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# Remedy Selection and Implementation for Radionuclides in Soil and Ground Water

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Pacific Northwest National Laboratory

- ▶ Attenuation and transport processes are important to consider for remediation decisions in the vadose zone and groundwater
  - important for both remedy selection and remedy implementation
- ▶ Remedy technology decisions consider the intersection of
  - radionuclide characteristics
  - the target problem
  - remedy functionality
  - remediation objective

- ▶ Case study background – Hanford Site
- ▶ Attenuation and transport processes
- ▶ Remedy selection considerations
- ▶ Remedy implementation considerations
- ▶ Conclusions

# Hanford Background

## Chemical Separations



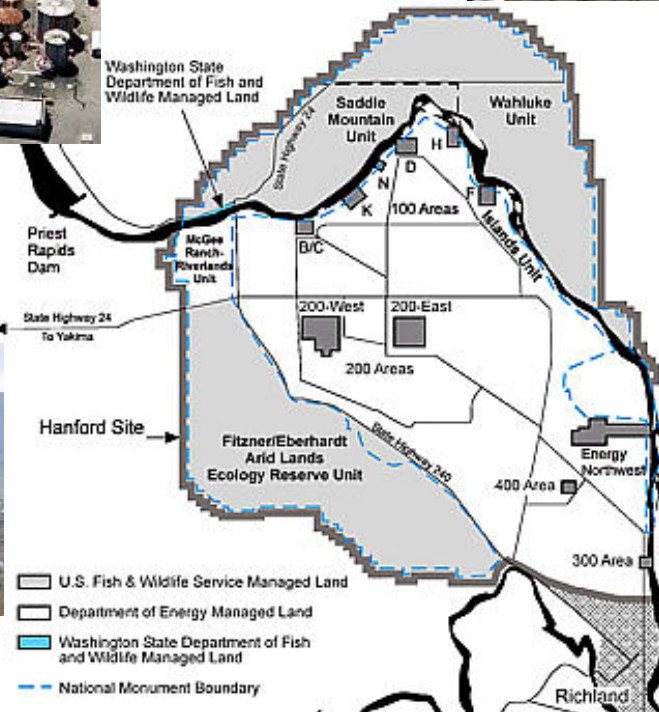
## Irradiate Fuel Elements



## Plutonium Finishing



## Manufacture Fuel Elements

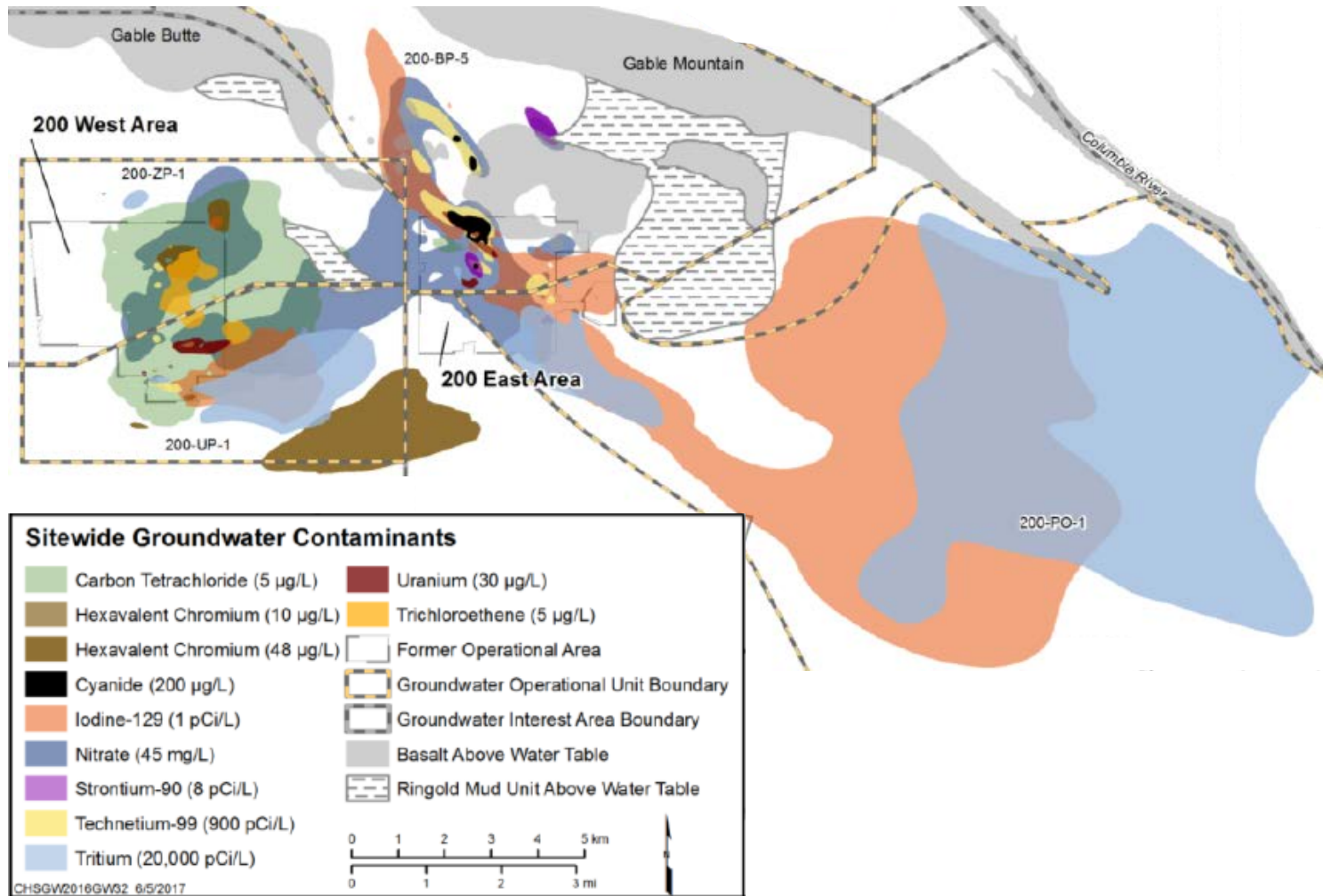


# Hanford Background



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# Central Plateau: Deep Vadose Zone Sites

**Tc-99:** ~40 Ci discharged;  
Groundwater @ ~ 100 X standard

**Tc-99:** 110 Ci discharged; ~5-20 Ci remain in deep vadose zone

**Uranium:** 10,000 kgs discharged; ~20 Kgs in groundwater @ 150 X standard; ~2,000 Kgs in mobile state and remain in deep vadose zone

