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Evaluation Approaches for Transitioning from Active to Passive Remediation

September 23, 2020

Katie Muller and Mike Truex

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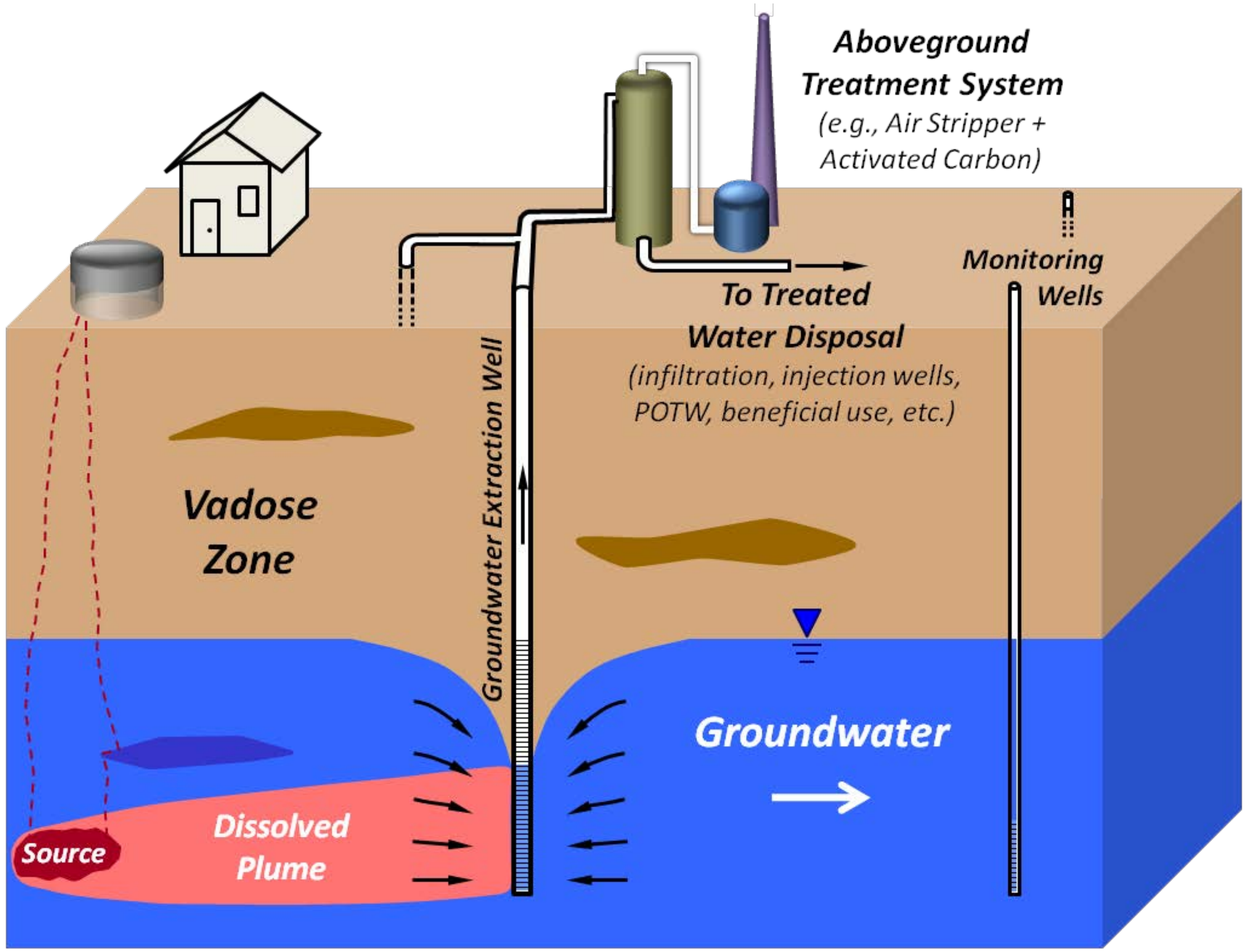
Outline

1) Transition Assessment Basics (Why, When and How)
2) Assessment Framework
3) Technical Justification
   - Tools and Methodology
4) Case Studies
5) After Transition



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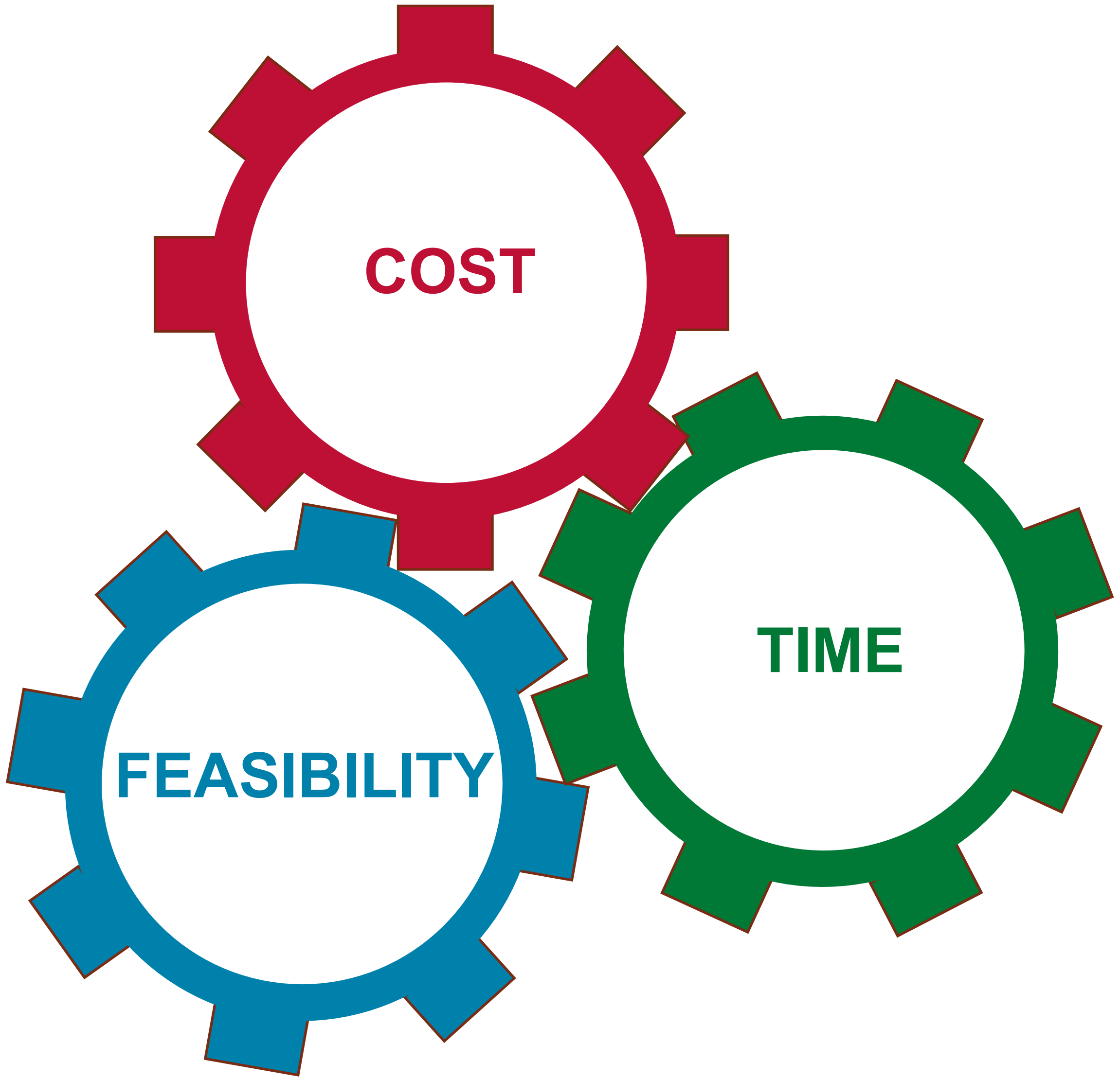
Why Transition from Active to Passive?

- Able to Manage Risk
  - ✓ Balance of time, cost, feasibility and potential risk

- Remaining mass may not constitute unacceptable risk
  - ✓ Mass removal does not necessarily equate to risk reduction

RISK MANAGEMENT



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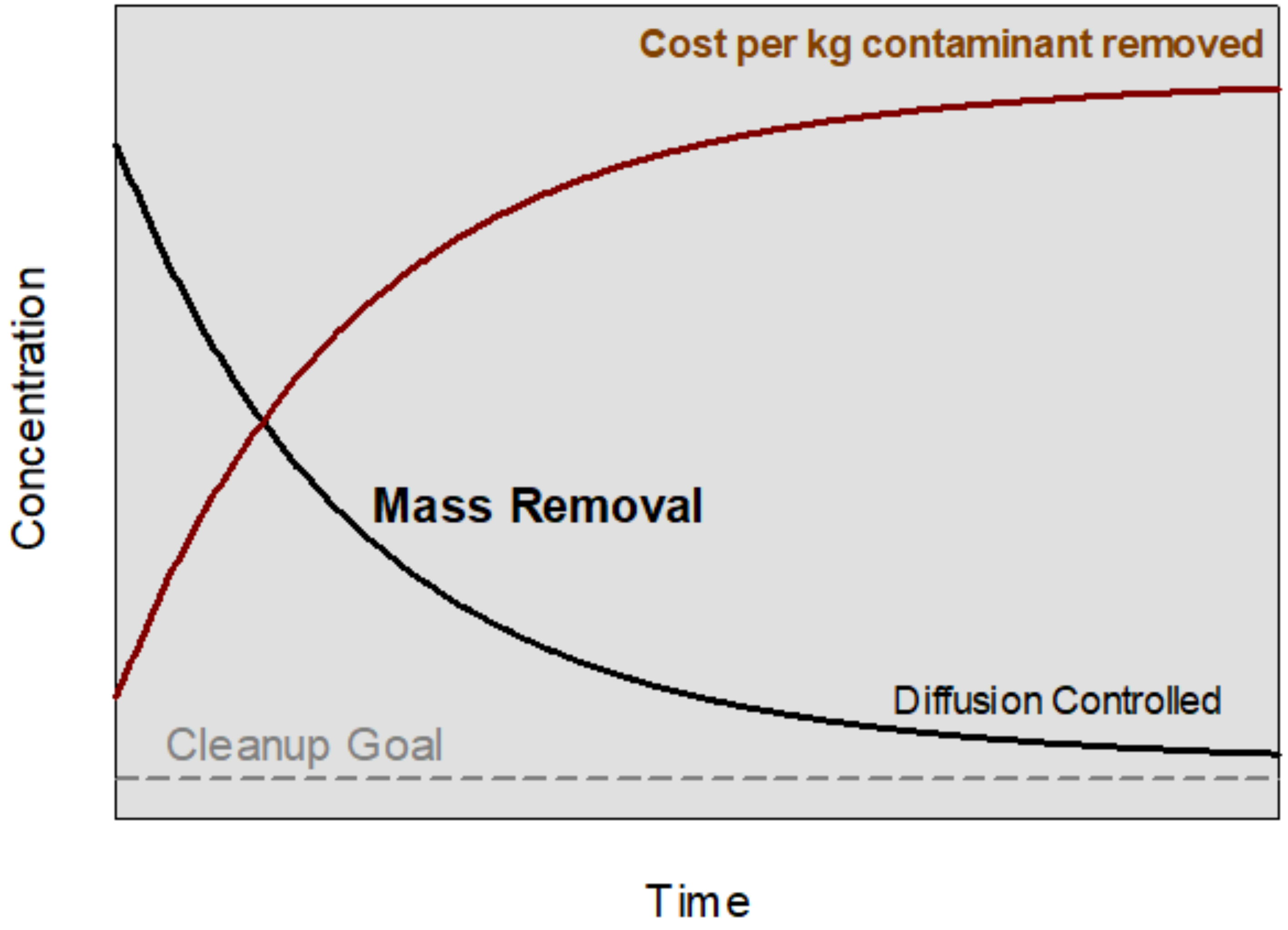
When to Consider a Transition Assessment?

- Predetermined condition is reached
  - ✓ Source strength, plume behavior, etc.
- Asymptotic behavior under current remedy
- Current remedy has become impractical
- Conditions warrant a TI evaluation or development of alternative RAOs



After NAVFAC, 2012

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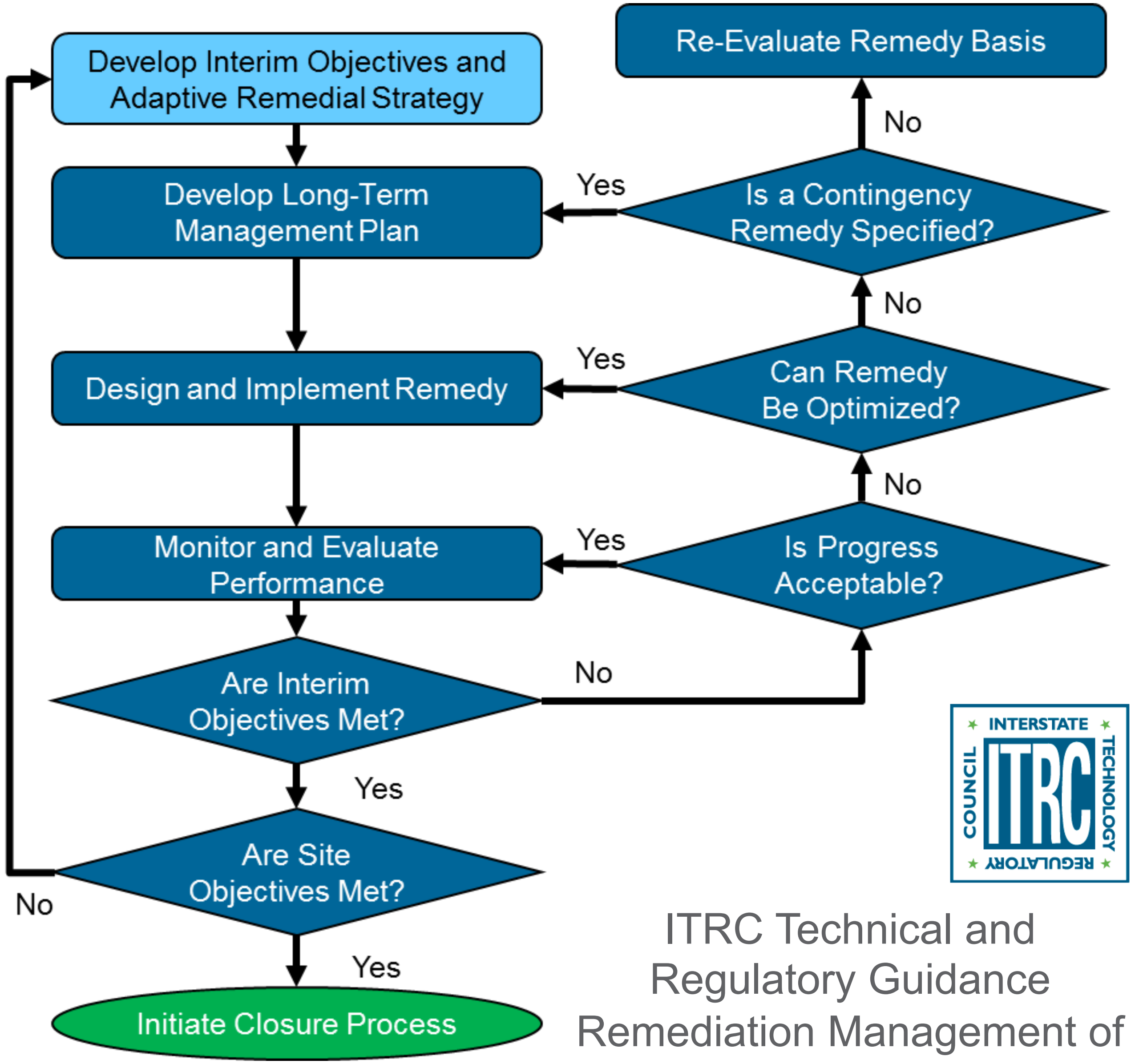
How to Consider a Transition Assessment

