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Characterization and Remediation Approaches for a Deep Subsurface Site: Hanford

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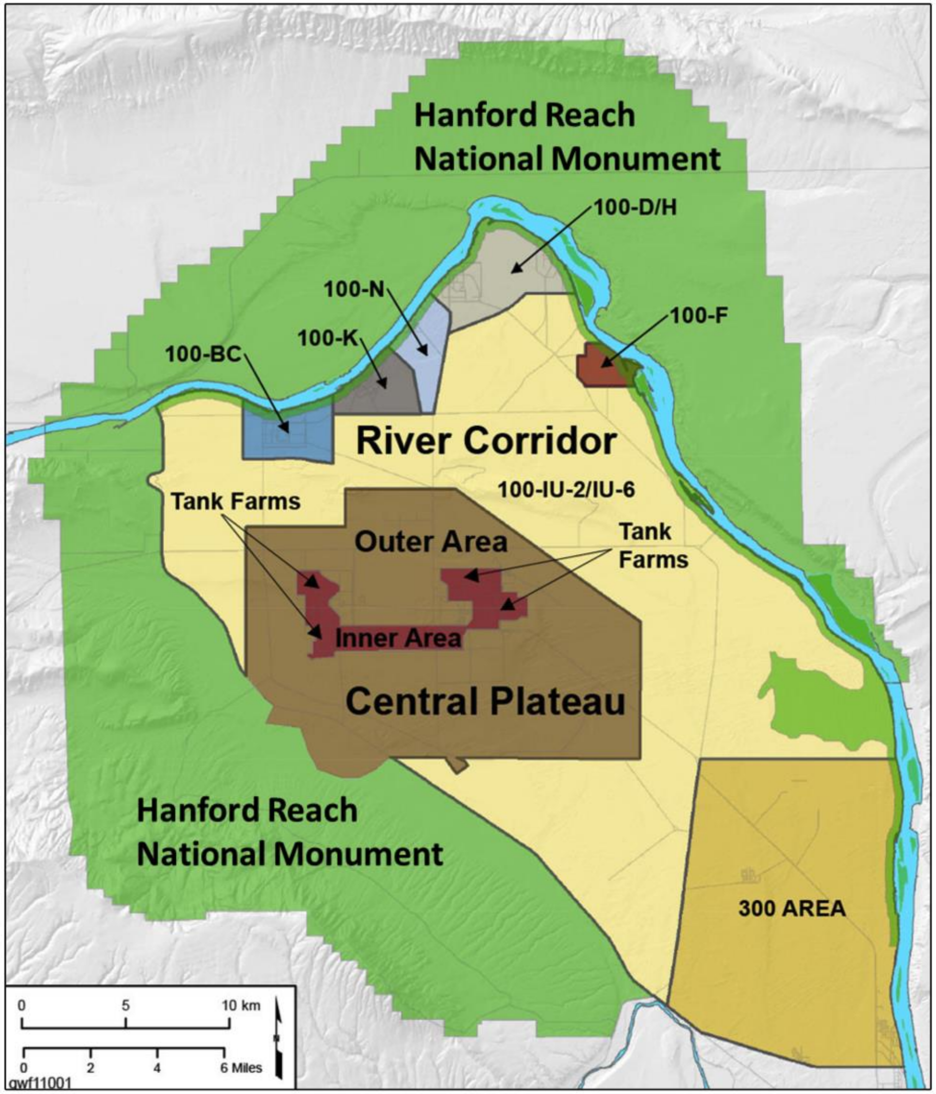
The Hanford Site



- 586 sq. miles
  - Shrub steppe desert in southeast WA
- Production period from 1944 to 1987
- 110,000 tons of nuclear fuel was processed
- Billions of gallons of liquid waste produced
  - Stored in single-shell and double-shell tanks
  - Discharged to liquid disposal sites (e.g., pits, cribs and trenches)