**Key Contaminants**  
 Tc-99  
 Uranium  
 I-129  
 Chromium

BY Cribs

B-BX-BY Tank Farms

T Tank Farm

U Cribs

PUREX Cribs

S-SX Tank Farms

**Inner Area**  
25 Km<sup>2</sup>

**Uranium:** 75,000 Kgs discharged; Minimal breakthrough to groundwater; Unknown mobility and presence in deep vadose zone

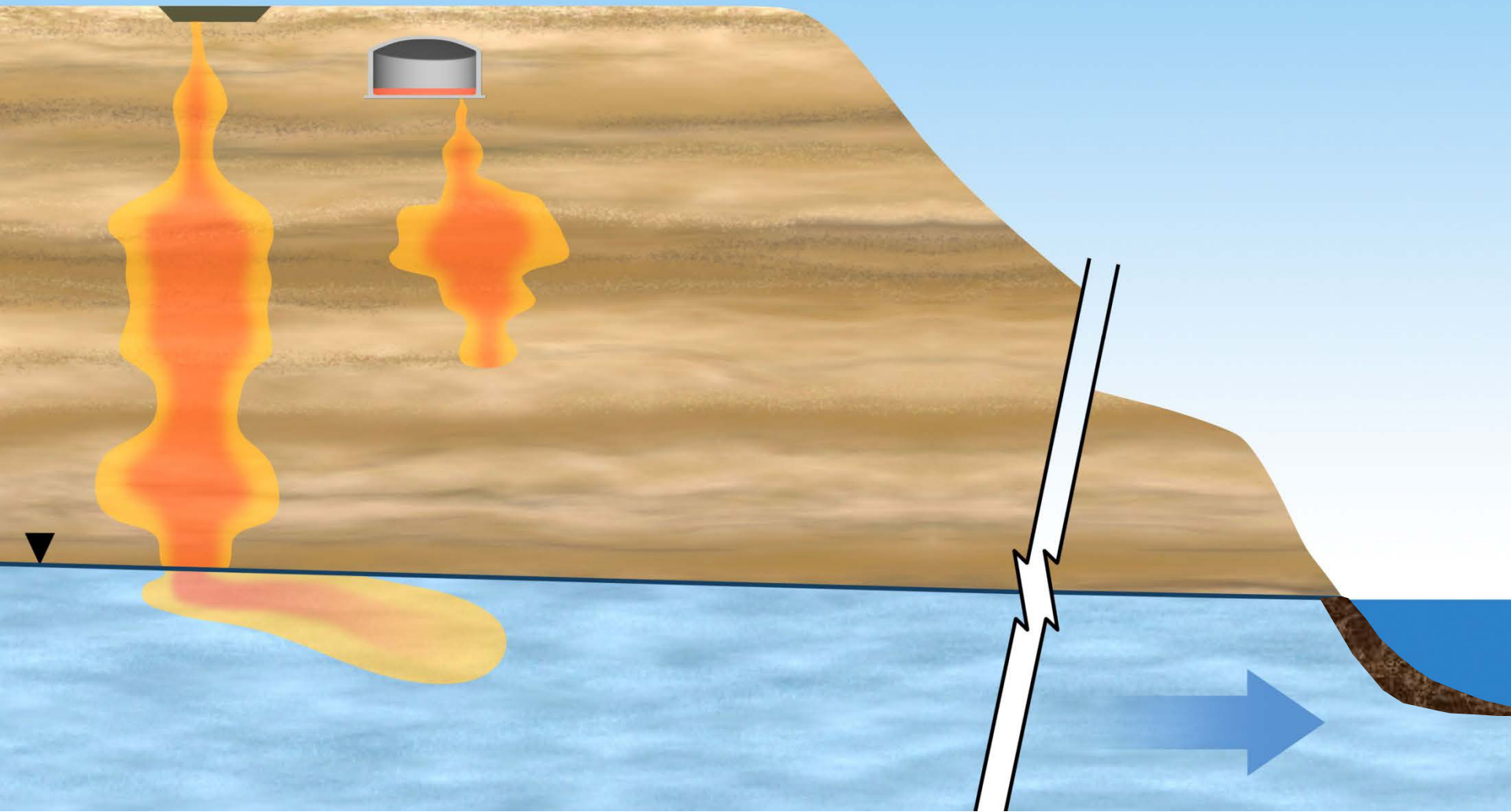
BC Cribs & Trenches

**Tc-99:** ~40 Ci discharged;  
Groundwater @ ~ 100 X standard

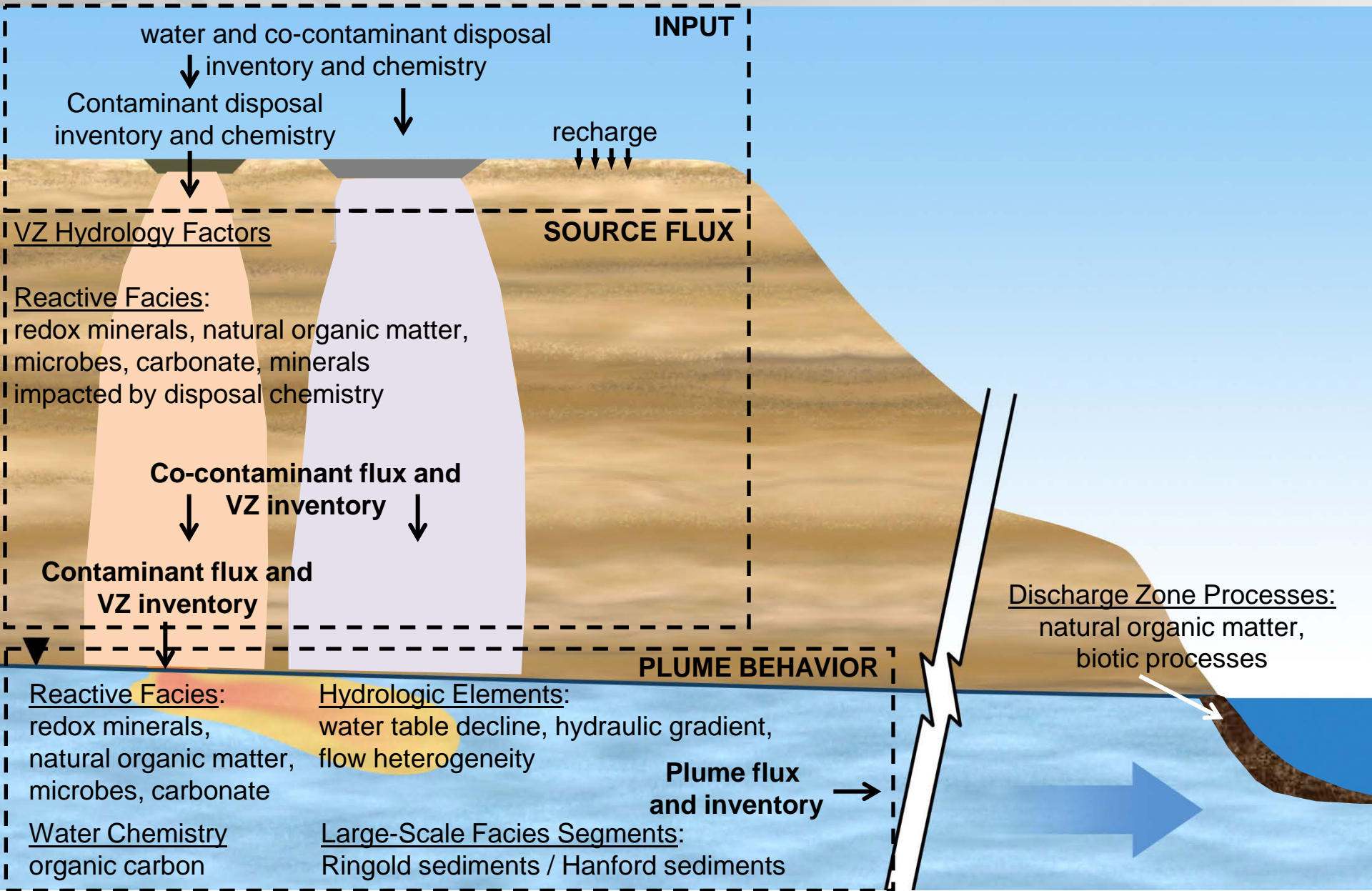
**Uranium:** 36,000 Kgs discharged; Minimal breakthrough to groundwater; Unknown mobility and presence in deep vadose zone

