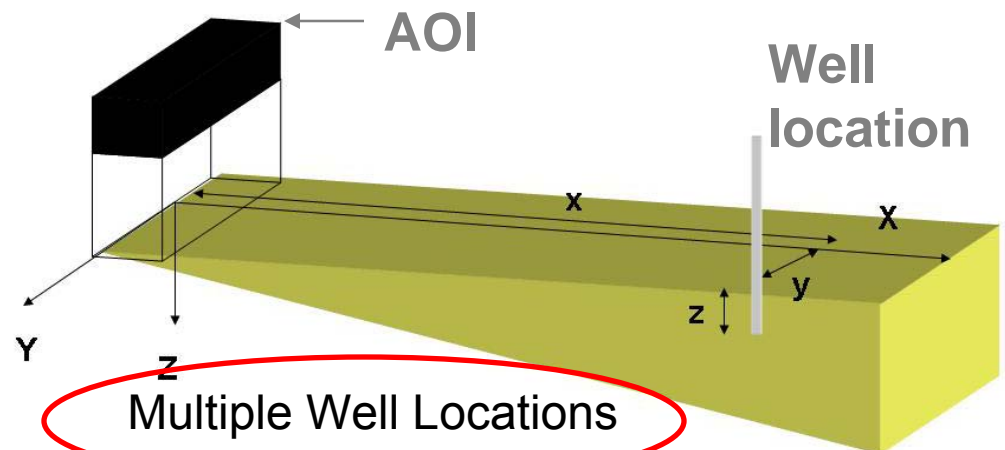
# MEPAS Vadose & Aquifer Models for Tier 2 with full Capabilities



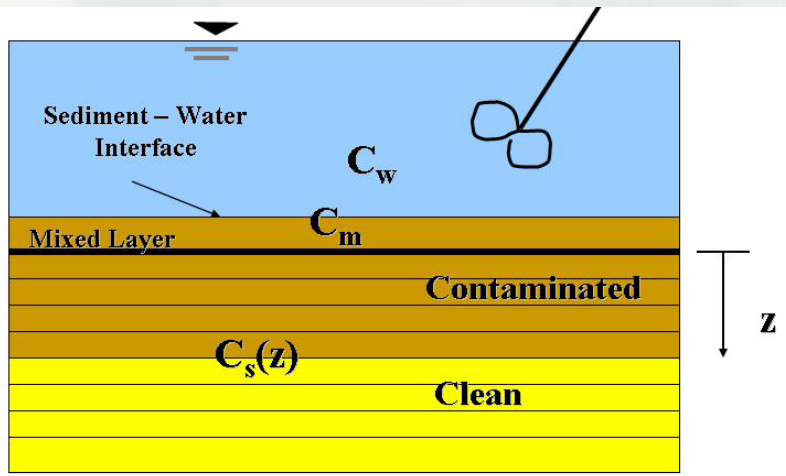
AOI length and width are input in Soil MUI