Methods for Water and Chemical Releases into the Ground

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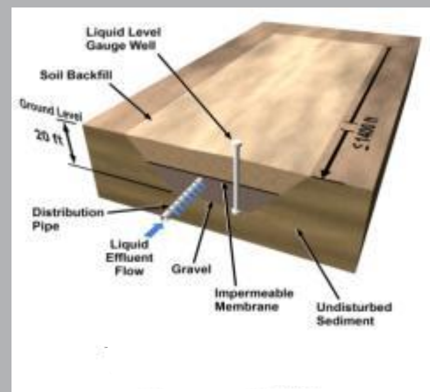
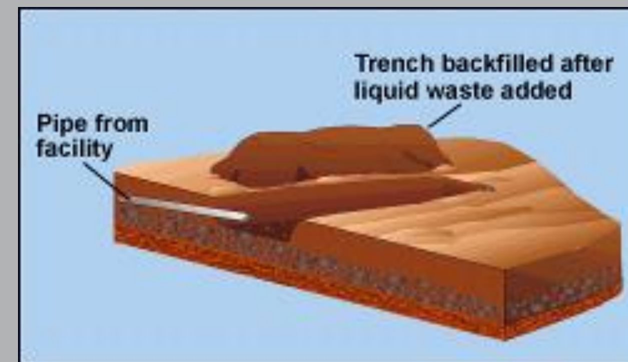
Tank Leaks
1959-1968

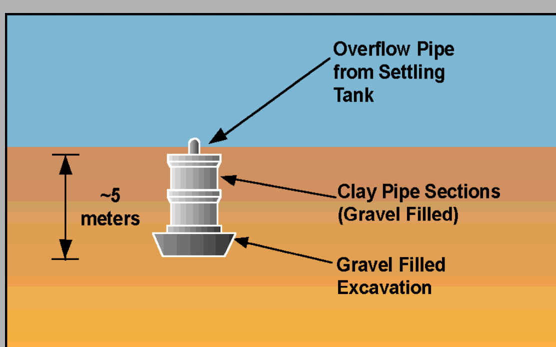
Cribs
1944-1990s



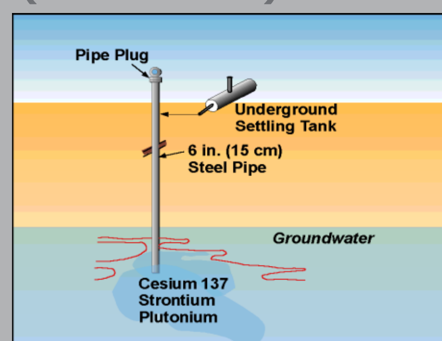
Specific Retention Trenches 1944-1973



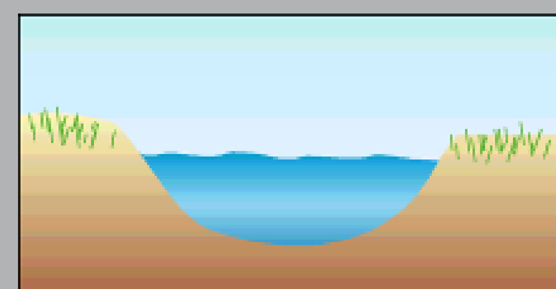
French Drains
1944-1980s



Reverse Wells
1945 - 1955
(one to 1980)