**Tc-99:** 410 Ci discharged; No breakthrough to groundwater; Most mass between 30 - 50 meters below surface

# Hanford Background



# Hanford Background





## ▶ What do we need to know?

### ■ Vadose Zone

- Quantify vadose zone contaminant flux to groundwater
- Determine where and what type of mitigation is needed

### ■ Groundwater

- Quantify plume dynamics and secondary source characteristics
- Exit strategy for P&T
  - ◆ Transition to MNA

### ■ Coupled System

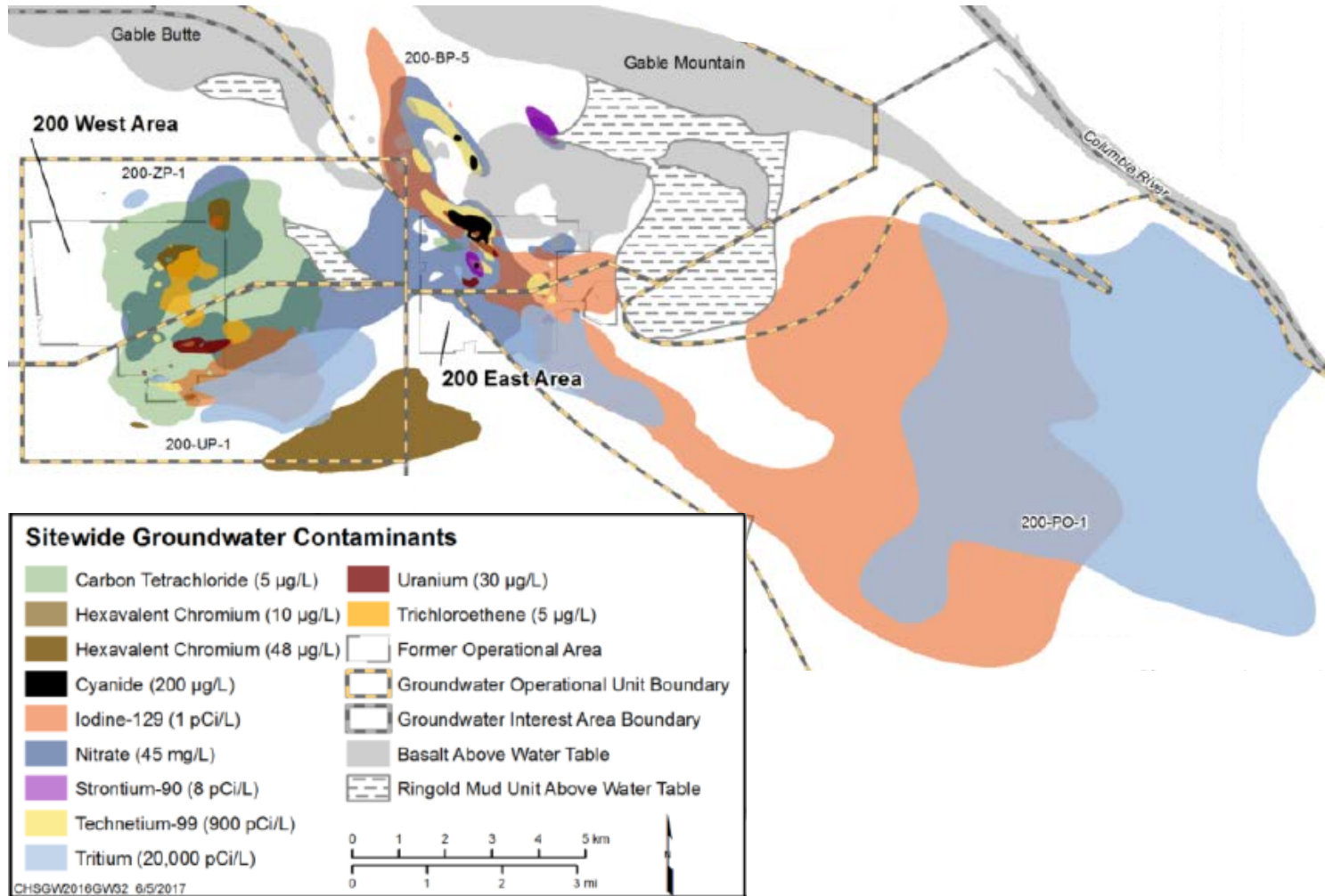
- Assess continuing and long-term sources not related to current plumes