- Adaptative management framework can be used for active to passive transition
  - ✓ Addresses uncertainties and enables interim actions
- Recent Guidance for Adaptive Site Management and End States
  - ✓ Remediation Management of Complex Sites (ITRC, 2017)
  - ✓ Groundwater Remedy Completion Strategy: Moving Forward with the End in Mind (EPA, 2014)
  - ✓ Groundwater Read Map- Recommended Processes for Restoring Contaminated Groundwater at Superfund Sites (EPA, 2011)
  - ✓ Alternatives for Managing the Nation's Complex Contaminated Groundwater Sites. (National Research Council (NRC), 2013)
- Technical Basis for Active to Passive Transition
  - ✓ Soil Vapor Extraction (Truex et al., 2013)
  - ✓ Pump and Treat (Truex et al., 2015, 2017)



ITRC Technical and Regulatory Guidance Remediation Management of Complex Sites RMCS-1
http://rmcs-1.itrcweb.org

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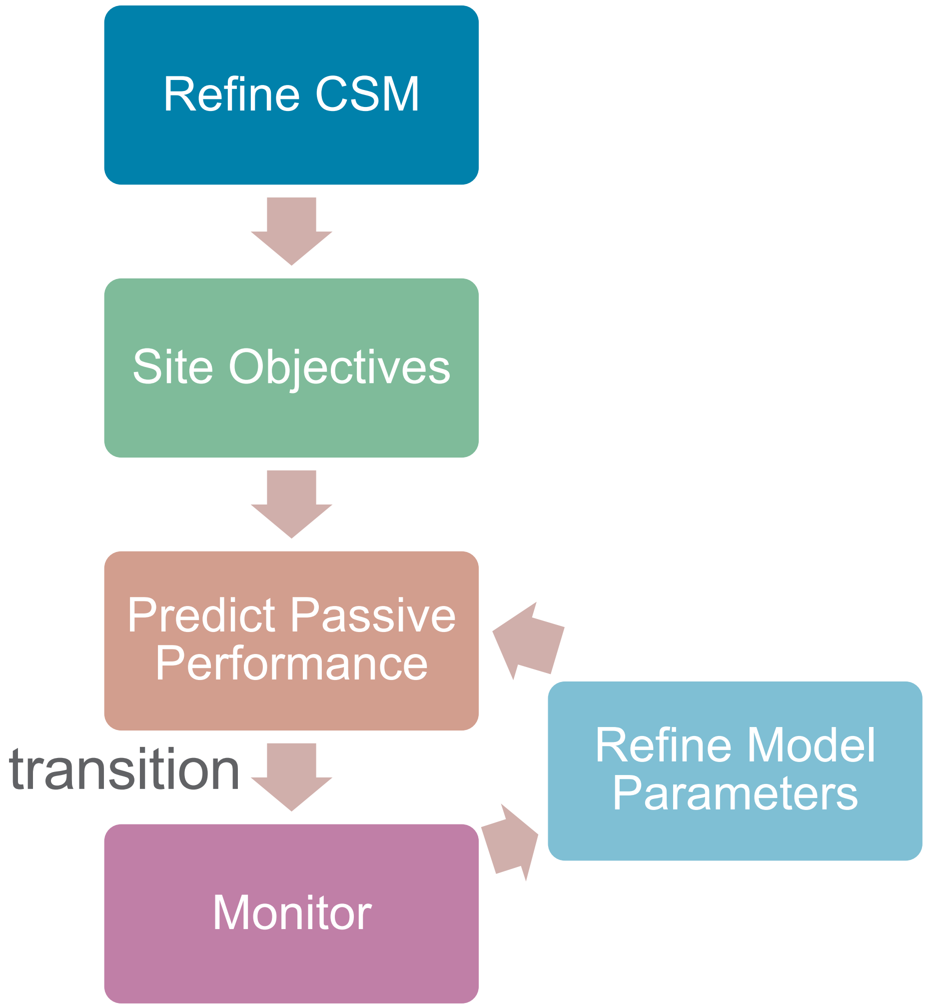
Transition Assessment Framework

1. **Refine Conceptual Site Model**
   - **Determine dominant processes under passive conditions**
   - **Identify key complexities at site**
   - **Estimate uncertainties**
2. Evaluate Site Objectives
   - Potential exposure pathways
   - Remedial Action Objective concentrations
   - Determine site constraints
3. Predict Passive Remedy Performance
   - Quantify potential impact of remaining source material
   - Estimate key fate and transport parameters
4. Monitor for Selected Performance Indicators
5. Refine and Update Model Parameters (if needed)



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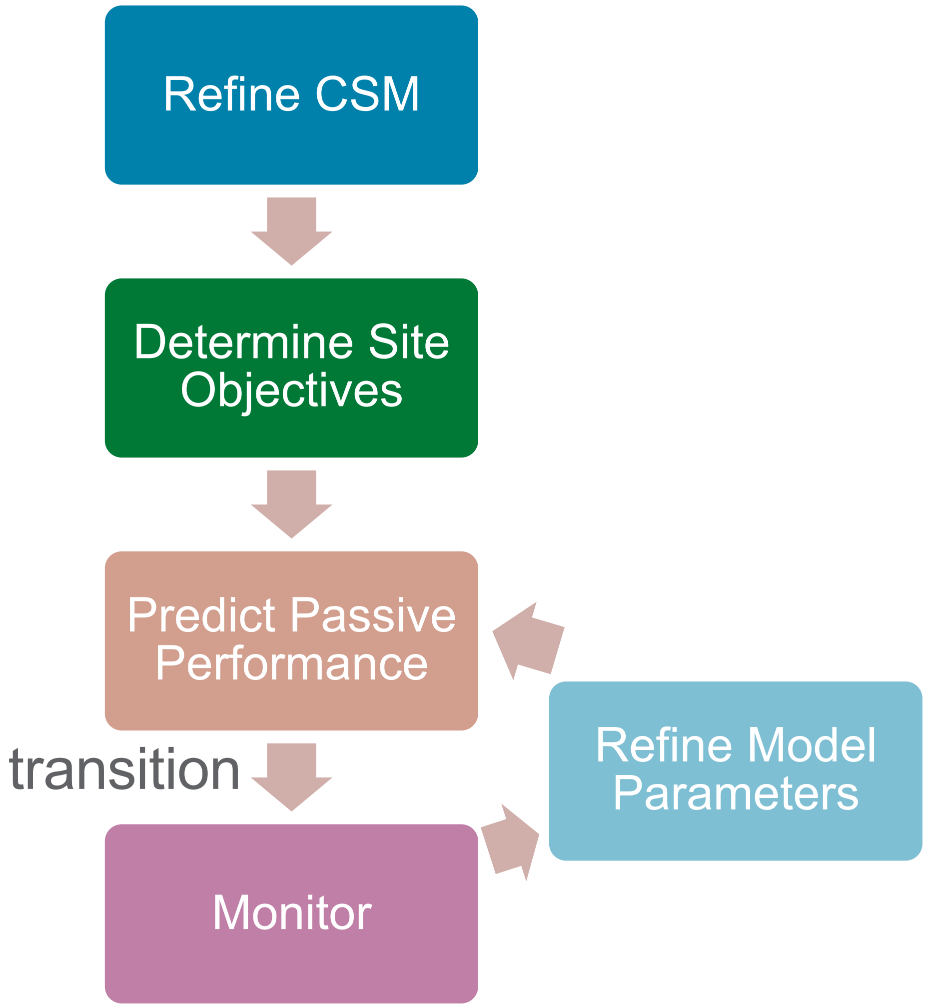

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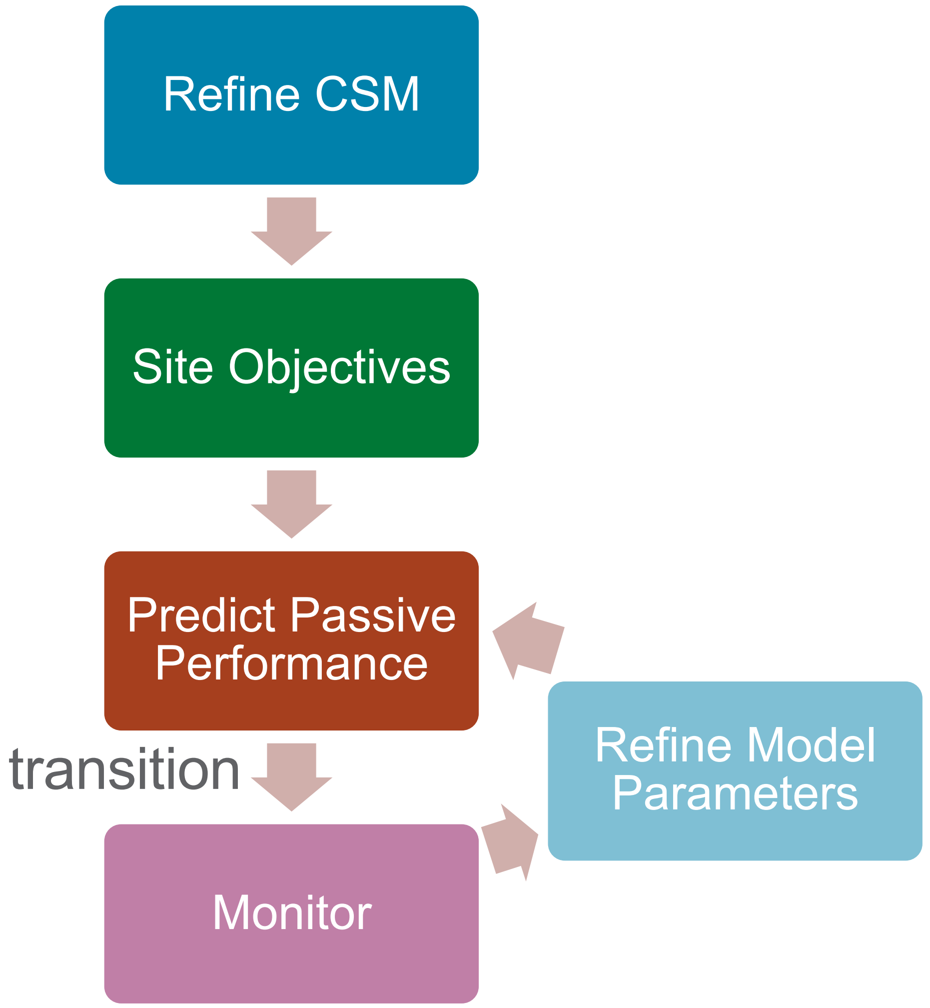

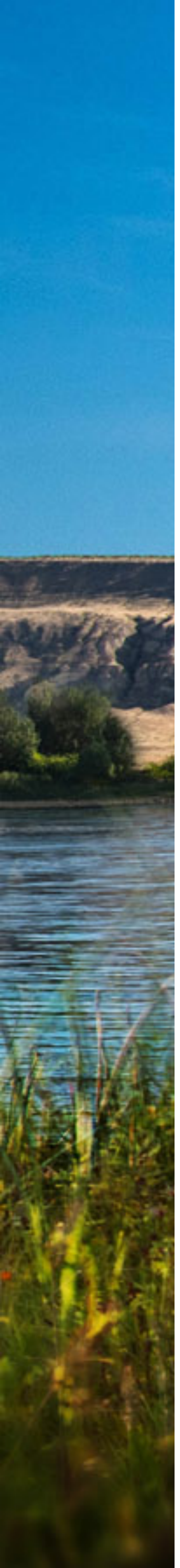

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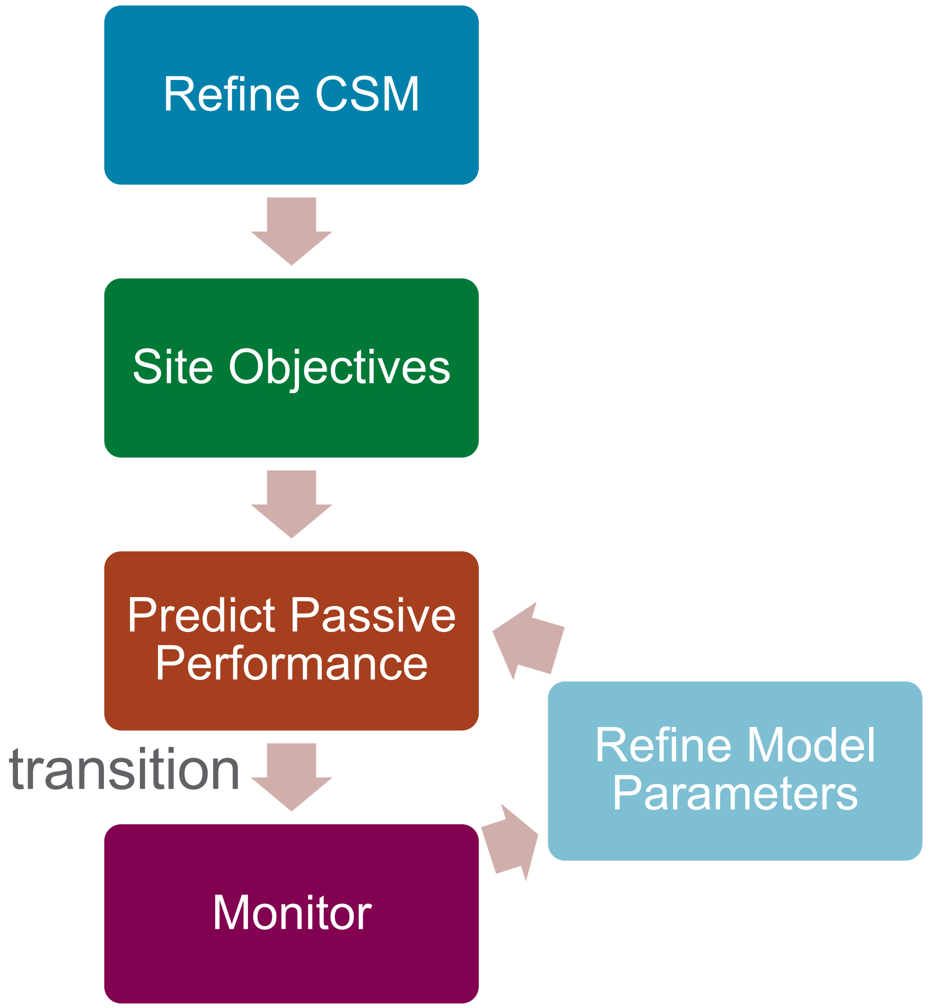