Ponds
1944-1990s



U-Pond and Adjoining 200 West Area

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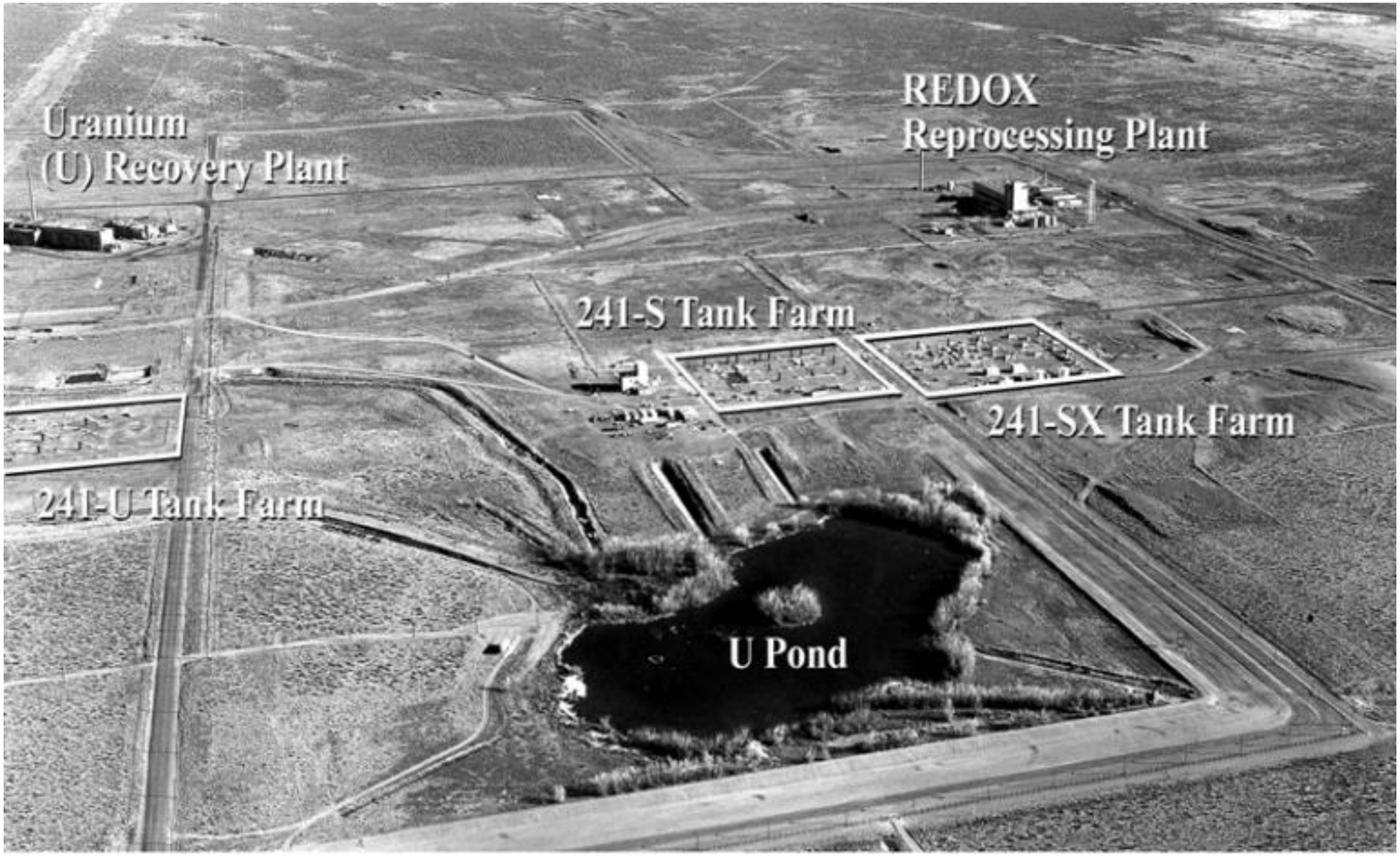

1962 Photo

30 surface ponds and ditches covering ~ 1.3 km² (1/2 mile²) built in central Hanford released 1.7 trillion liters (450B gallons) of liquids into ground.

Inventory Estimates for Select Radionuclides in Subsurface from Liquid Releases

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Radionuclides	Discharges to Soil (Curies)	Tank Leaks to Soil (Curies)	Total (Curies)
Cs-137	75,000	150,000	**225,000**
Sr-90	38,000	14,000	**52,000**
Tc-99	600	100	**700**
I-129	4.6	0.1	**4.7**
Am-241	28,700	-	**28,700**
U (total)	270	15	**285**
Np-237	55	-	**55**
Pu (Pu-239, -240, -241)	52,000	-	**52,000**

Historical information sources: Corbin et al (2005); Kincaid et al (2006)
Additional information (2009): Sunil Mehta (Intera)
Numbers approximated and rounded
(-) means essentially zero
(Most radionuclides decayed to 2005)

Estimated Inventory for Select Non-Radioactive Metals and Chemicals Discharged in the Central Plateau