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## ▶ Processes

- Hydraulic attenuation
- Adsorption
- Transformation
- Sequestration

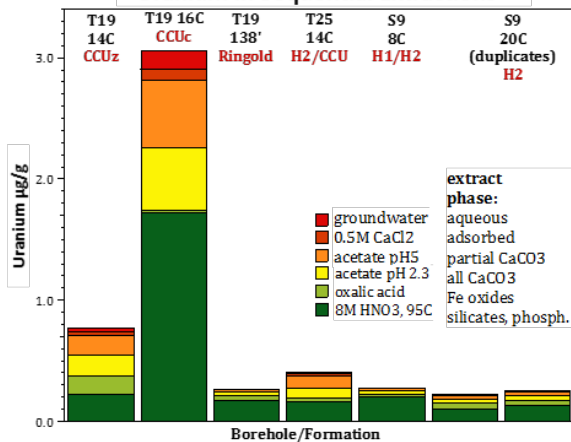
## ▶ Ramifications

- Temporal profile of source flux and concentrations
- Inventory of mobile contaminants
- Spatial distribution information
- Plume dynamics

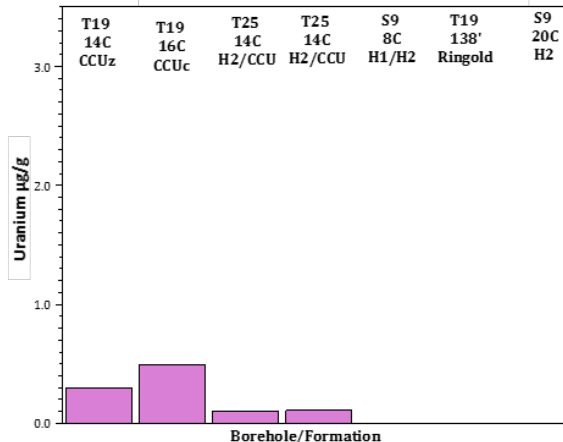
- ▶ Vadose zone attenuation/transport SAP
  - Target sampling and analysis for
    - Important hydrologic units
    - Representative contaminant discharges
    - Problematic waste sites
  - Define analyses based on national guidance for attenuation tailored to site needs
    - COC and primary biogeochemistry
    - Sequential extractions and other indicator diagnostics
    - Leaching or batch  $K_d$  studies to support estimating transport parameters
    - Hydraulic/physical properties where needed to support model configuration