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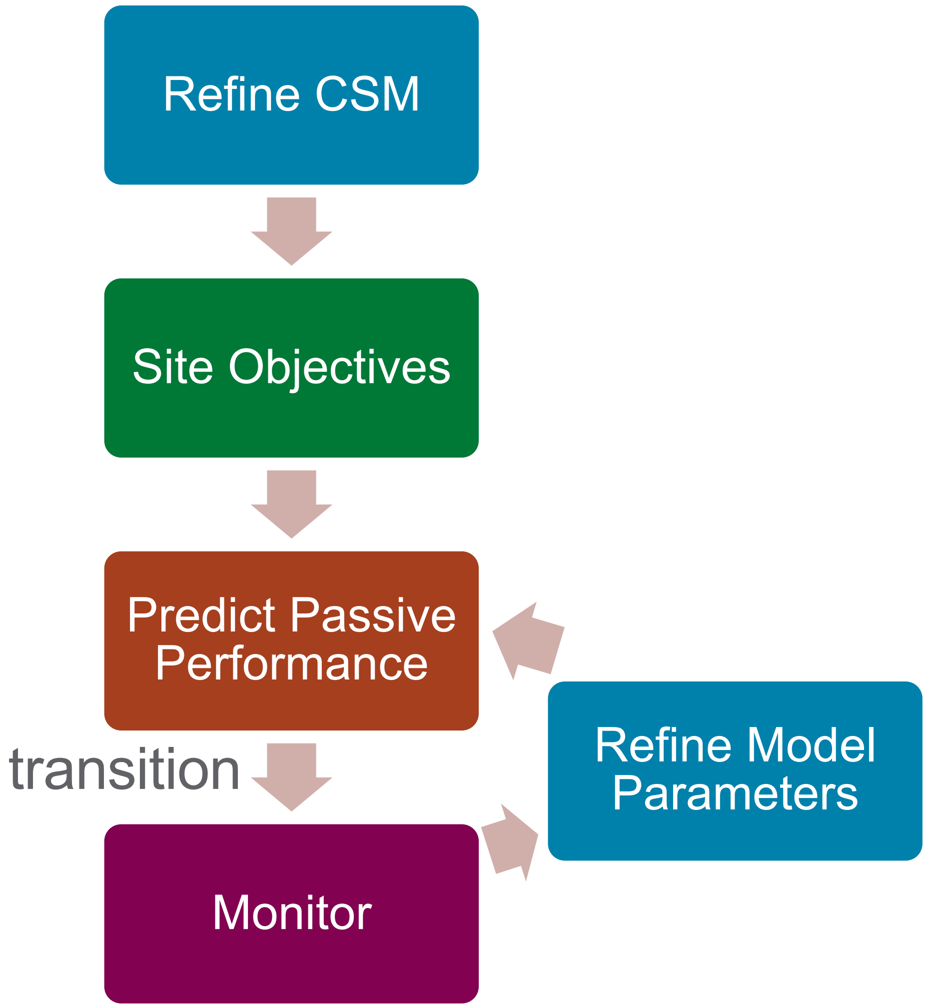

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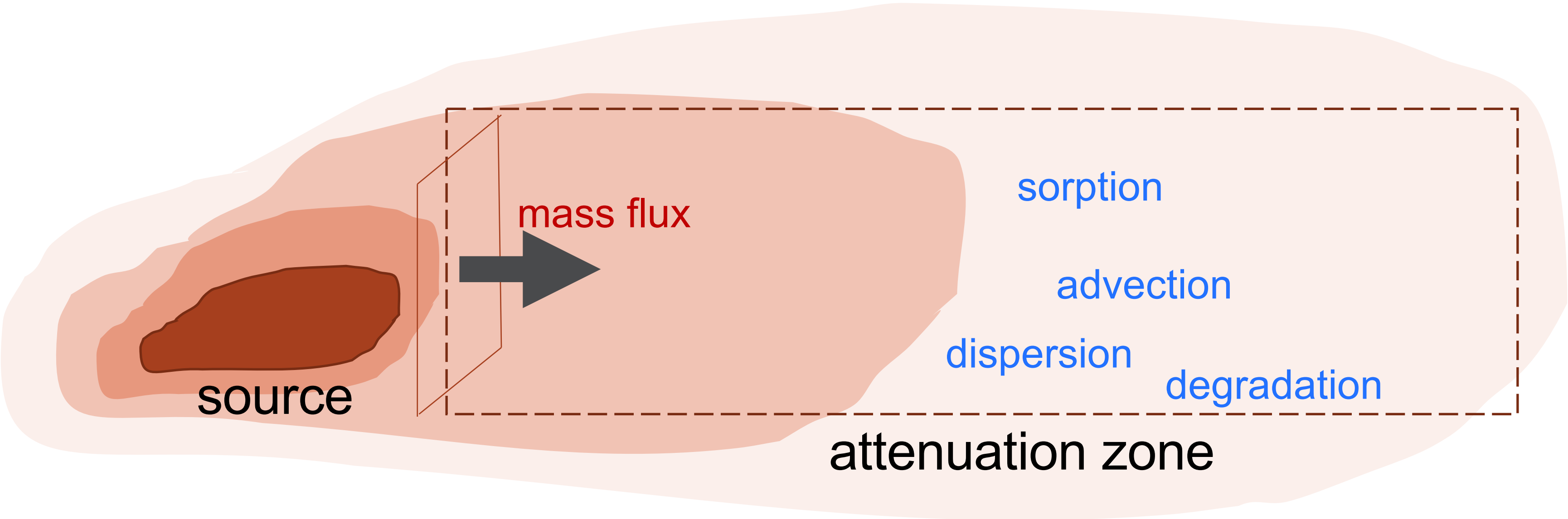
Relating Mass Estimates to Potential Site Impacts

Balance source and attenuation rates



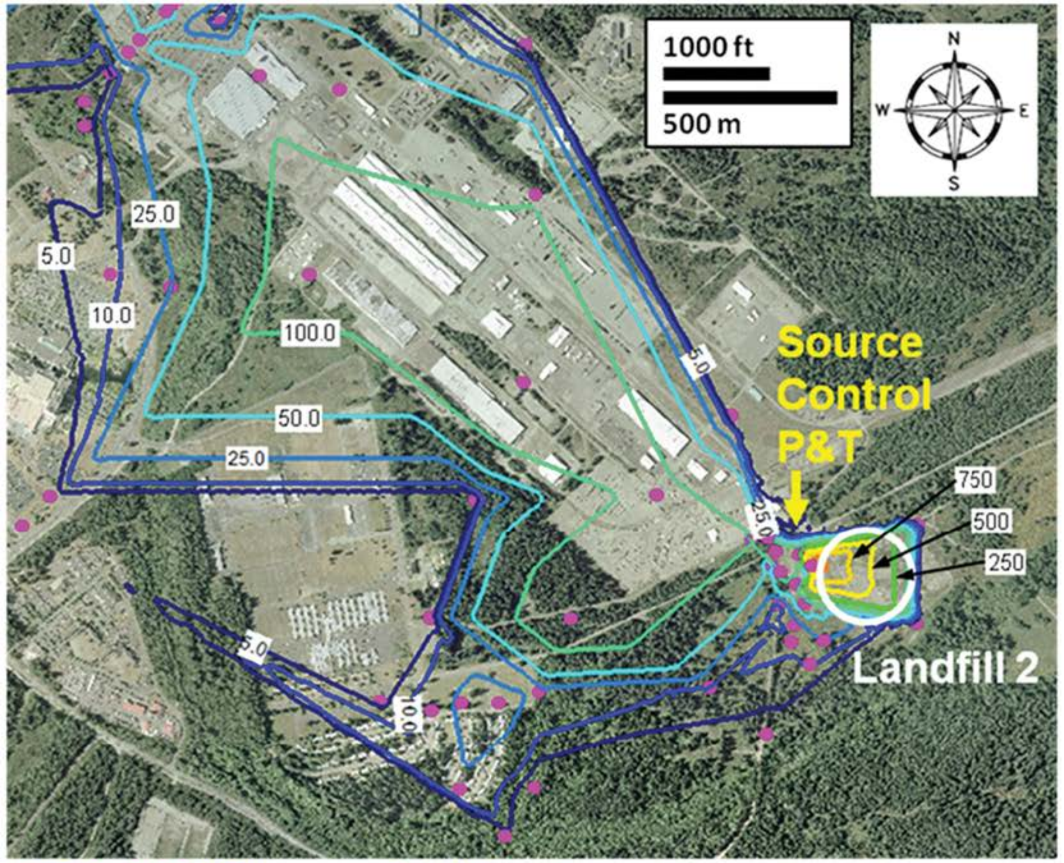
Decision Tools:
- Contaminant Concentrations and Trends
- Contaminant Mass Discharge
- Attenuation Rates and Capacity
- Fate and Transport Assessment
- Comparison to Threshold Concentration (RAO)

Quantifying Source: Mass-In-Place

- Inventory of contaminant mass
  - Form (aqueous, sorbed, NAPL, gaseous, etc.)
  - Location (depth, saturated, unsaturated, different aquifers, aquitards, and porous medias)

Methods:

- **Volume x Concentration Estimation**
- **Isoconcentration Contours**



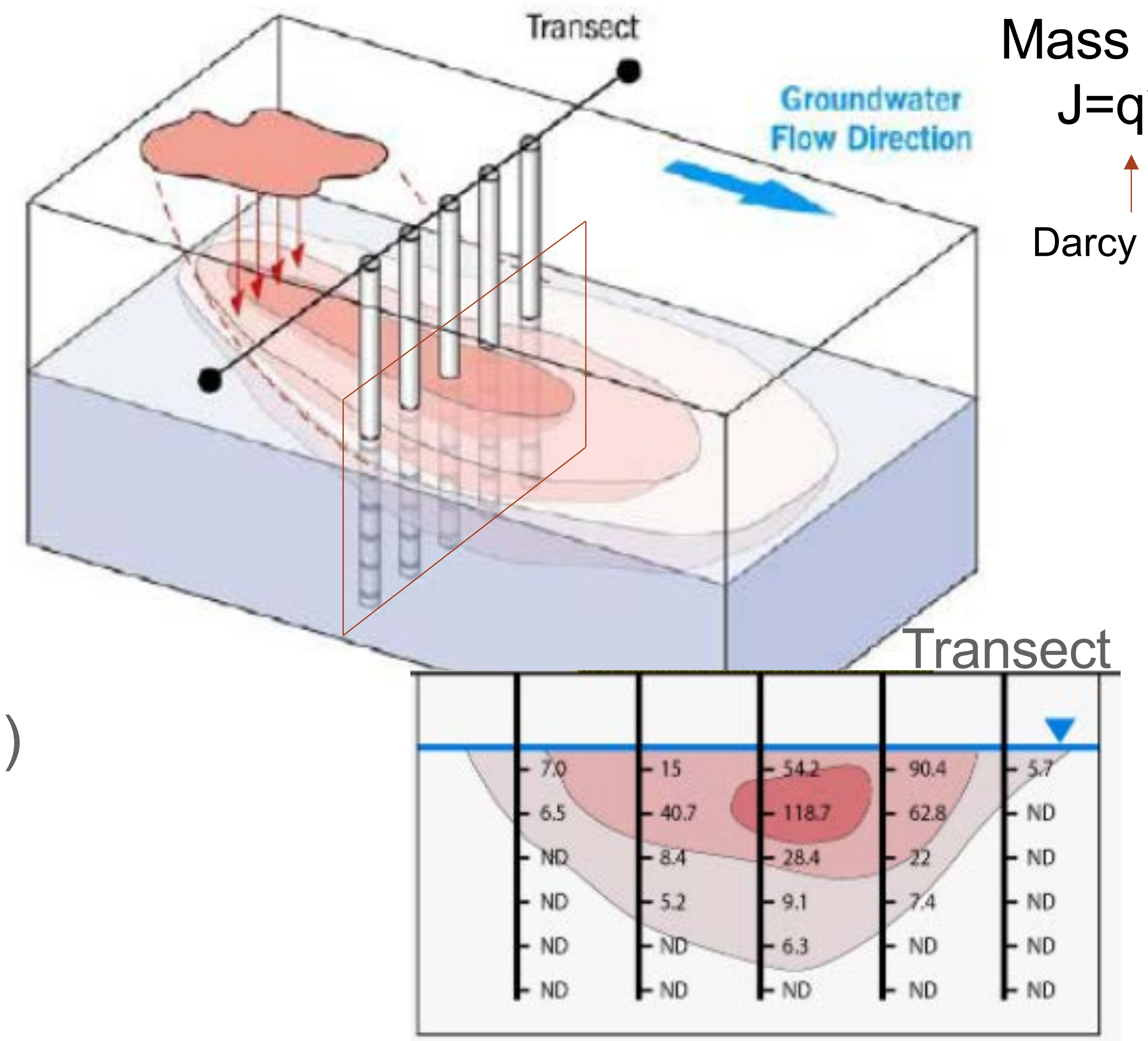
TCE Isoconcentration Contours Truex et al 2017

Quantifying Source: Mass Discharge

- Mass discharge is the mass of COC per time [M/T]
- Mass flux mass per area per time $[M/L^2/T]$

Methods:

- Transect Method ($M_d = \sum C_i * A_i * q_i$)
  - ✓ Increasing complexity
    - Variable groundwater velocity
    - Variable conc with depth (multilevel sampling)
- Pump tests (can use existing P&T systems)
- Passive flux samplers
- Rebound testing



Mass Flux
$J = q * C$

Darcy flux [L/T]