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Chemical or Metal	Liquid Waste Release Sites (Kg)	Tank Leaks (Kg)
Nitrate + Nitrite	9.8E+07	2.5E+05
Sodium	4.1E+07	2.0E+05
Chloride	4.0E+06	5.1E+03
Phosphate	3.6E+06	7.8E+03
Carbon tetrachloride	9.2E+05	0
Tributyl Phosphate	7.4E+05	0
Chromium	3.1E+05	2.0E+03
Lead	8.1E+04	1.0E+02
Iron	3.8E+05	4.6E+02
Bismuth	5.3E+04	5.0E+01
Total	1.5E+08	4.6E+05

Remediation and Monitoring of Hanford Subsurface Contaminants

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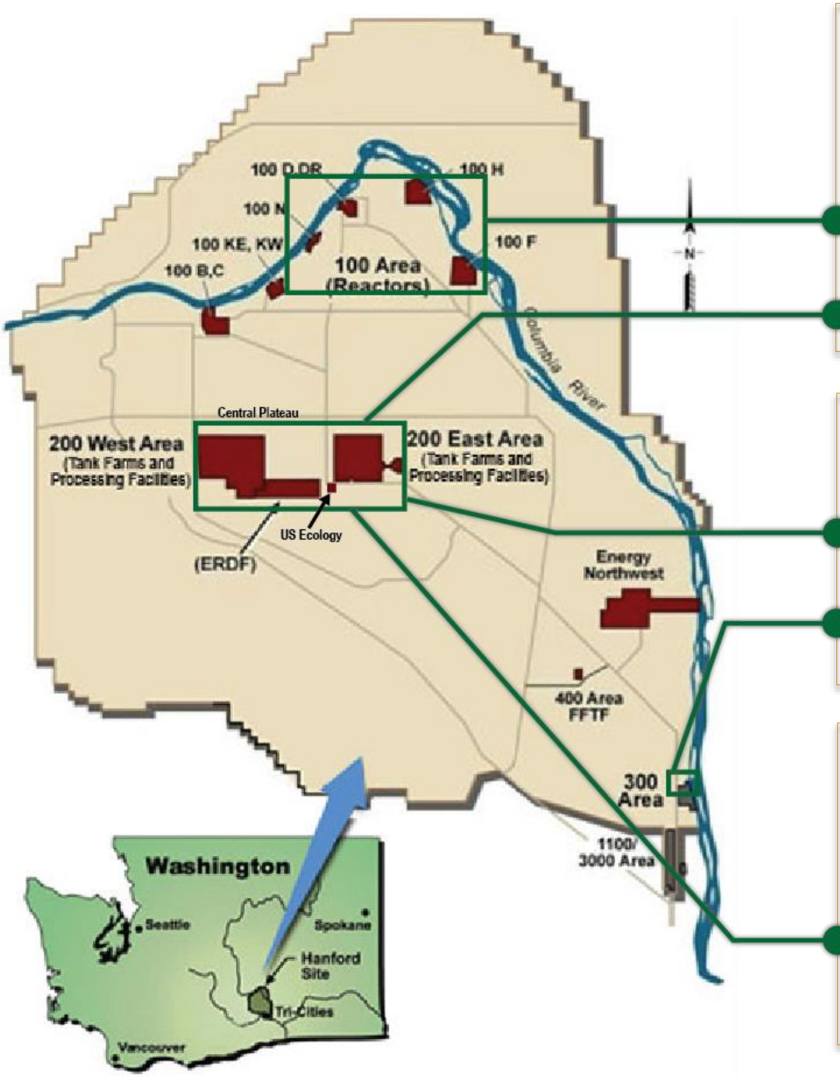


Technical Basis for Remediation

- Quantify natural attenuation processes and rates for 100 Area chromium
- Provide the technical basis for characterizing, assessing, and treating ^{129}I
- Develop template for MNA of ^{129}I, ^{99}Tc, and U in the Central Plateau
- Identify biogeochemical interactions impacting remediation of comingled plumes
- Assess ^{99}Tc, ^{129}I, and U remediation using biogeochemical immobilization/degradation
- Evaluate novel materials for ^{99}Tc, ^{129}I, and U removal by pump and treat