# Reaction and Mobility – Vadose Zone

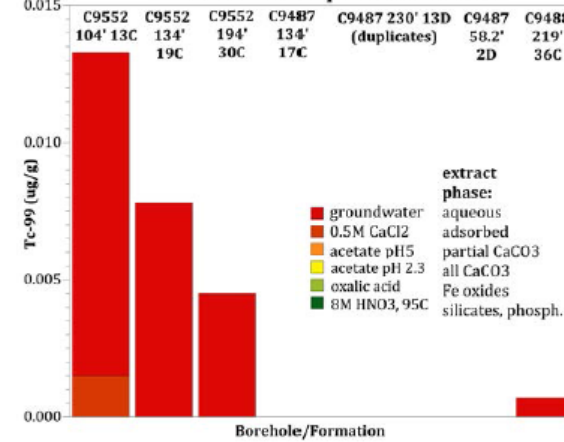
Uranium in Sequential Extractions



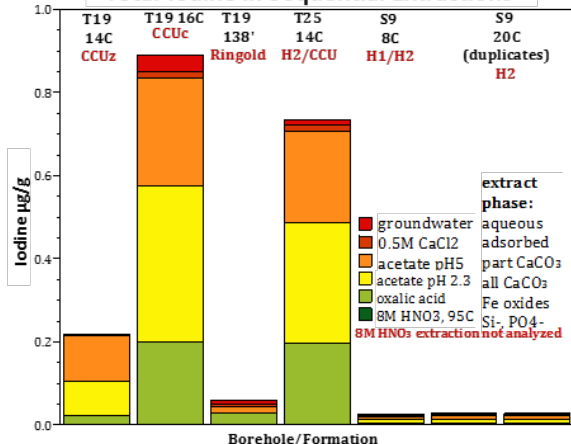
Uranium Leached in 1-D Columns



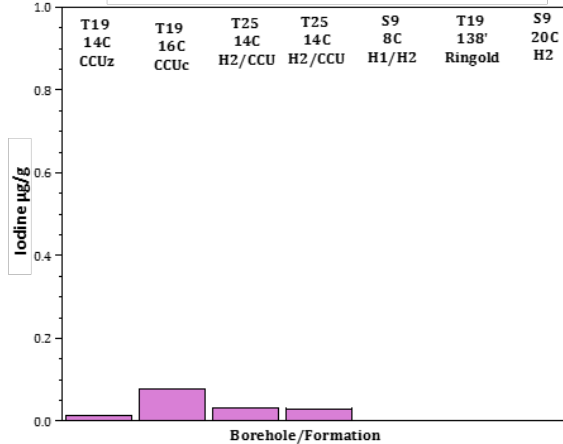
Tc-99 Pre-Leach Sequential Extractions



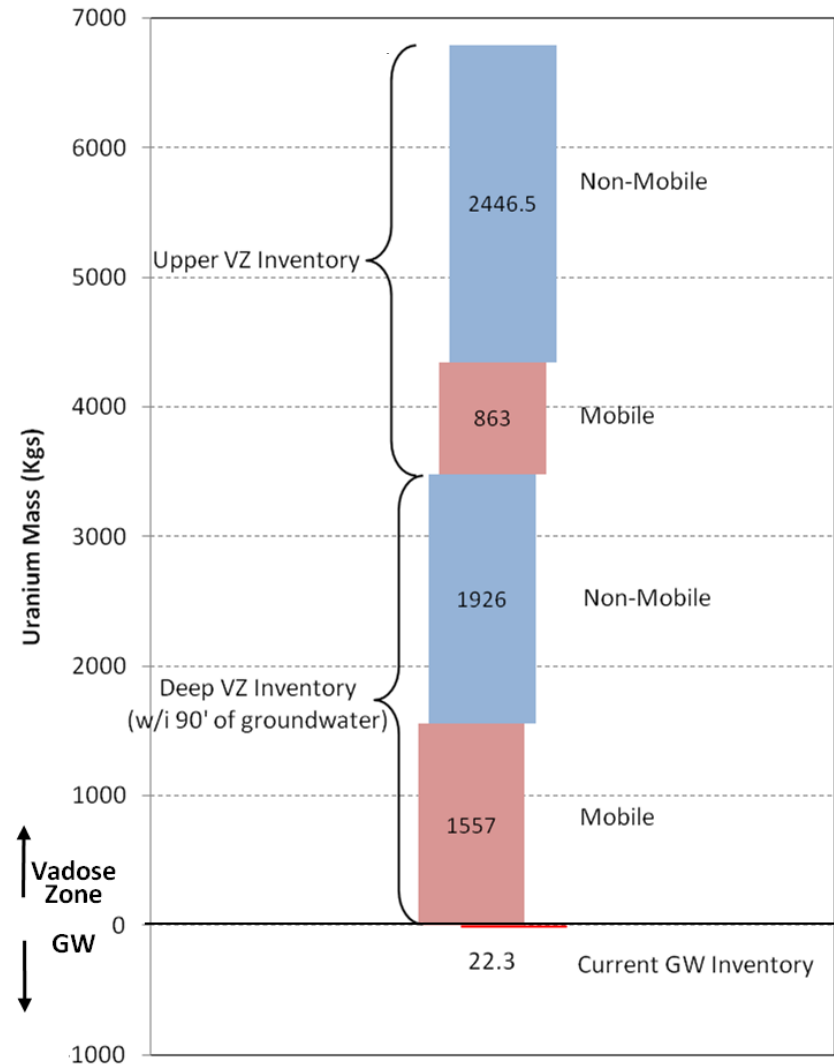
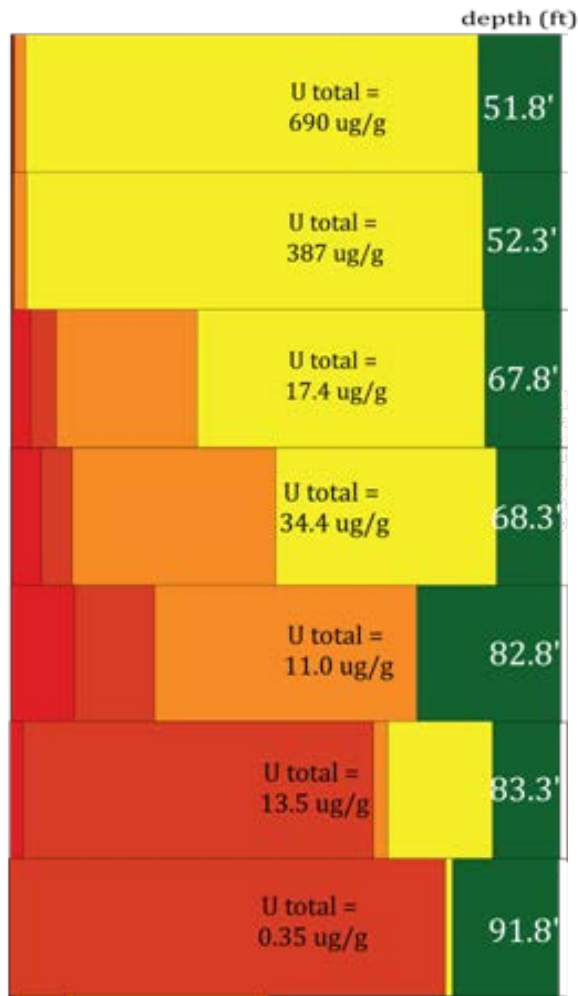
Total Iodine in Sequential Extractions