Mass Flux ToolKit (GSI)
Nichols and Roth, 2004

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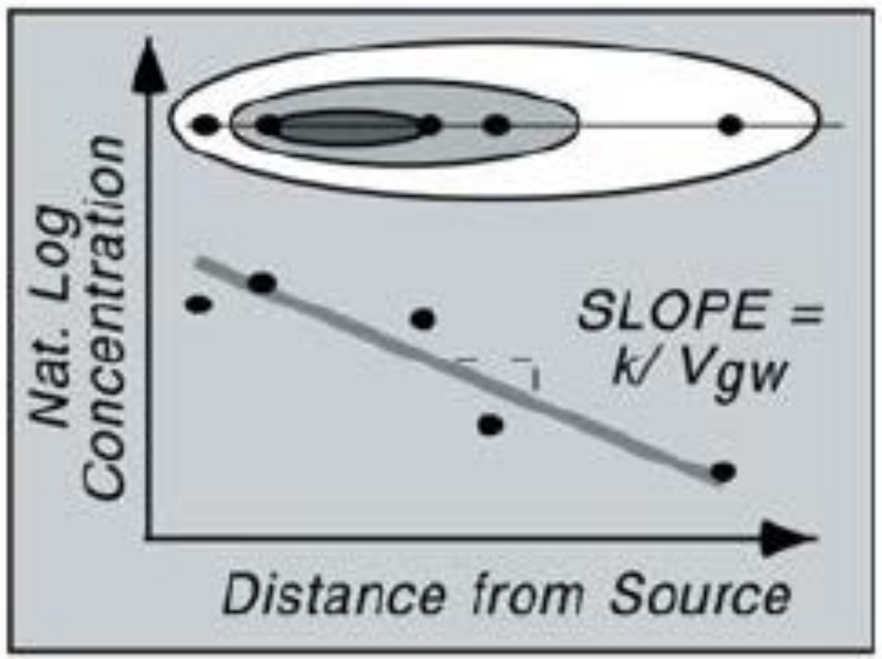
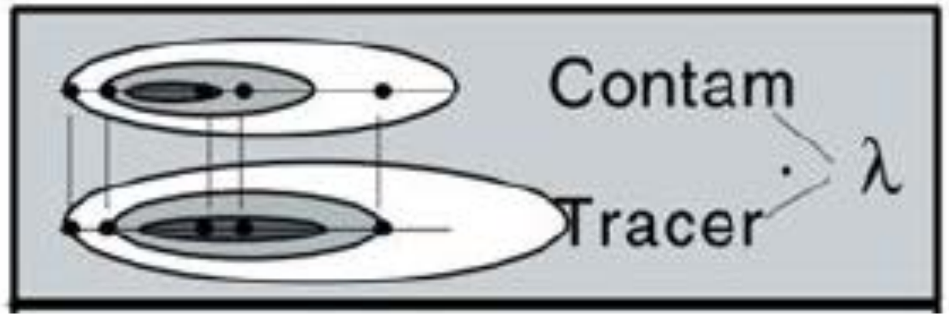
Natural Attenuation Rates and Capacity

- Estimate processes that reduce downgradient concentrations
  - Advective, dispersive mixing, sorption, abiotic/biotic degradation and transformations

Methods:

- Sampling of multiple downgradient wells along the flow path
- Tracer/Push-Pull Tests
- Compound Specific Isotope Analysis (CSIA)
- Microbial Analysis





EPA 2002

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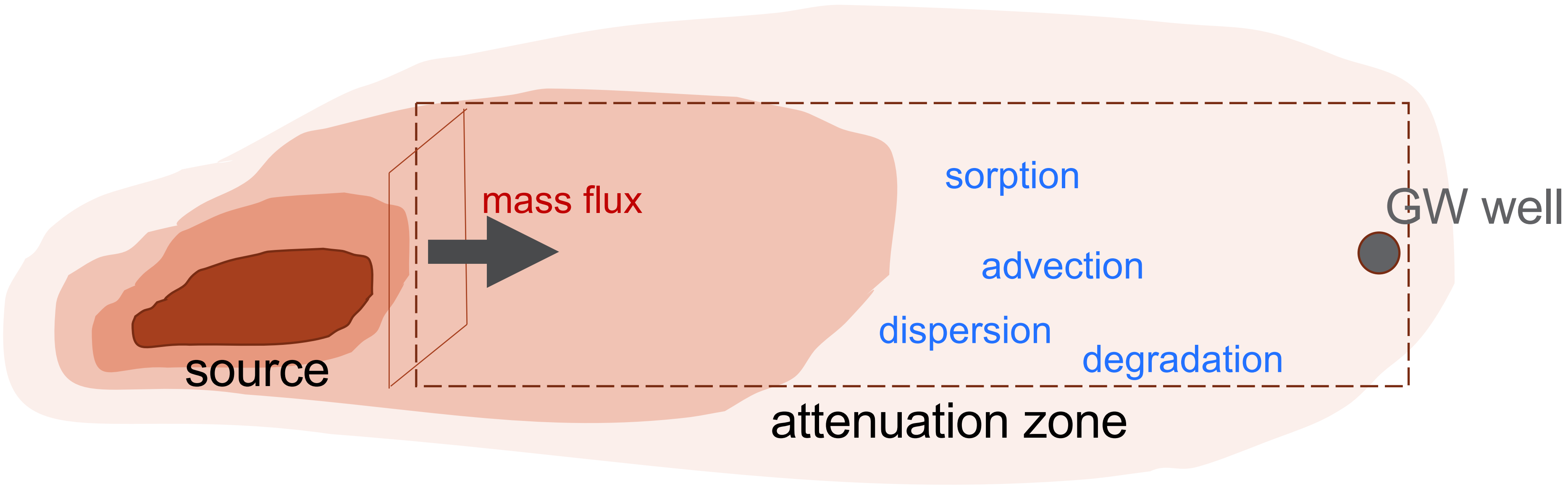
Estimating Impacts

Put Source and Attenuation estimates together

- Threshold-concentration
  - ✓ mass discharge – attenuation < RAO?

$$Threshold\ Conc = C_{RAO} + k\frac{x}{v_{COC}}$$

$$v_{COC} = \frac{\frac{q_{ambient}}{n}}{R_{COC}}$$



- Fate and transport assessments

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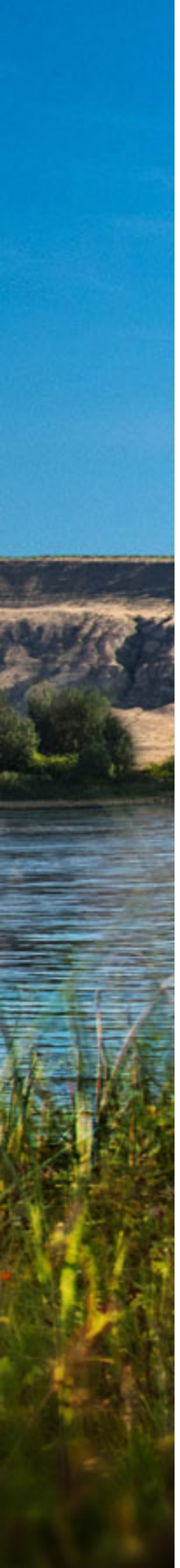
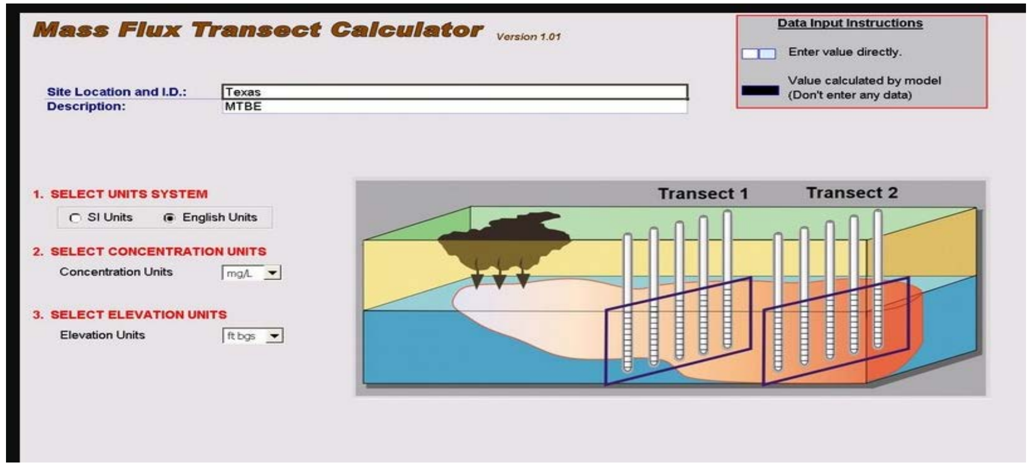


Software Tools

Mass Flux Toolkit (GSI, ESTCP)
https://www.gsi-net.com/en/software/free-software/mass-flux-toolkit.html

SourceDK (GSI, 2011)
https://clu-in.org/products/dst/DST_Tools/SourceDK.htm

Matrix Diffusion Toolkit (GSI, 2012)
https://www.gsi-net.com/en/software/free-software/matrix-diffusion-toolkit.html



Natural Attenuation Software (NAS)
https://www.nas.cee.vt.edu/index.php

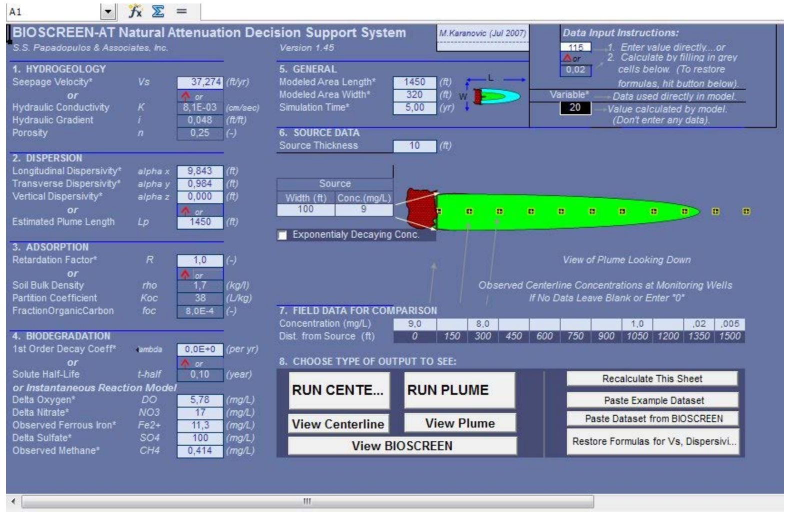
BIOCHLOR (chlorinated solvents)
https://www.epa.gov/water-research/biochlor-natural-attenuation-decision-support-system

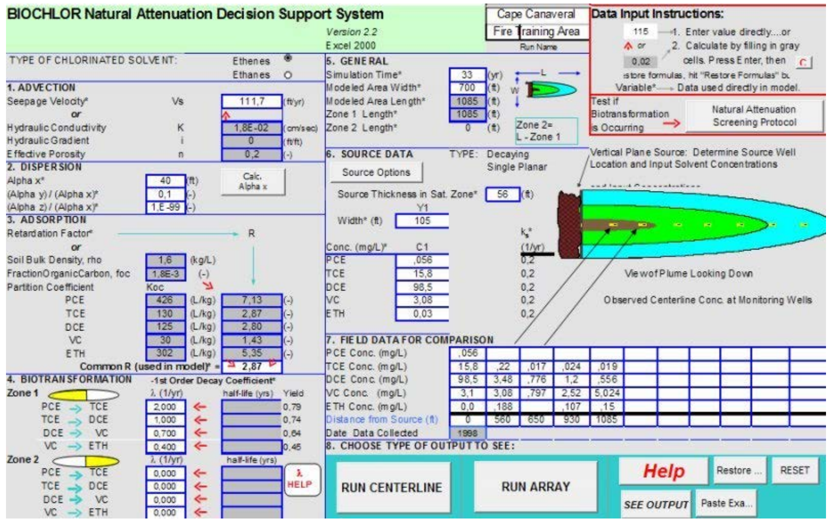
BIOSCREEN (Petroleum Hydrocarbons) (EPA, 1997, 2002)
https://www.epa.gov/water-research/bioscreen-natural-attenuation-decision-support-system

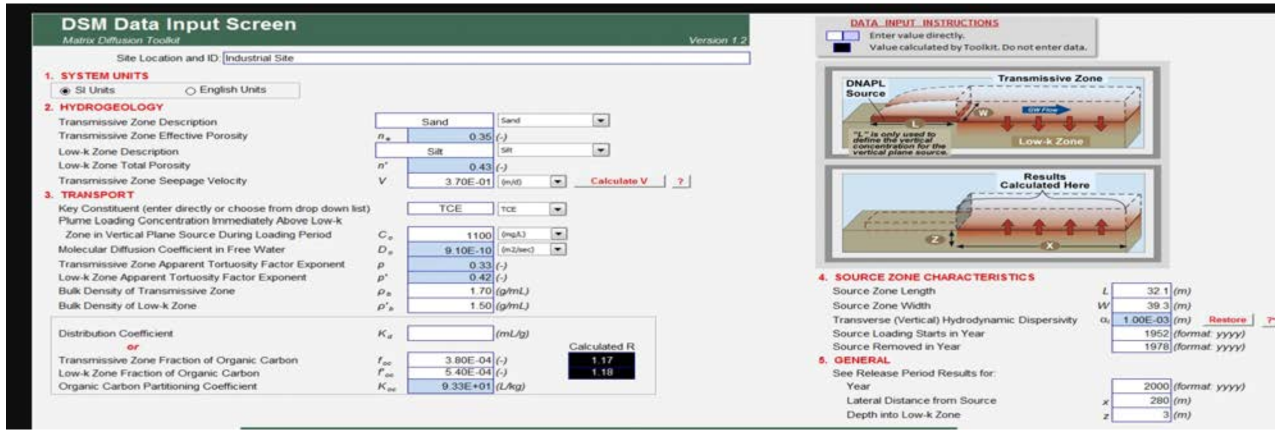
REMChlor/REMFuel
https://www.epa.gov/water-research/remediation-evaluation-model-chlorinated-solvents-remchlor