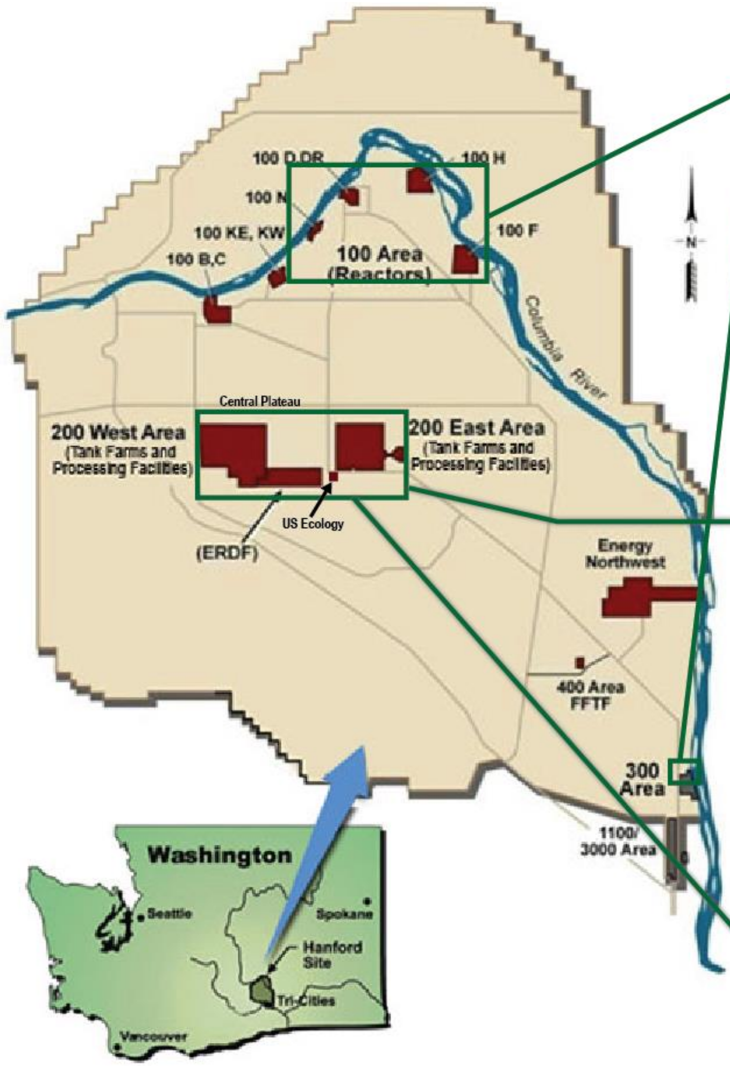
Systems-Based Assessment for Remediation

- Develop technical foundation for pump and treat exit strategy
- Provide a template for MNA in the Central Plateau focused on ^{99}Tc, ^{129}I, and U
- Support development of remediation endpoints for U in the 300 Area
- Evaluate candidate remediation technologies for ^{99}Tc, ^{129}I, and U in the DVZ

Systems-Based Monitoring

- Provide technical input on monitoring plans to streamline the program
- Develop and enhanced control and monitoring system for DVZ treatability tests
- Assess performance of BC Cribs desiccation test
- Summarize issues and uncertainties in surface barrier performance for DVZ remediation

Understanding Processes Controlling Subsurface Contaminants



River Corridor

- Quantified mechanisms for Cr sequestration, resulting in implementation of the In Situ Redox Manipulation Barrier
- Developed methods for ^{90}Sr sequestration using apatite, resulting in installation of a permeable reactive barrier
- Resolved U geochemistry in the 300 Area providing the technical basis for current remediation activities