Total Iodine Leached in 1-D Columns

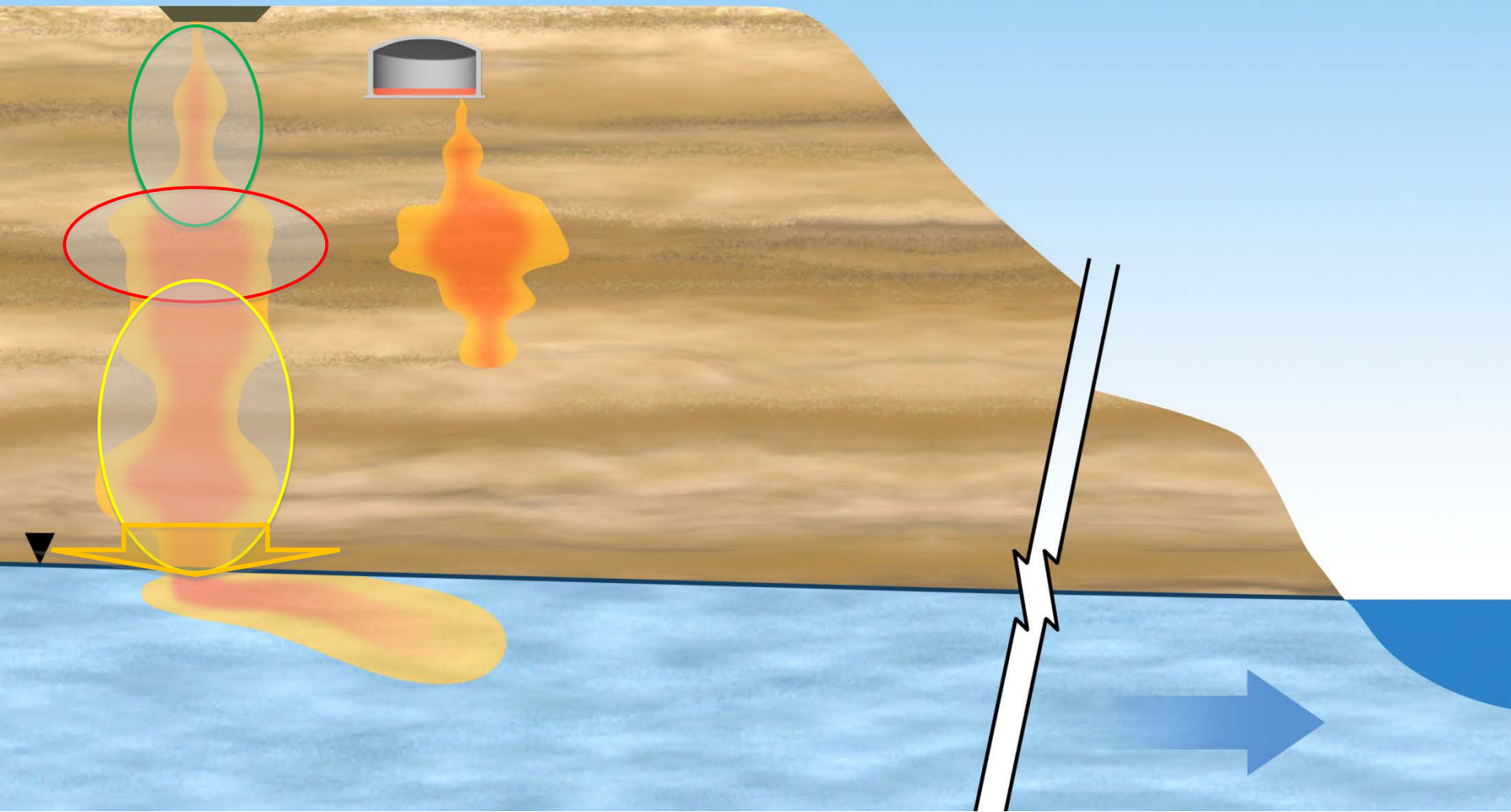


# Distribution and Mobility



Serne et al. 2010

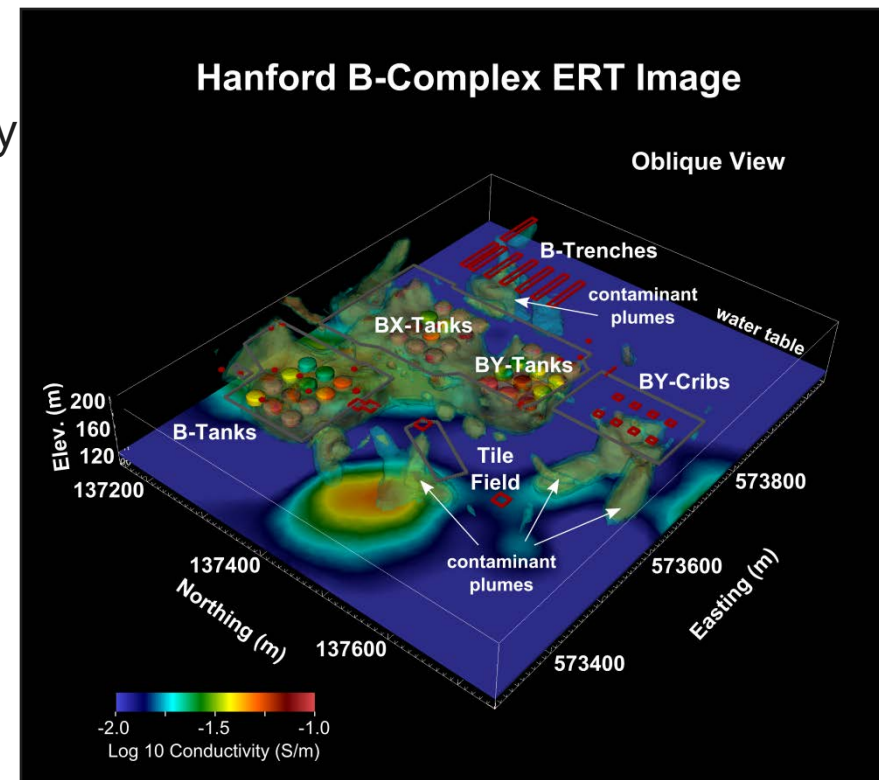
# Source characteristics (location/flux)



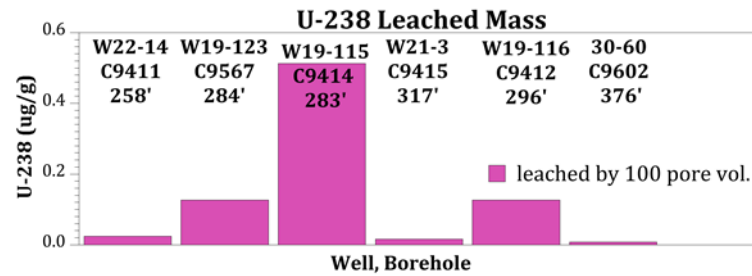
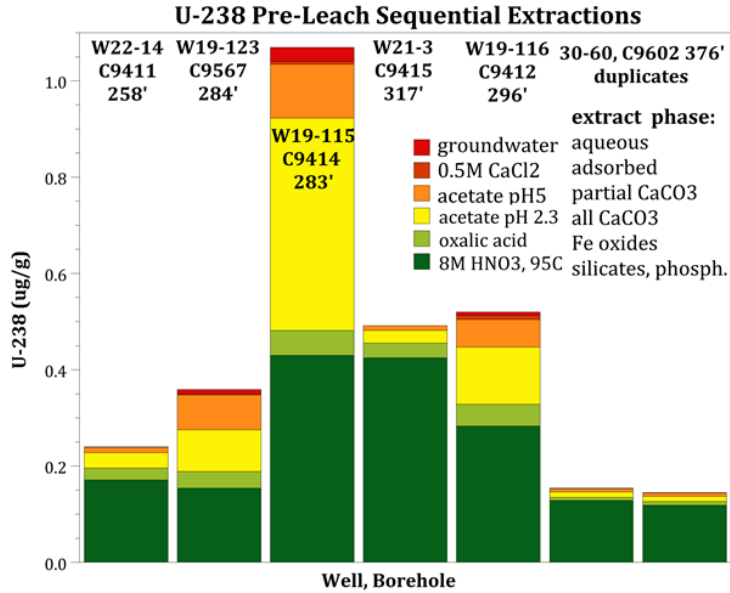


# Evaluation of VZ Transport

- ▶ Contaminant Distribution
  - Geophysical logging
    - Spectral gamma log
    - Neutron moisture log
  - Geophysics
    - Electrical Resistivity Tomography