MEPAS coordinates

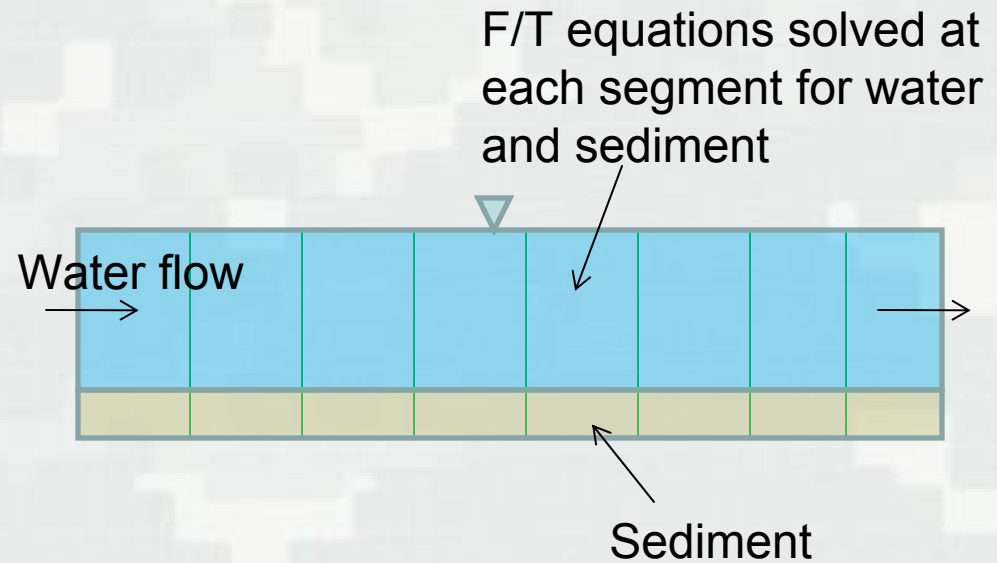
Vadose Zone included



# Tier 2 Surface Water Models, *RECOVERY* and *CMS* with full Capabilities



**RECOVERY Model conceptualization**



**CMS conceptualization**



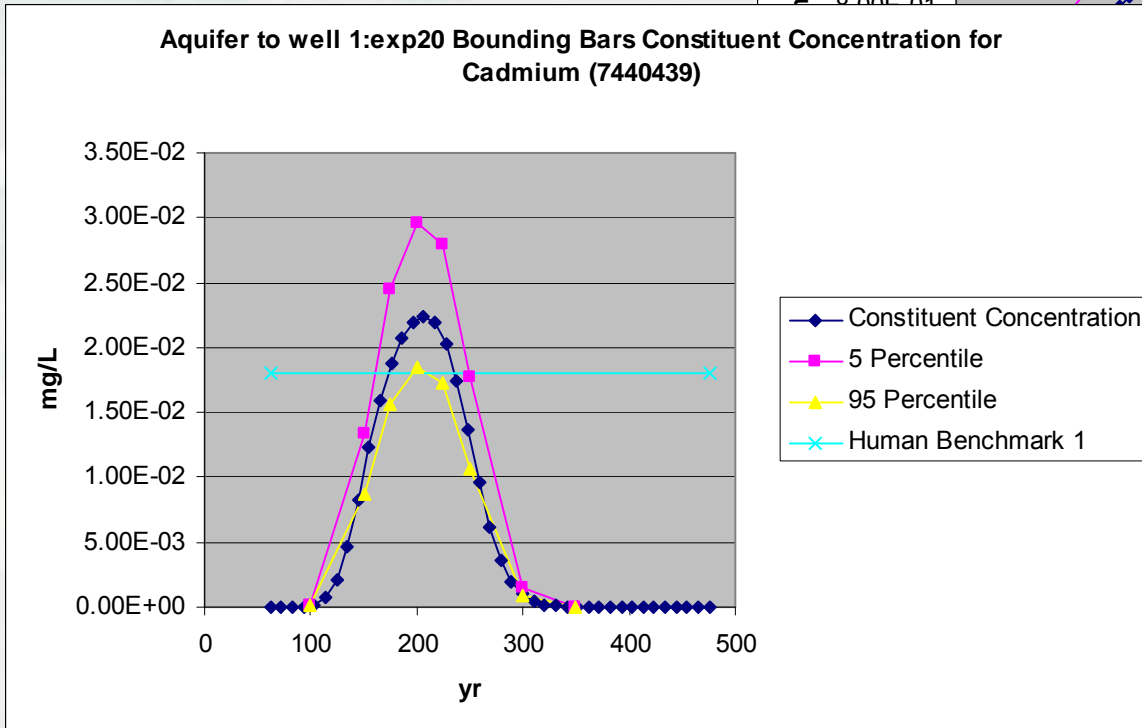
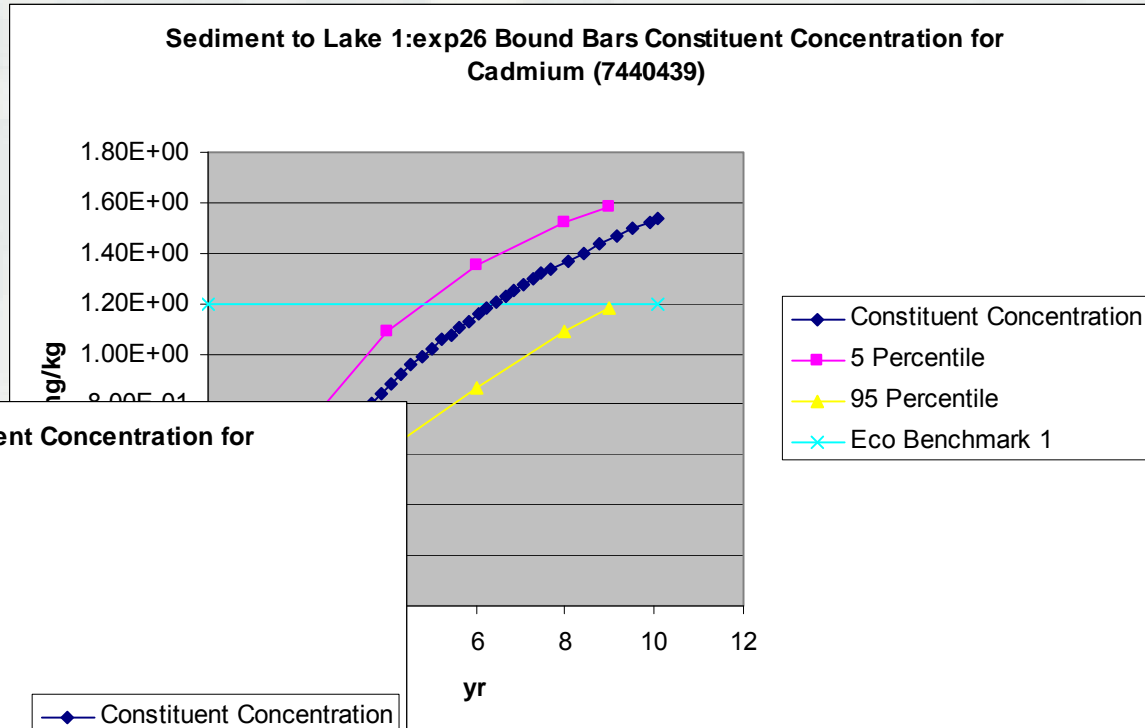
# *Sensitivity/Uncertainty Module*

- Declare uncertain parameters
- Declare variables and their features to watch for output, e.g., aquifer concentration at specific years or peak concentration for simulation
- Specify the type of distribution and its statistics for each uncertain parameter, e.g., normal distribution with mean, upper and lower bounds, and standard deviation
- Set random seed and number of Monte Carlo iterations



# S/U Example Output Viewer

Concentration versus time  
with confidence limits



# TREECS Status

- Currently being tested and validated using existing training range data by EL, AEC, and CHPPM personnel
- Used to help support ORAP Phase II Assessments
- FY11-FY13 – Further enhancements to Tier 1 and Tier 2 modeling capabilities and database expansions
- FY11-FY13 – Development and Implementation of a Fully Explicit Physically Based Watershed Modeling capability within the TREECS Framework – *Useful for evaluating mitigation scenarios for multiple AOIs covering complex terrain*



# *Questions?*



<http://el.erdc.usace.army.mil/treecs/>

Billy E. Johnson

601-634-3714

Billy.E.Johnson@usace.army.mil



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