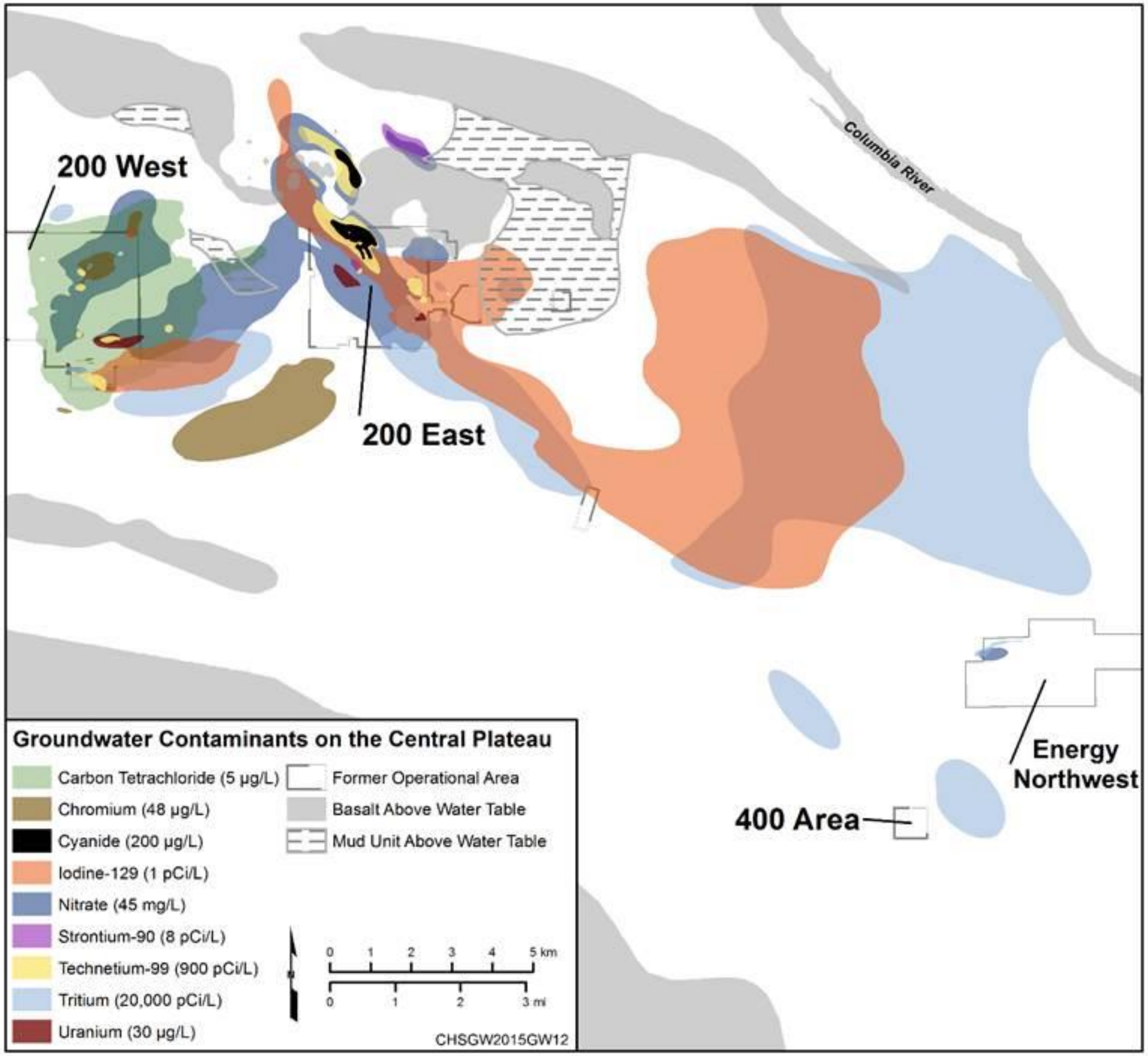
Central Plateau

- Quantified waste source inventories in the Soil Inventory Model (SIM) to enable site-wide and site-specific assessments
- Developed mass-flux strategy enabling termination of the carbon tetrachloride vapor extraction system
- Identified mechanisms for lateral transport of vadose zone contaminants that guided site characterization and treatability tests for ^{99}Tc at BC Cribs and trenches
- Resolved U geochemistry at a number of waste sites, providing the technical basis for future remediation strategies
- Identified, tested, and developed geophysical methods for characterizing and monitoring contaminant plumes in the vadose zone and groundwater