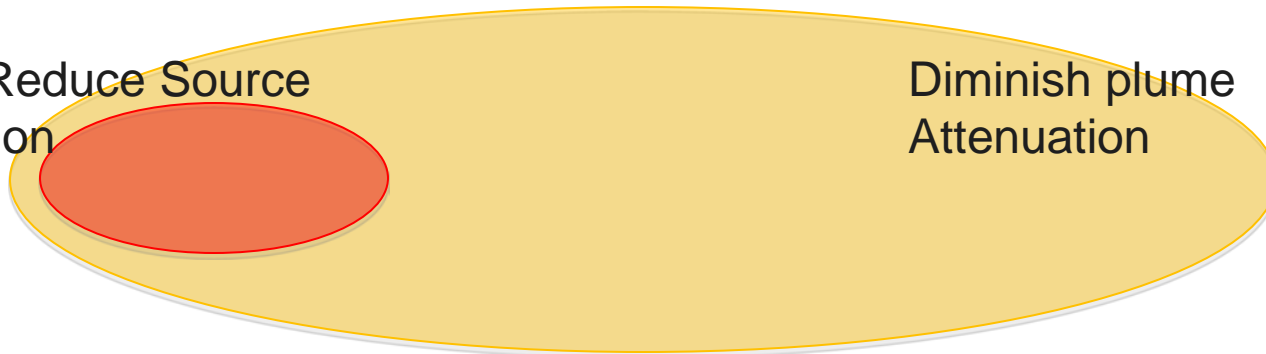
# Reaction and Mobility - Groundwater



Lee et al. 2017

Control/Reduce Source  
Attenuation

Diminish plume  
Attenuation



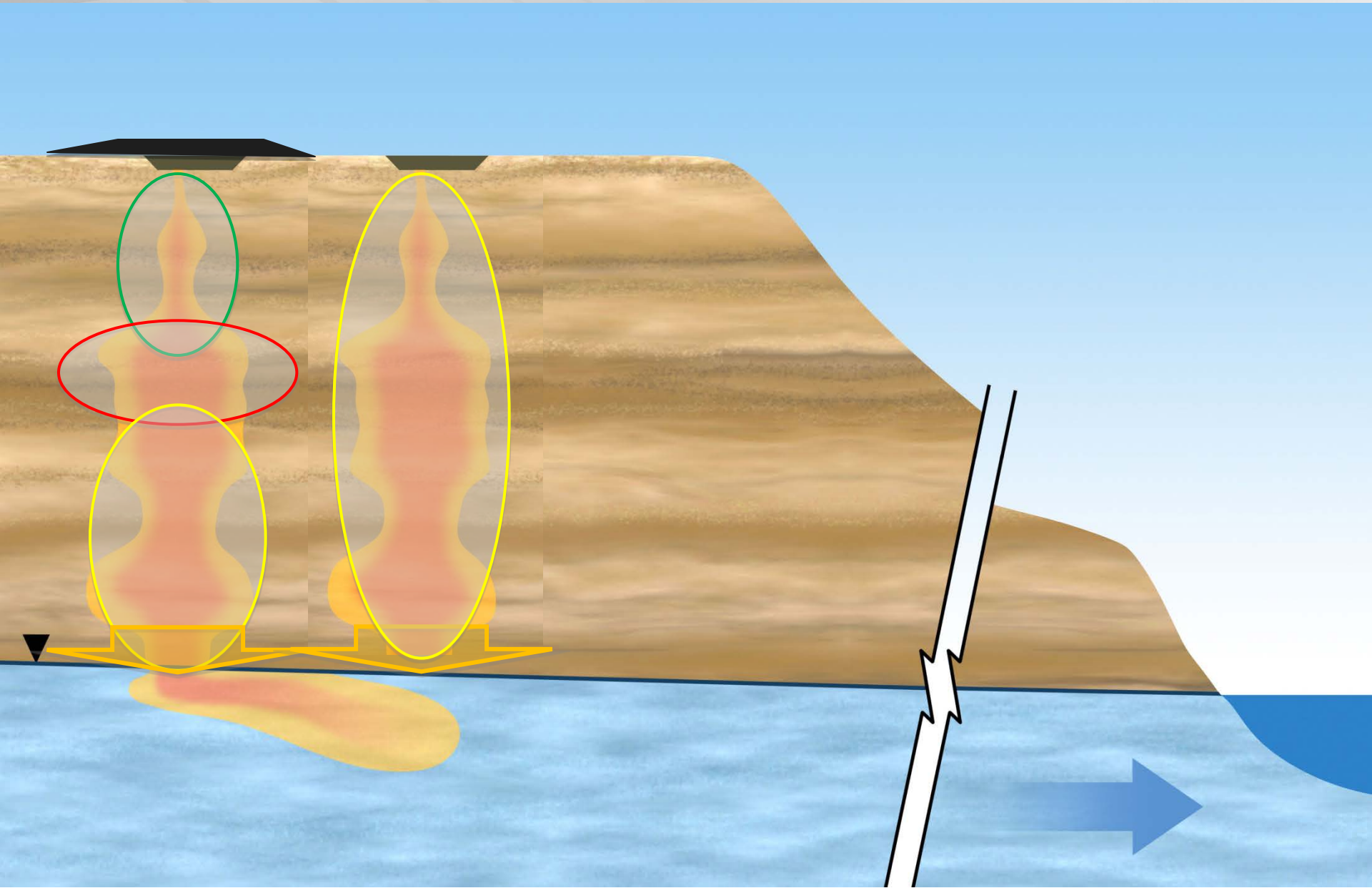
## ▶ Treatability tests and assessments

- Determine technology in relation to
  - radionuclide characteristics
  - the target problem
  - remedy functionality
  - remediation objectives

## ▶ Examples

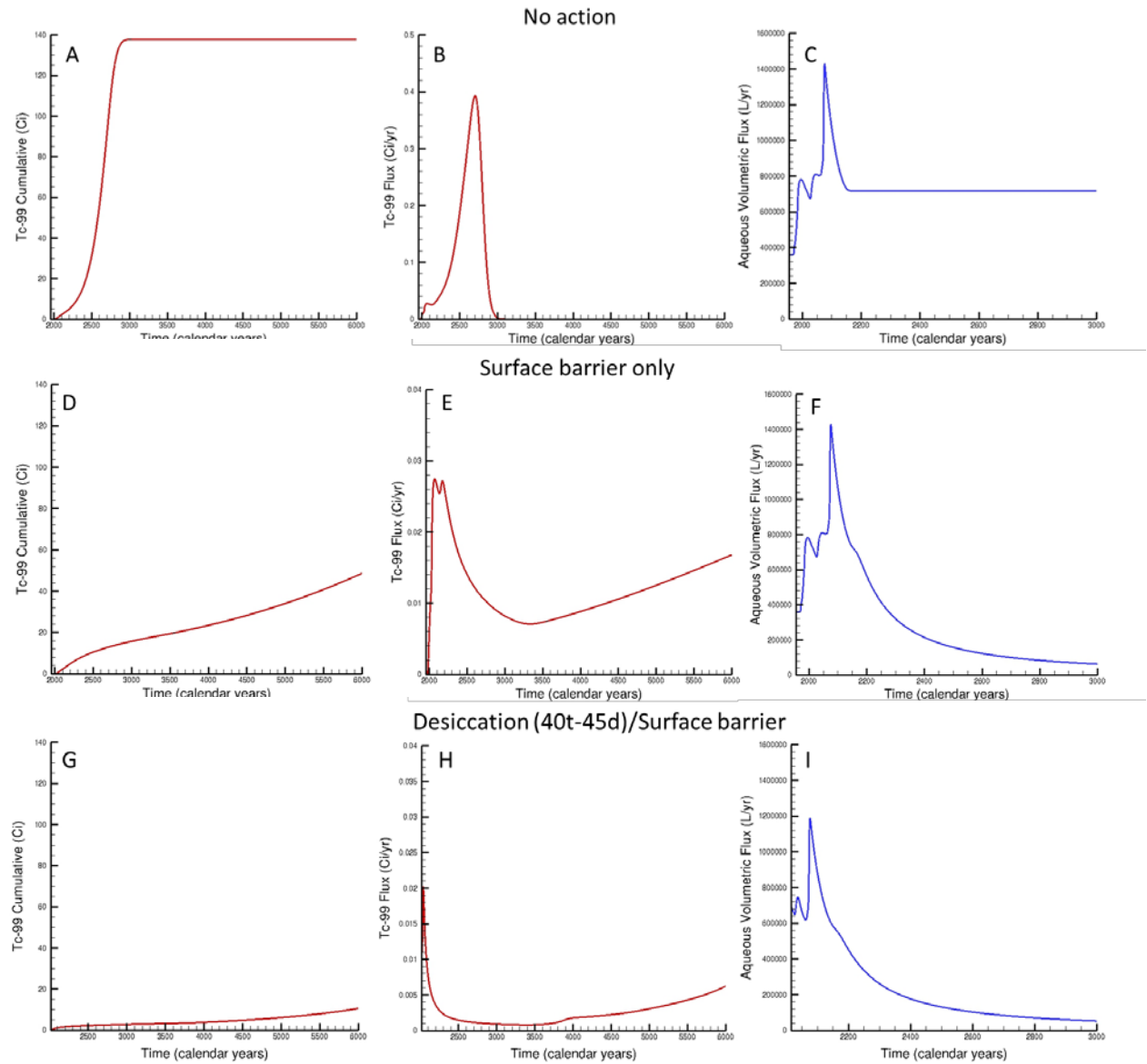
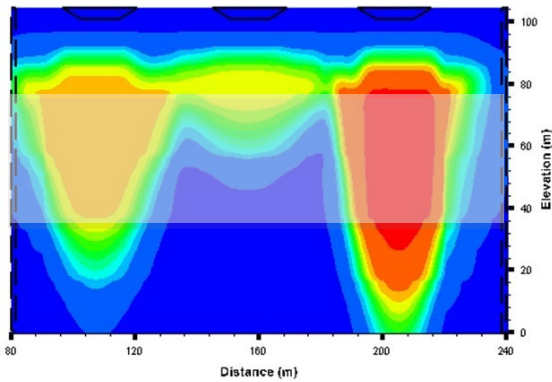
- Soil flushing
- Surface barriers/desiccation
- Uranium sequestration