Fate and Transport Models

✓ STOMP, MODFLOW, MT3D, RT3D







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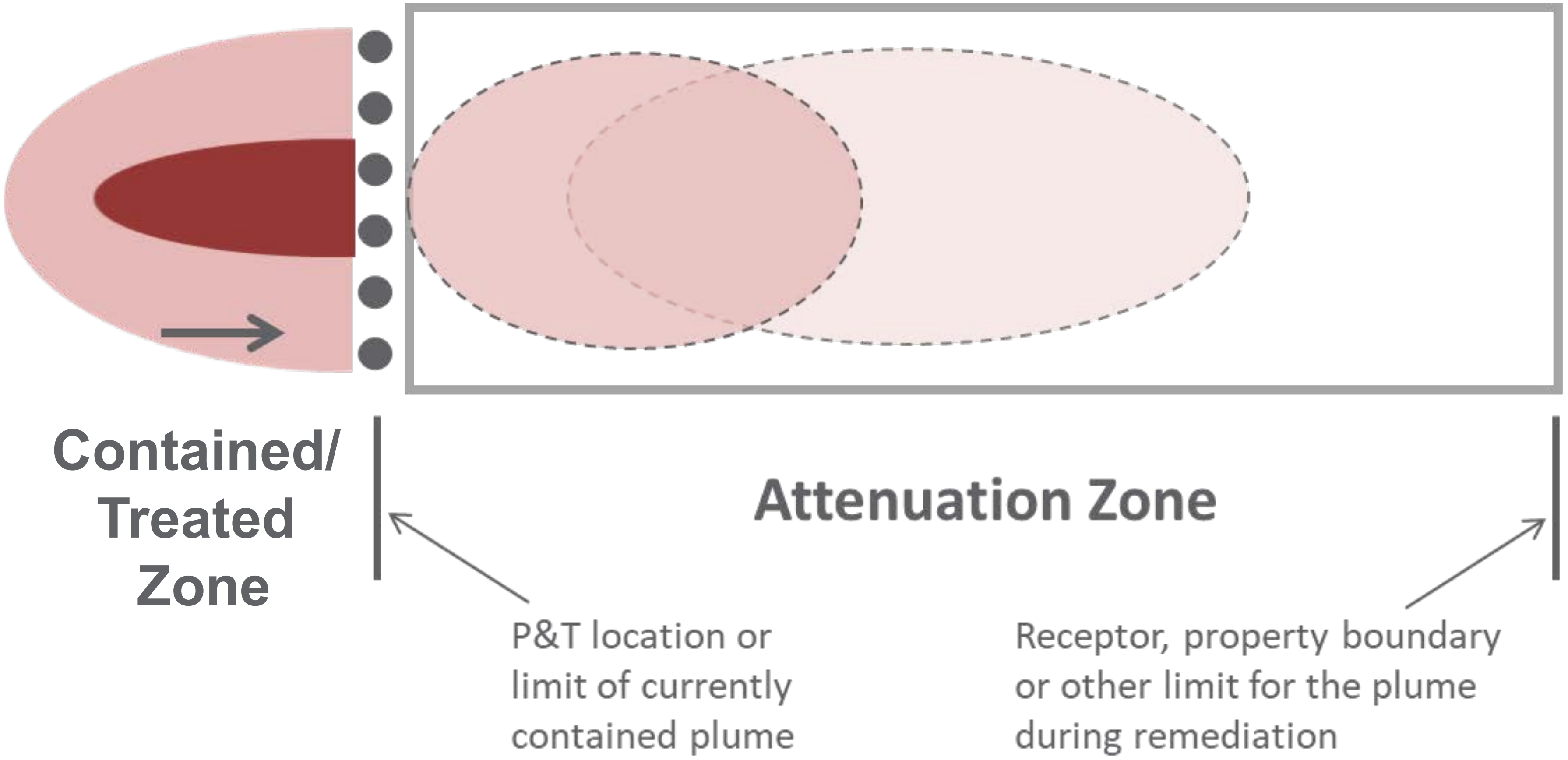
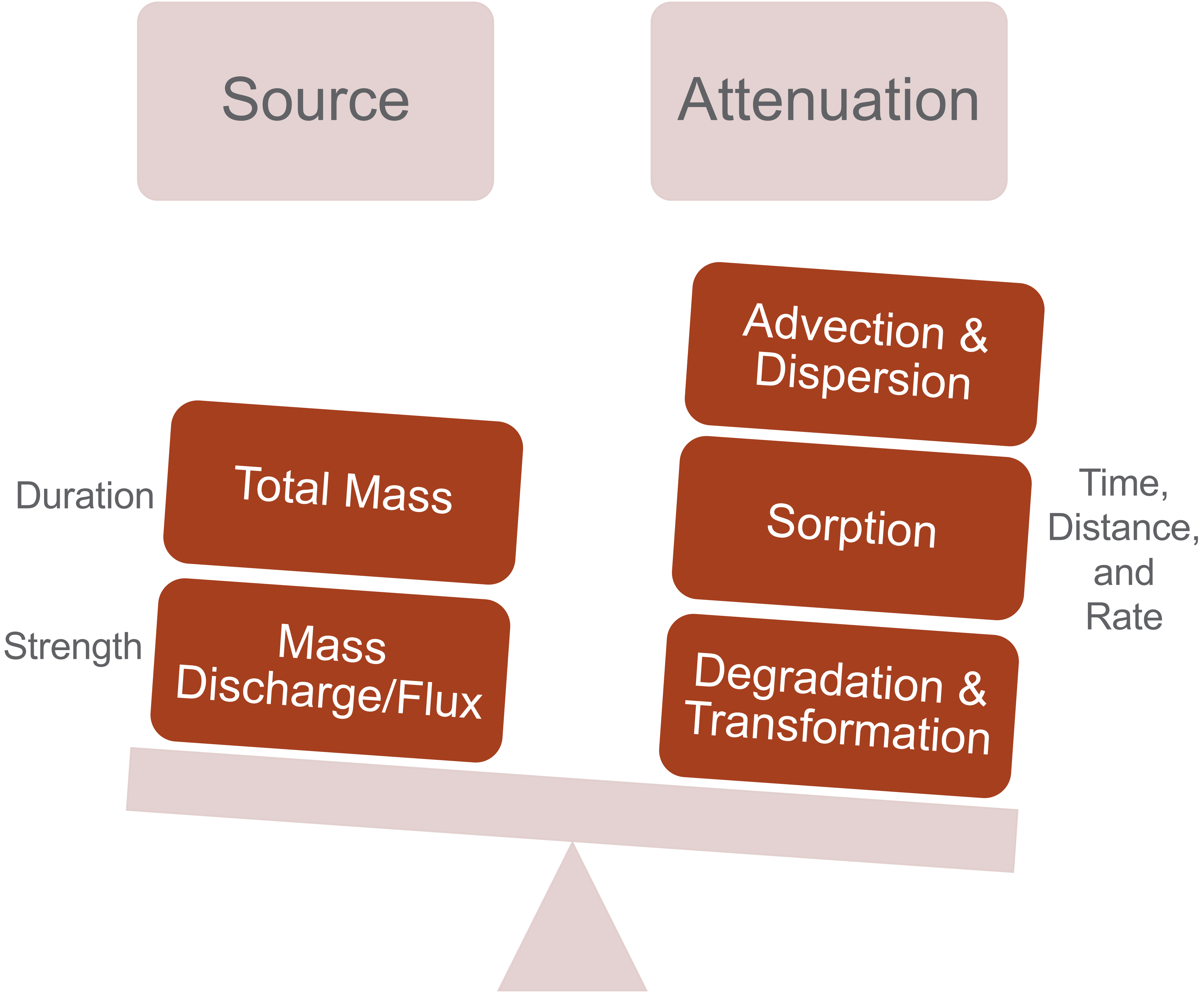
Active/Passive Transition Considerations

- Transient conditions after transition
- Contaminants in contained/treated zone must be balanced by attenuation
- Define size of attenuation zone and timeframe
- Need for verification of transition

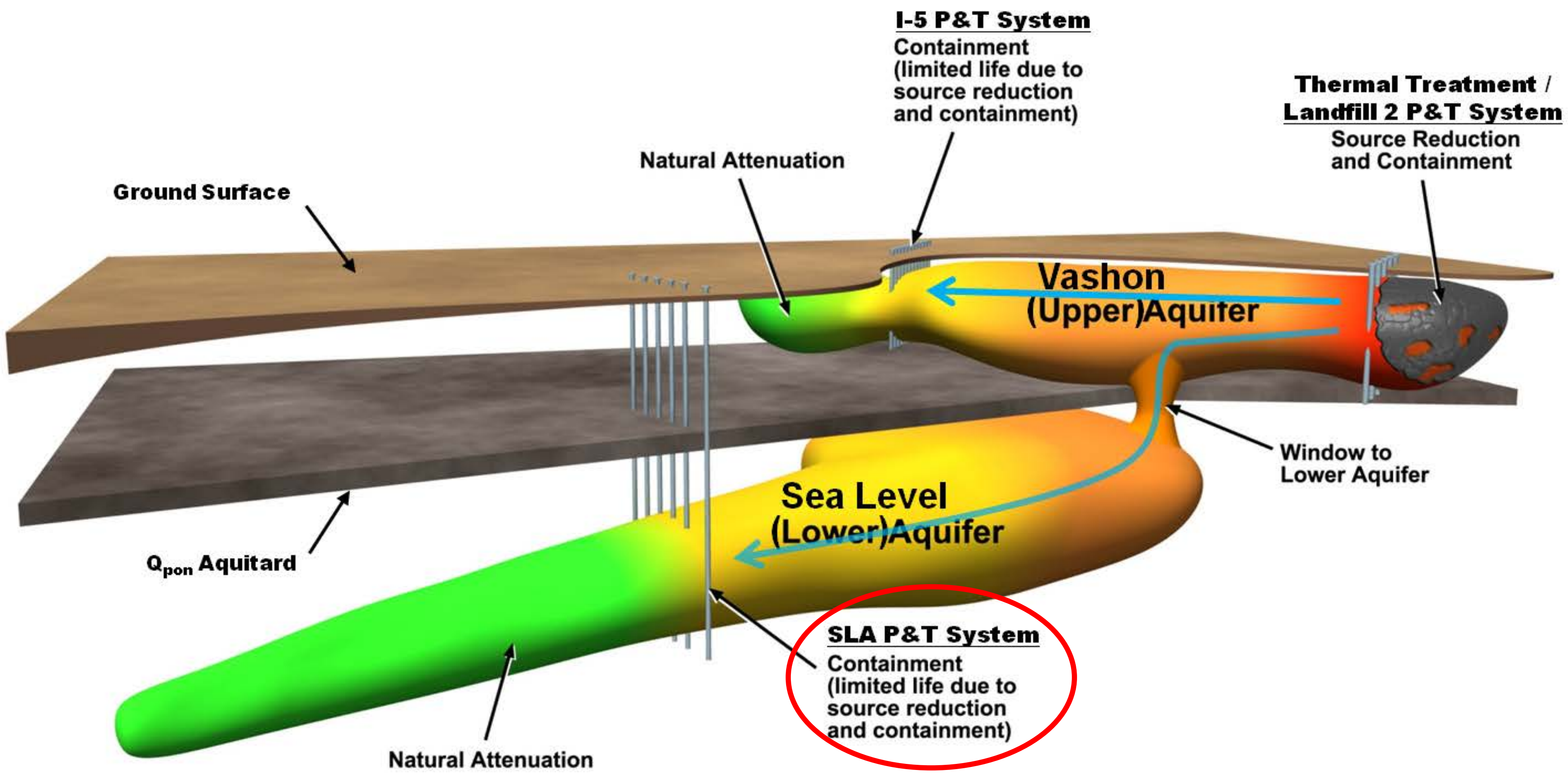


Compare Contaminant Contribution against Aquifer Attenuation Capacity



Case Study

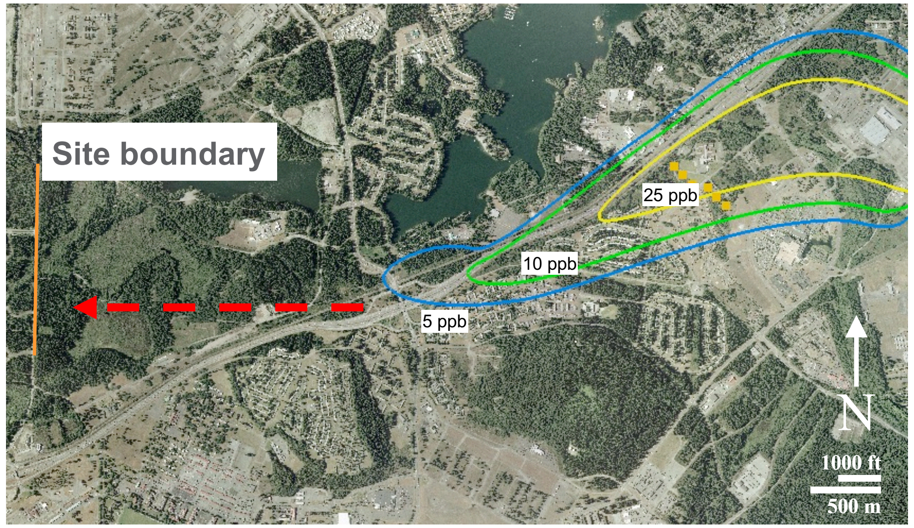
- Joint Base Lewis McChord
- System of P&T and source treatment
- Example: Sea Level Aquifer
  - Upgradient flux cut off
  - How long to P&T before transition to natural attenuation



Truex et al. 2007, 2017

Case Study

- Remedy considered an attenuation zone and evaluation of active/passive transition for the P&T/NA system in the SLA
- Top figure, plume just before initiating P&T
- Bottom figure, estimated plume at end of P&T just before transition