# Source characteristics (location/flux)



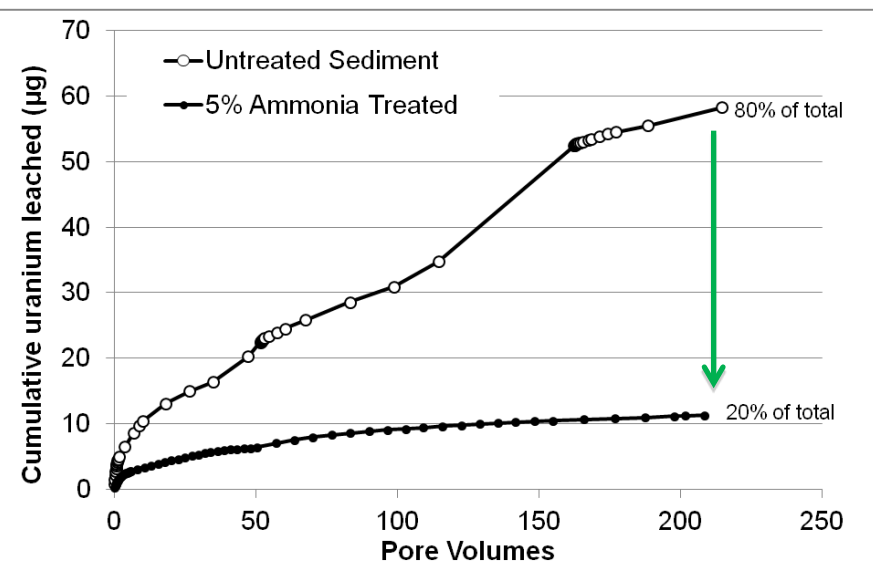
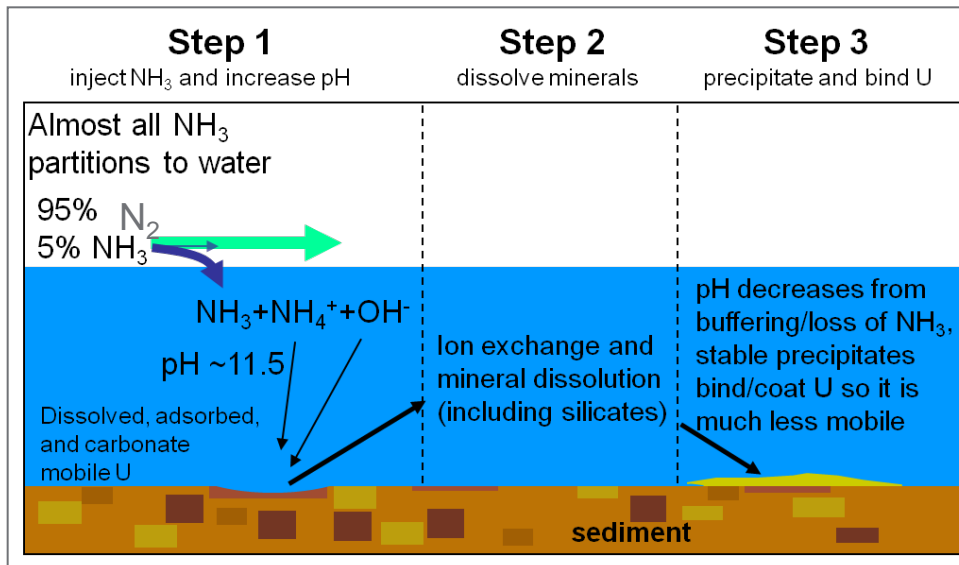
# Surface Barrier

## ► Effect of drainage



# Geochemical stabilization – vadose zone

## ► Ammonia gas for uranium sequestration



- ▶ Vadose zone remediation target
  - Where
  - What chemical form
  - How much flux reduction
- ▶ Diminishing plumes
  - How much is needed
  - Secondary or continuing sources
- ▶ Transition to MNA
- ▶ Current plumes versus long-term sources

- ▶ Adaptive Site Management
  - National Research Council
  - ITRC
    - Remediation Management of Complex Sites
    - <http://rmcs-1.itrcweb.org/>
- ▶ Exit Strategies (P&T)
  - <http://bioprocess.pnnl.gov/Pump-and-Treat.htm>
- ▶ Monitoring
  - Objectives based
  - Performance metrics
  - Transition for long-term



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