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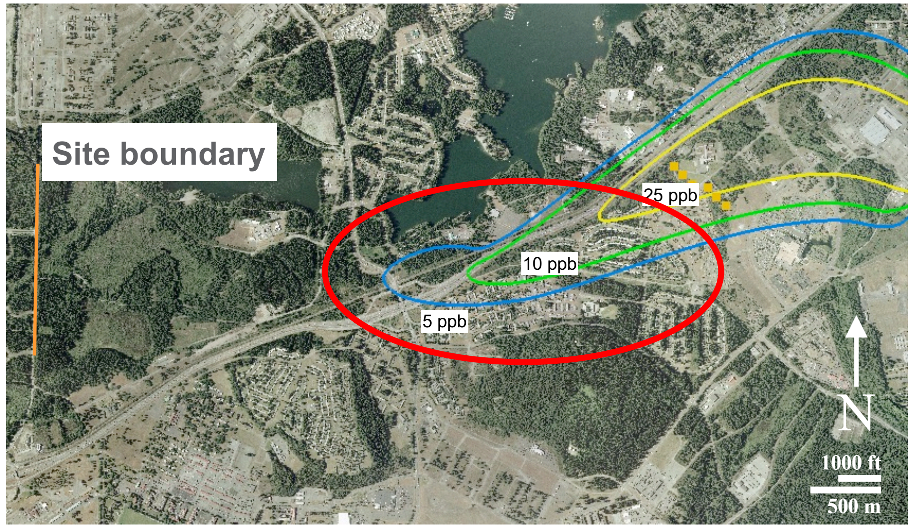
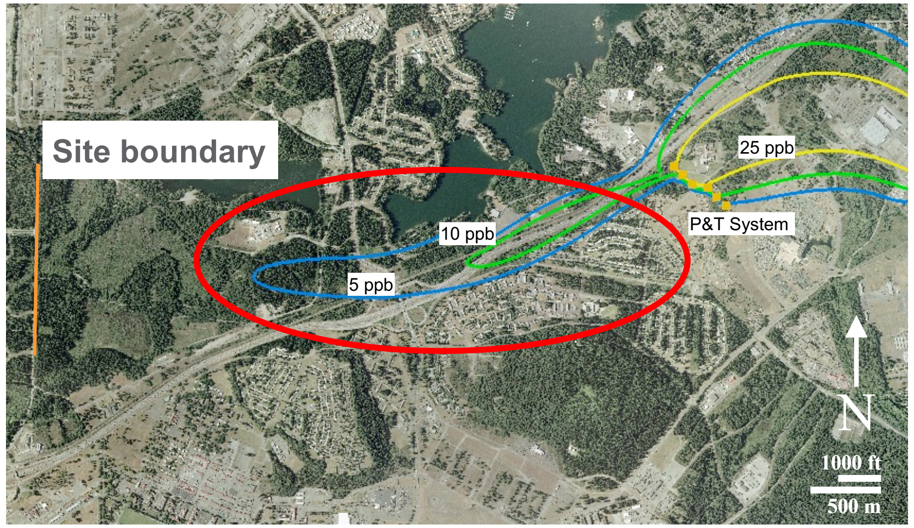
Case Study

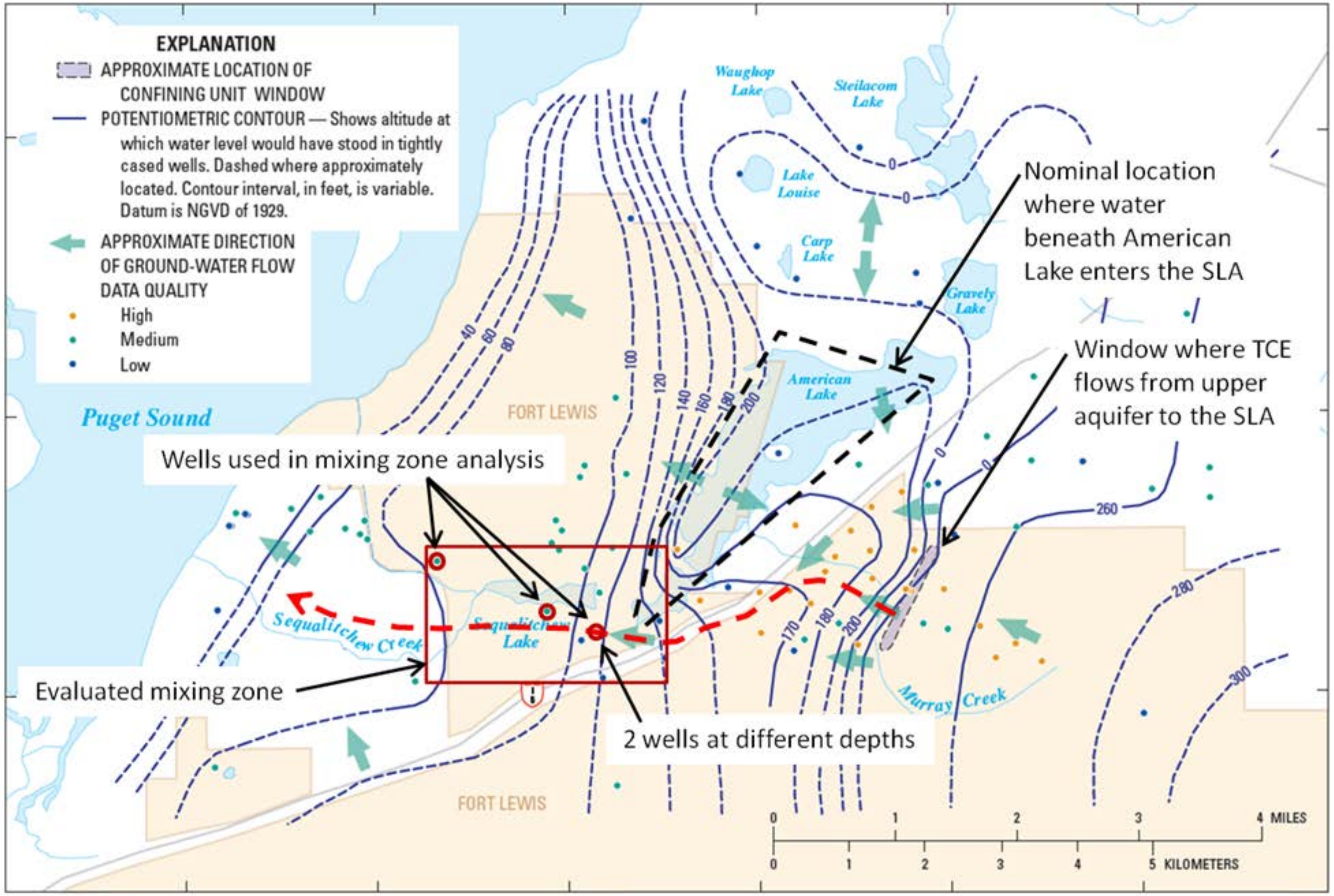
- Prior to P&T, evaluated attenuation processes and plume migration to estimate attenuation rate
- Threshold concentration = $C_{RAO} / [e^{(-k \times t)}] = 20$ ppb
- Predictive modeling estimates
- Initial verification through monitoring of downgradient plume natural attenuation during P&T





Case Study

- Accounting for attenuation processes and spatial aspects of the system through modeling

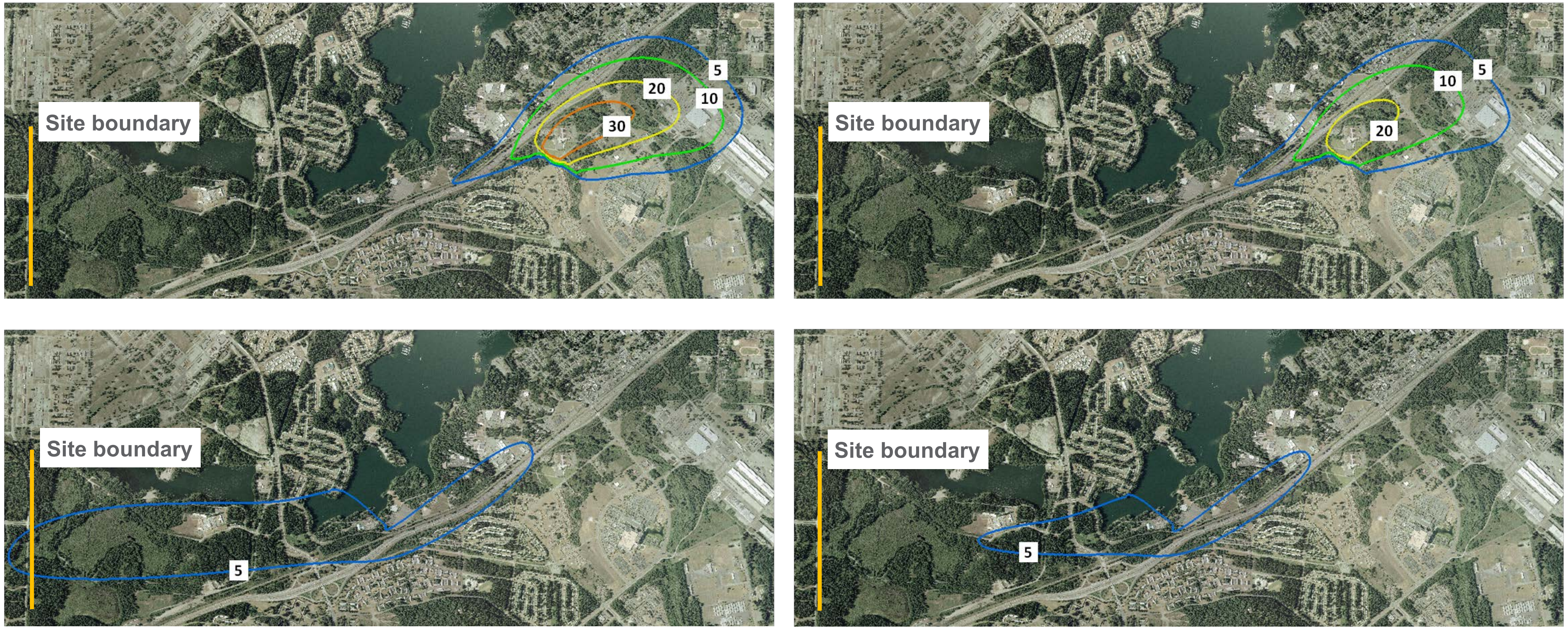


Case Study

~20 years of pumping | ~28 years of pumping

At transition

Max. plume extent



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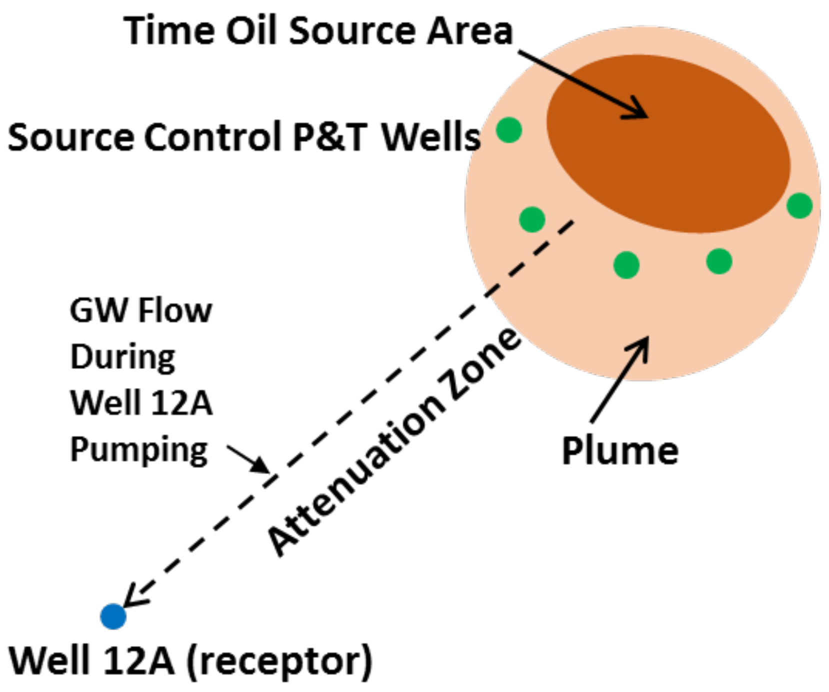
Transition Criteria

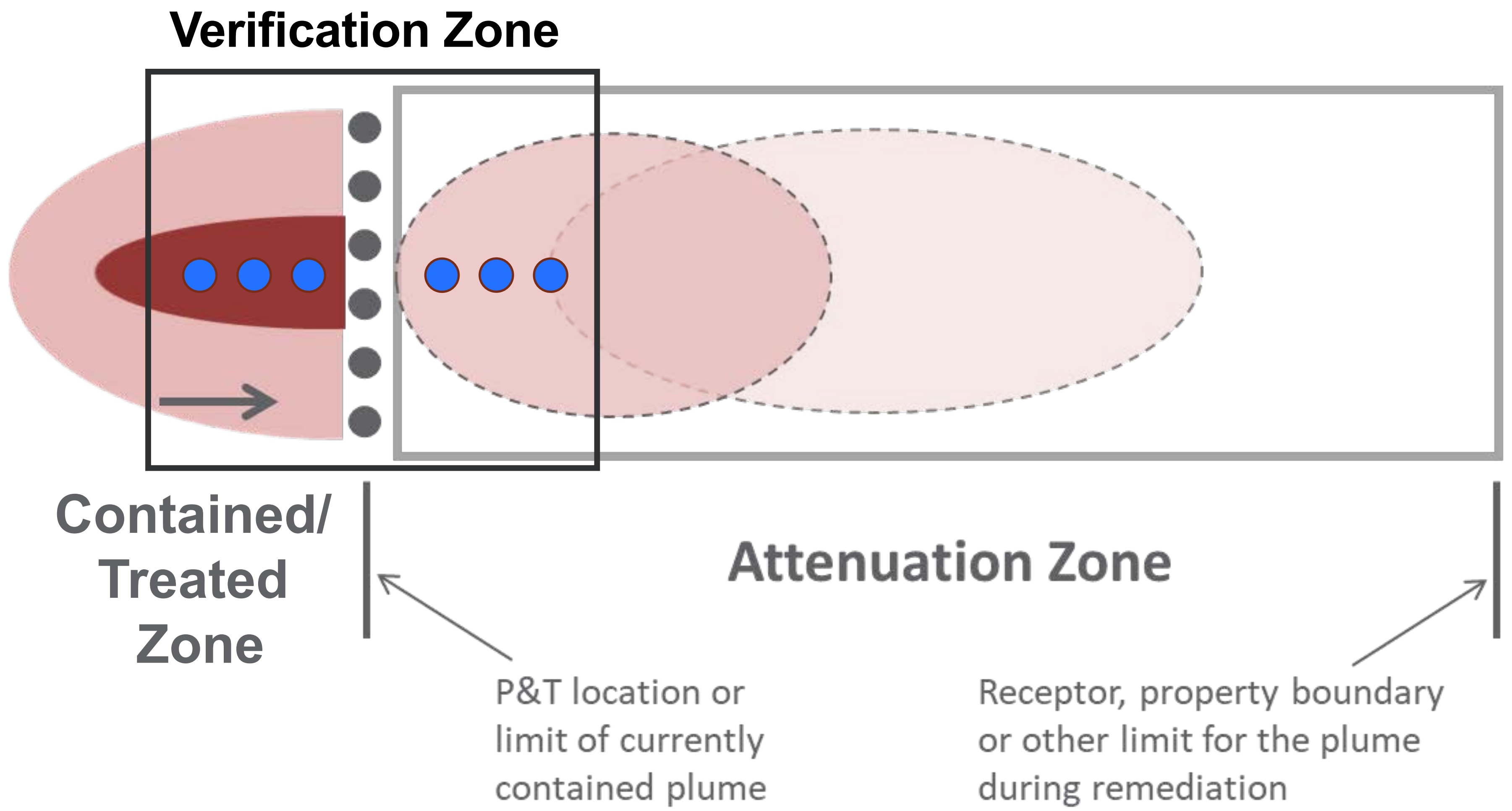
- Threshold Concentrations or Mass Discharge
- Identify P&T timeframe, threshold concentration, mass discharge reduction goal, and timeframe for plume/source in relation to selected attenuation zone
- Document transition criteria
  - Setting of interim goals in ROD
  - Verification/reassessment



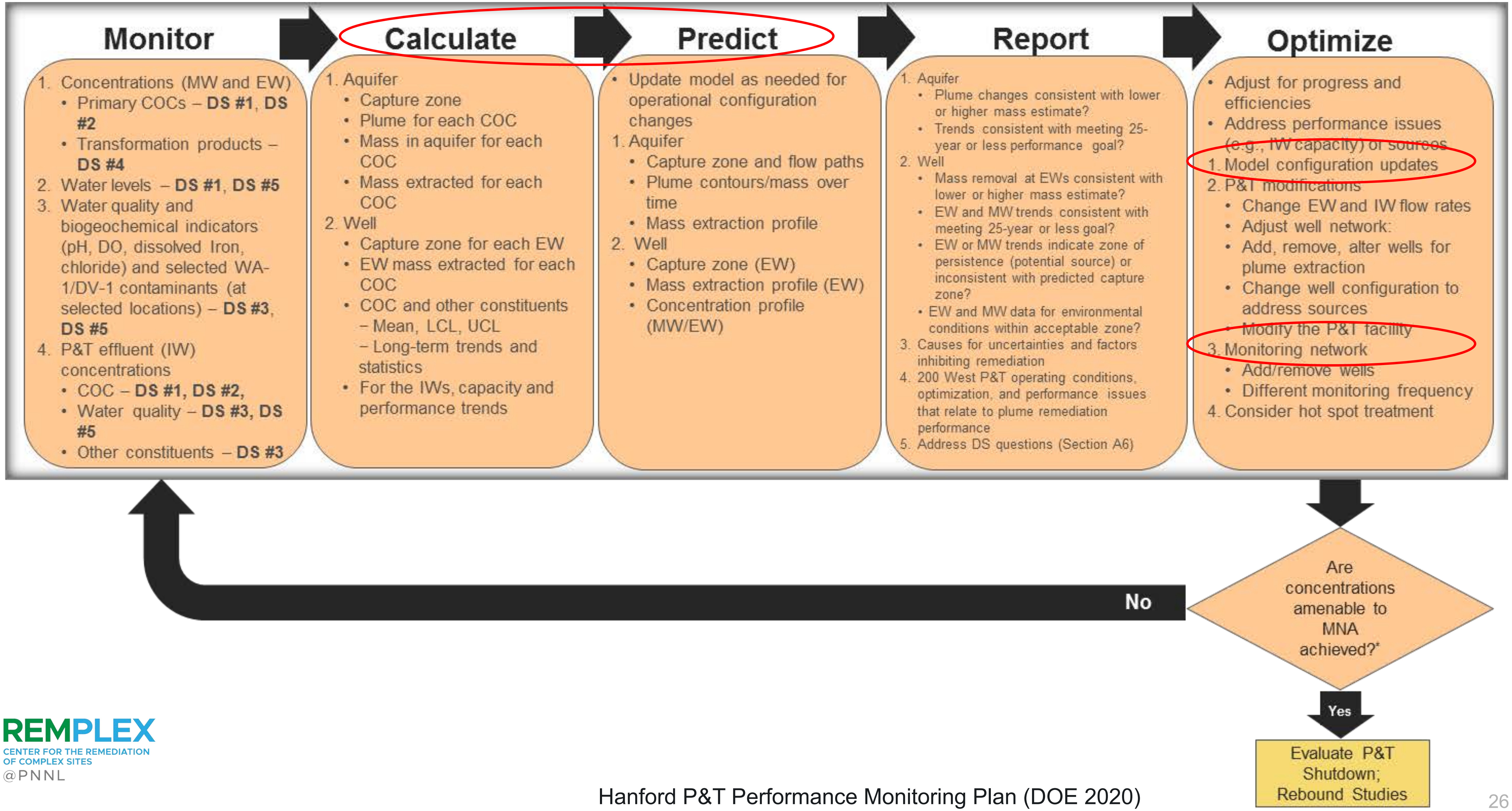
Truex et al. 2017

Verification Approaches

- Active remedy performance assessment
  - Active zone
  - Downgradient zone
- Staged verification
  - rebound testing
- Post-transition verification
  - contingency actions

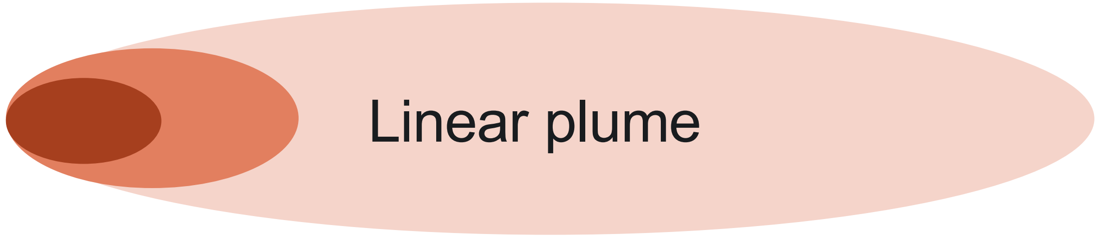


Performance Assessment Example



Hanford P&T Performance Monitoring Plan (DOE 2020)

Source/Groundwater and 3D Considerations



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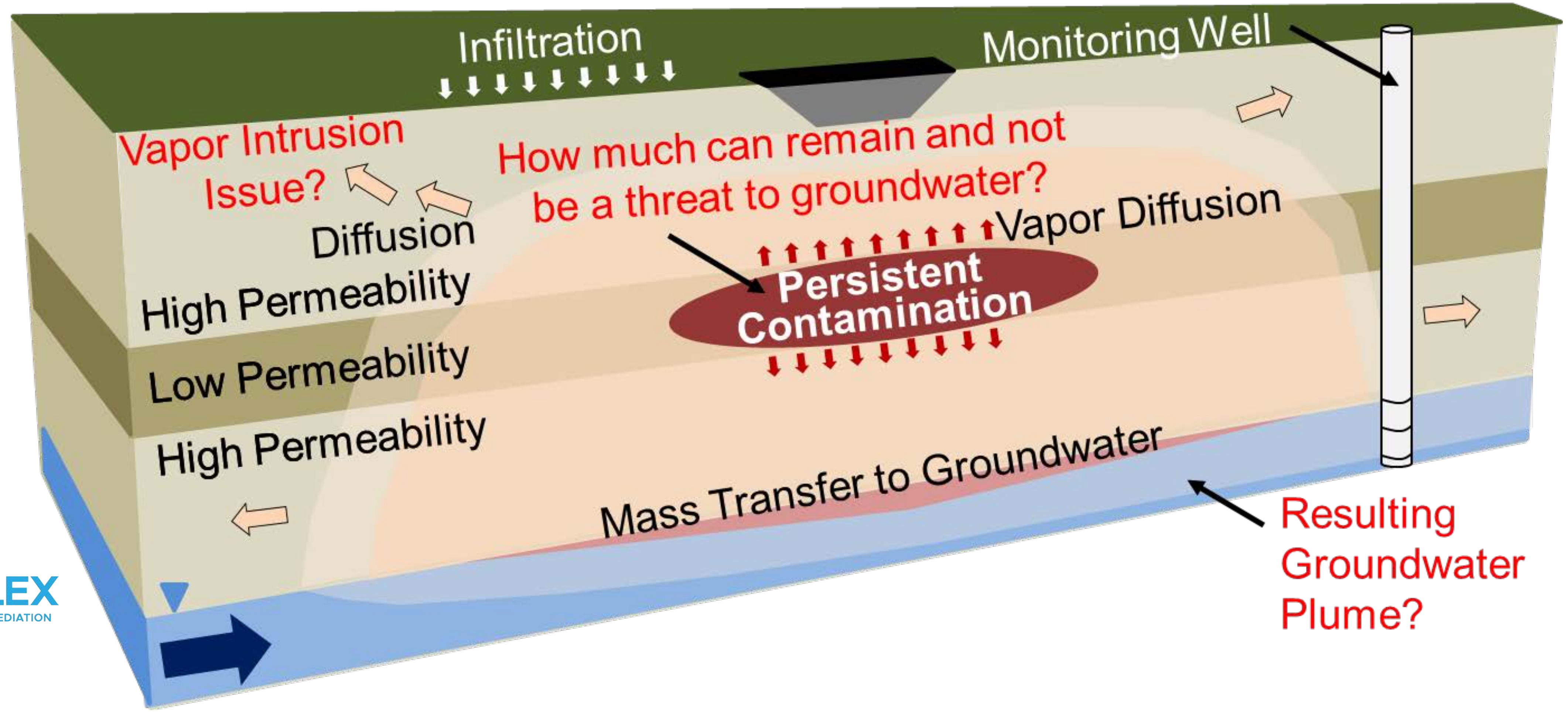

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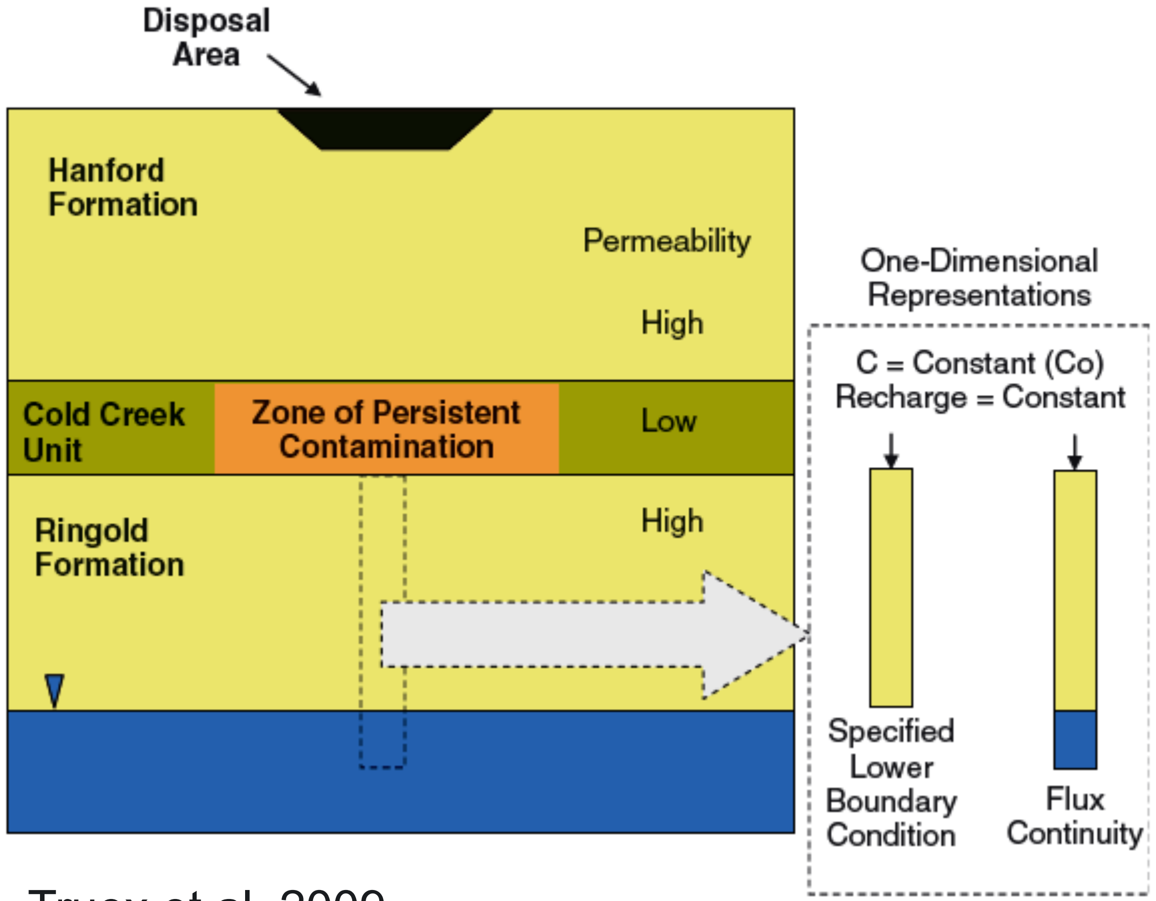
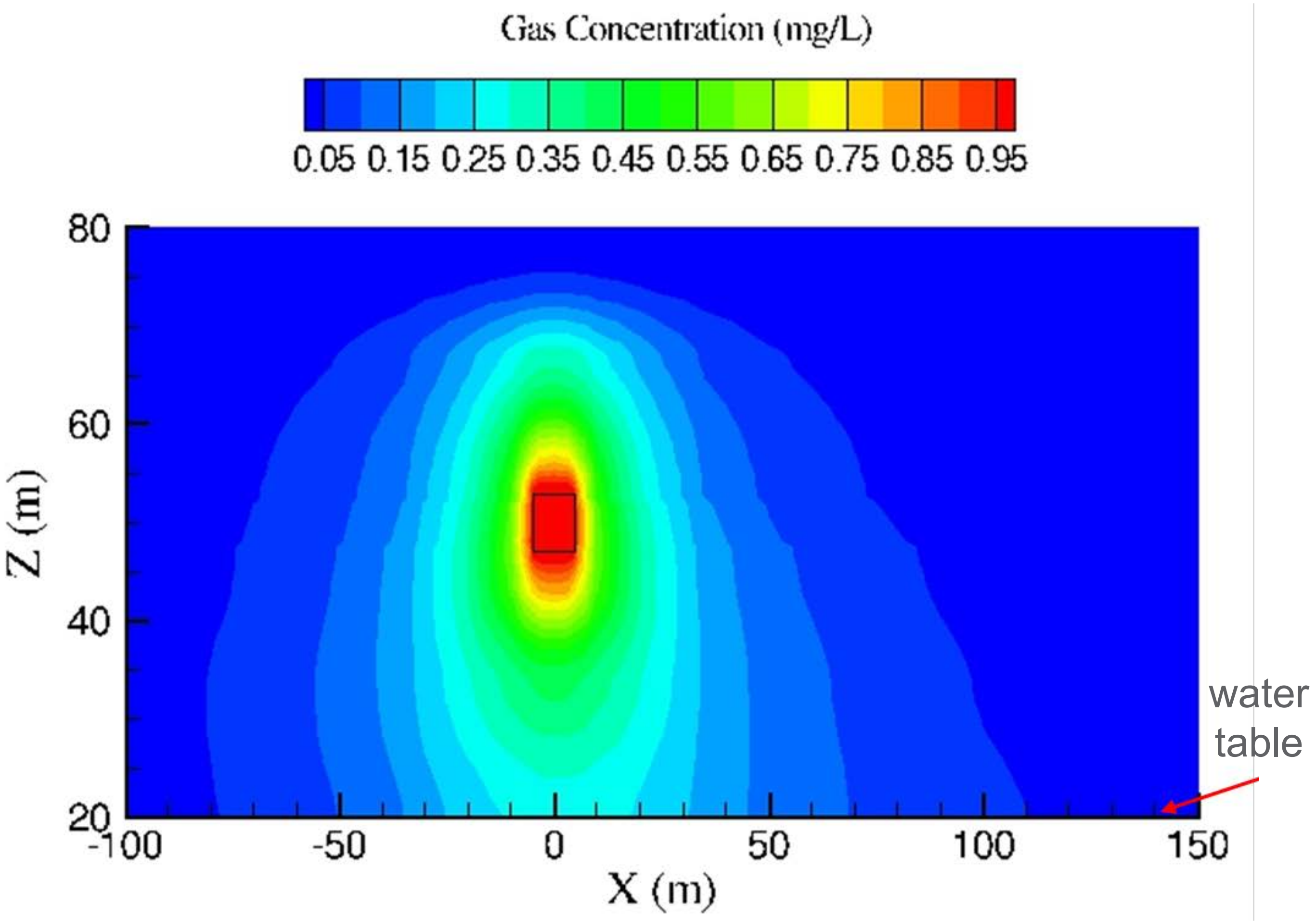
Dimensionality of Situation and Transport



Truex et al. 2009



Oostrom et al. 2010

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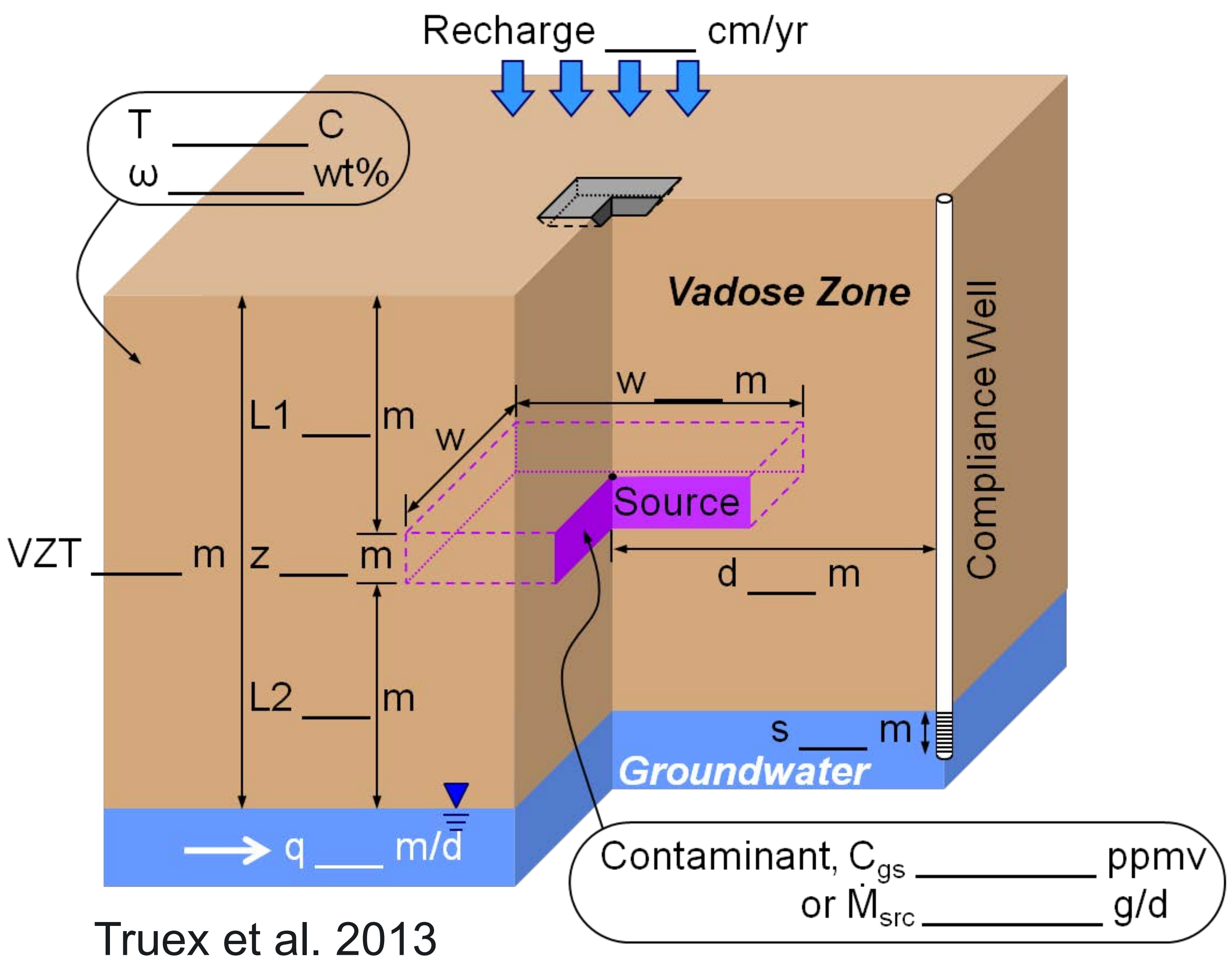
Conceptual Site Model and Quantitative Assessment

- Analysis approach needs to consider CSM elements and complexity of transport
- Consider CSM refinement during active remediation
- Identify controlling features and processes
- Identify sufficient analyses and appropriate verification

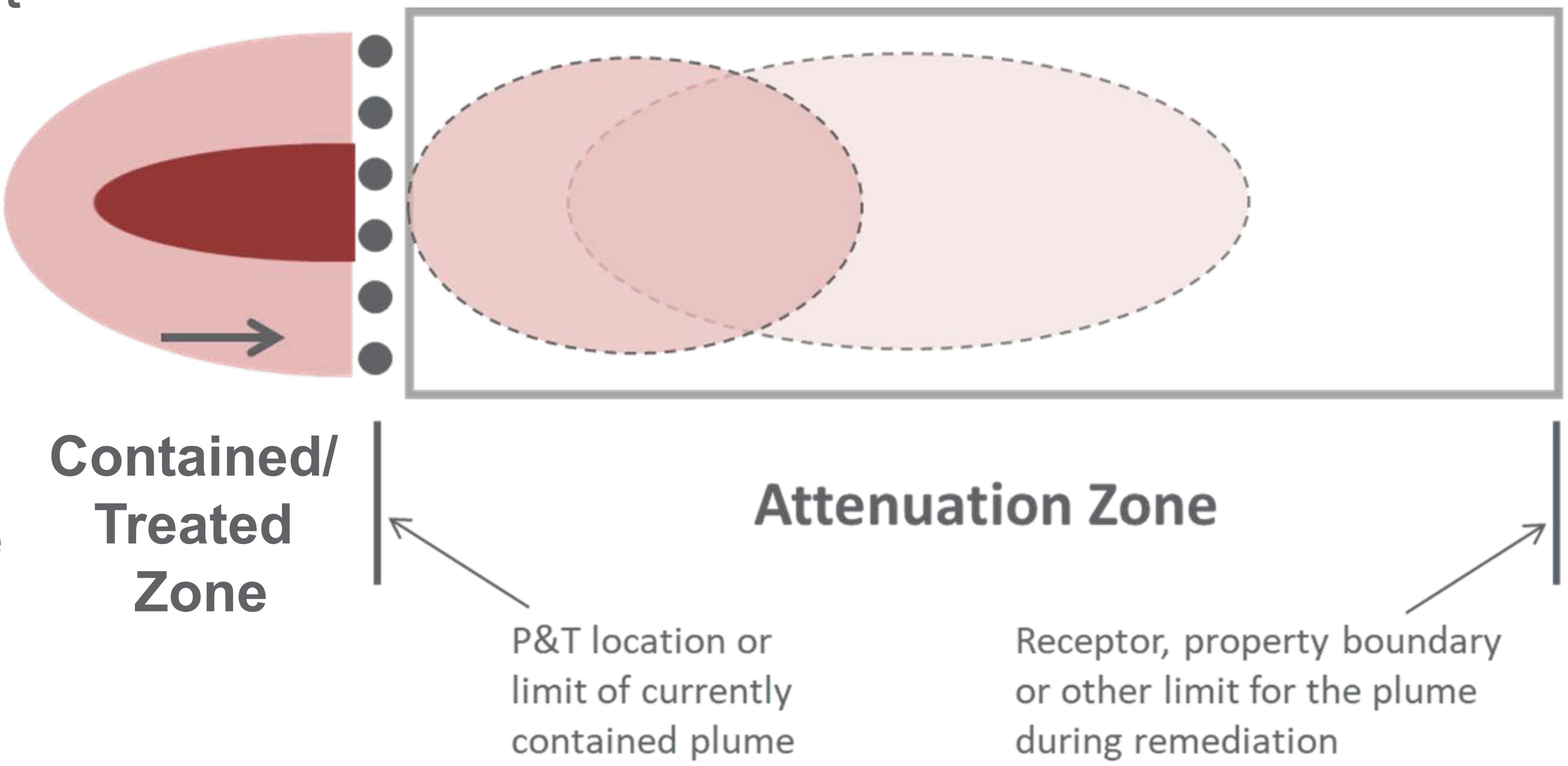
Example SVE Analysis Approach



Truex et al. 2013

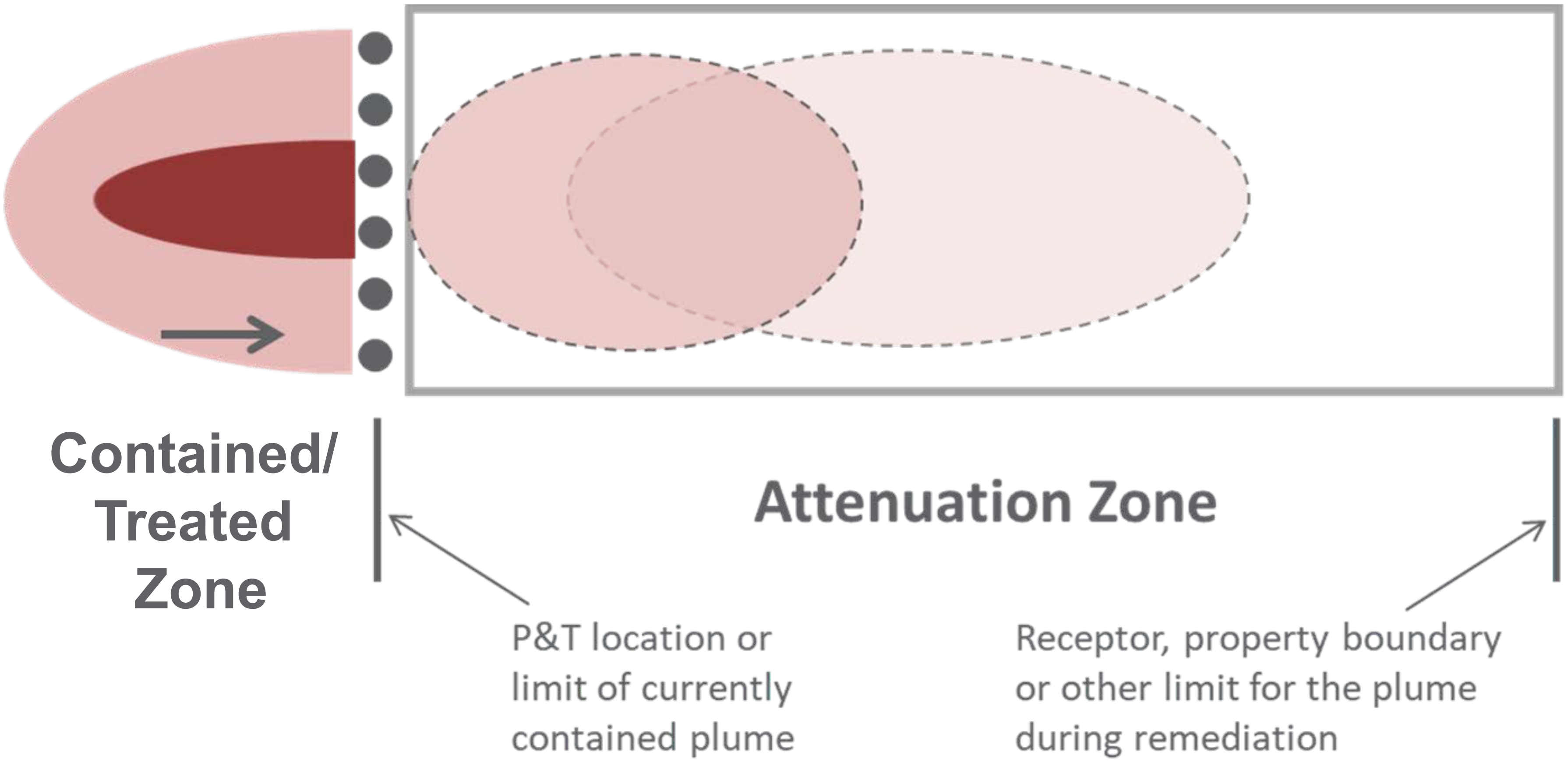
Other Active/Passive Transition Considerations

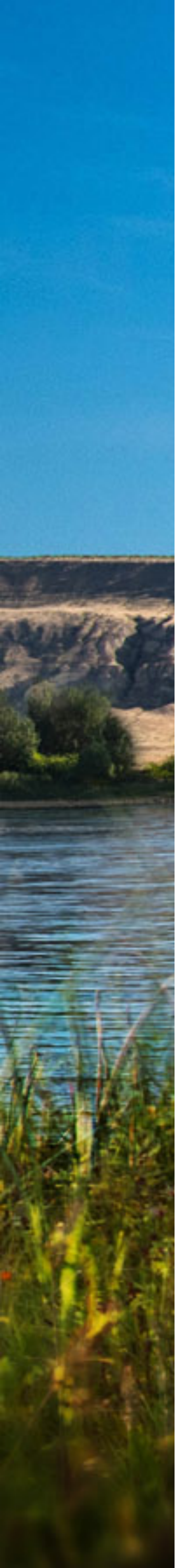
- Adaptive Site Management
  - Organizes active-passive transition within overall remediation management
- Time and space
  - Is there a zone where you can afford to have contamination during remediation and allow time to reach ultimate concentration goal?



Other Active/Passive Transition Considerations

- Time and Space
  - May need additional considerations when lingering sources are present – extended time, ARAR waivers
- Contingency actions for passive elements
  - e.g., as identified in the MNA directive
- Passive monitoring elements to evaluate changing conditions





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Thank you

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