Tank Farm Waste Management Areas

- Improved conceptual and numerical models predicting past ^{137}Cs, ^{99}Tc, U, and Cr migration beneath leaked single-shell tanks
- Developed new process-level descriptions of leaked HLW in the vadose zone enabling prediction of future behavior
- Refined geophysical methods for waste tank leak detection and monitoring

Hanford Central Plateau Groundwater Plumes



200 West Groundwater Plumes

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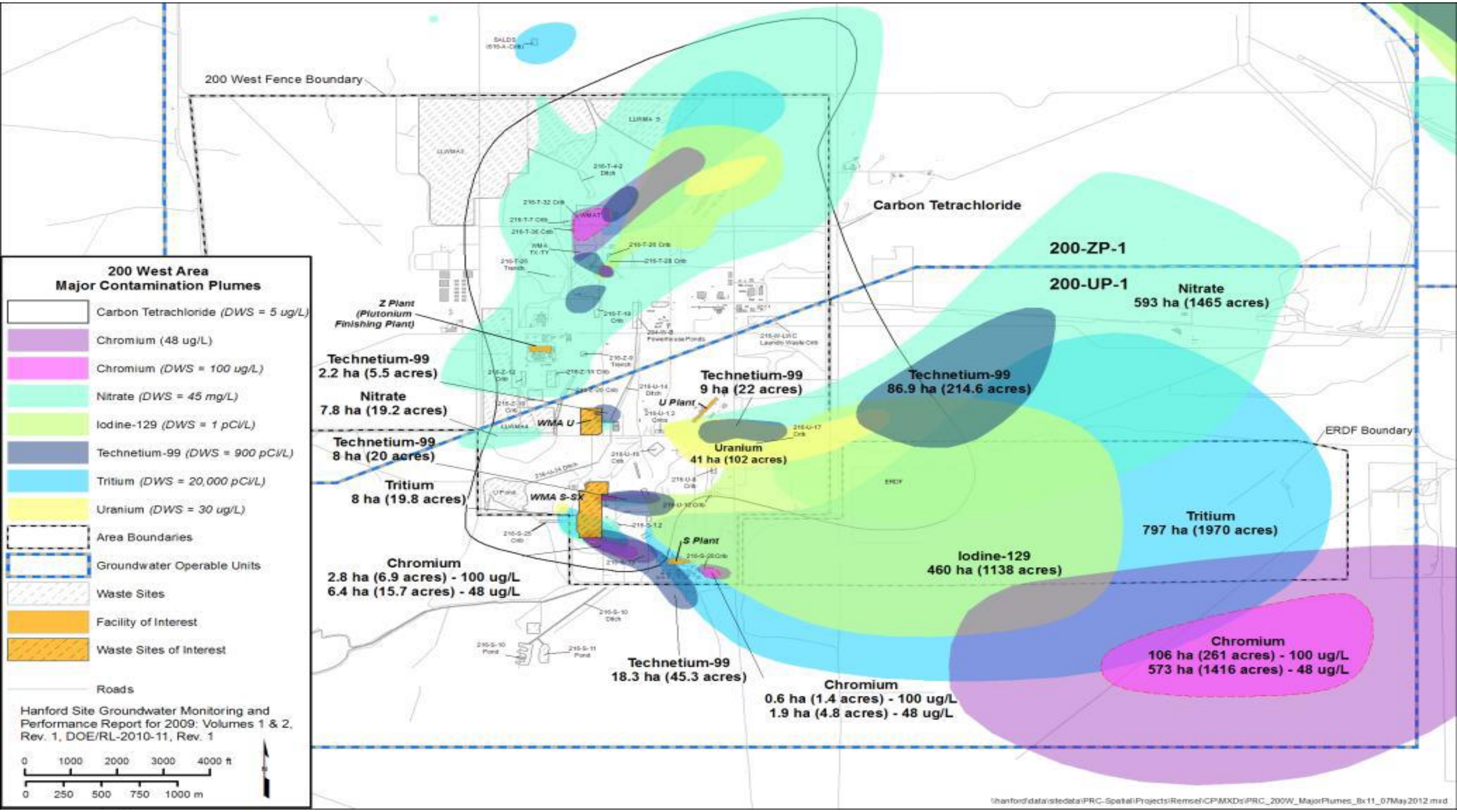
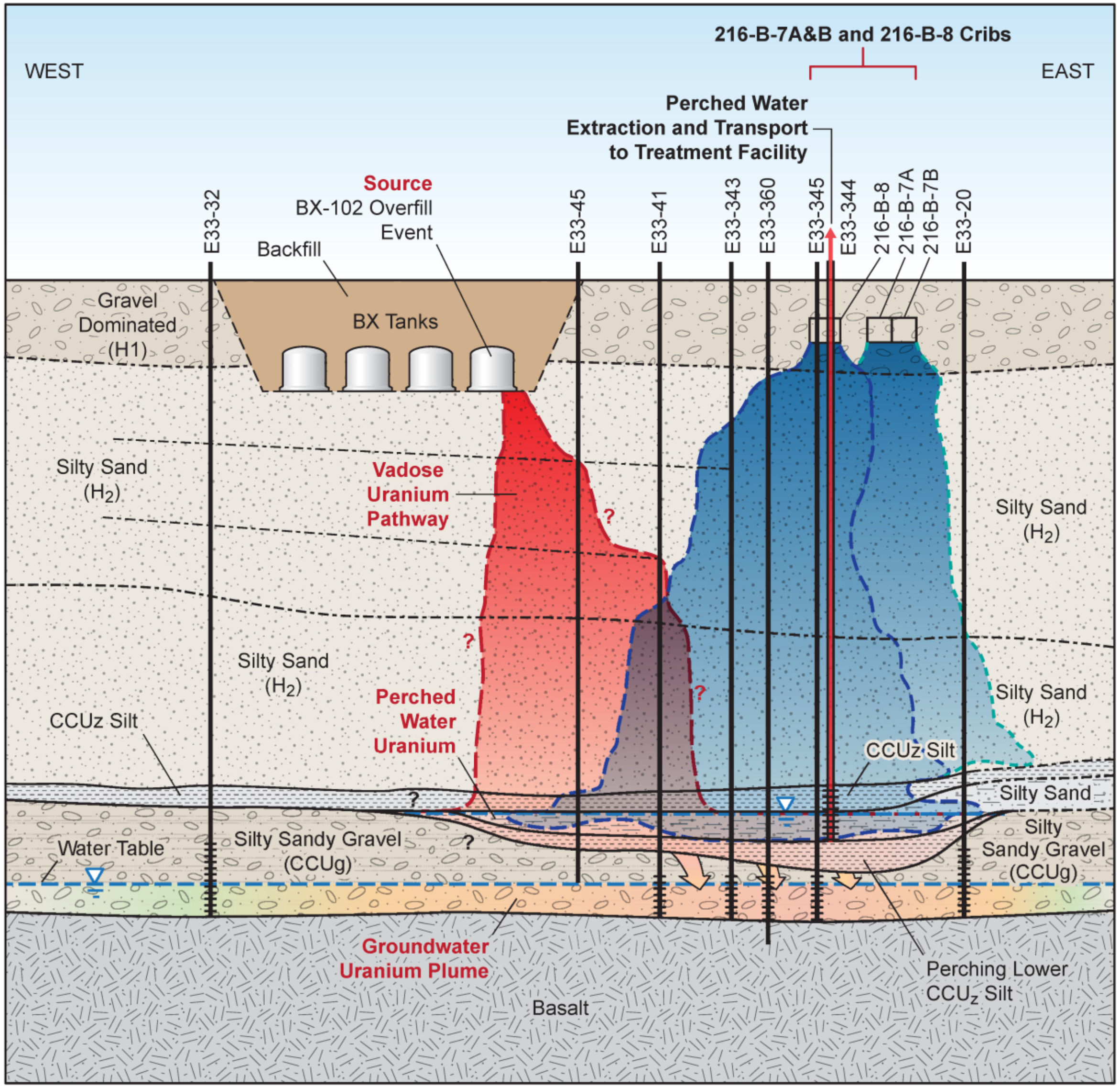
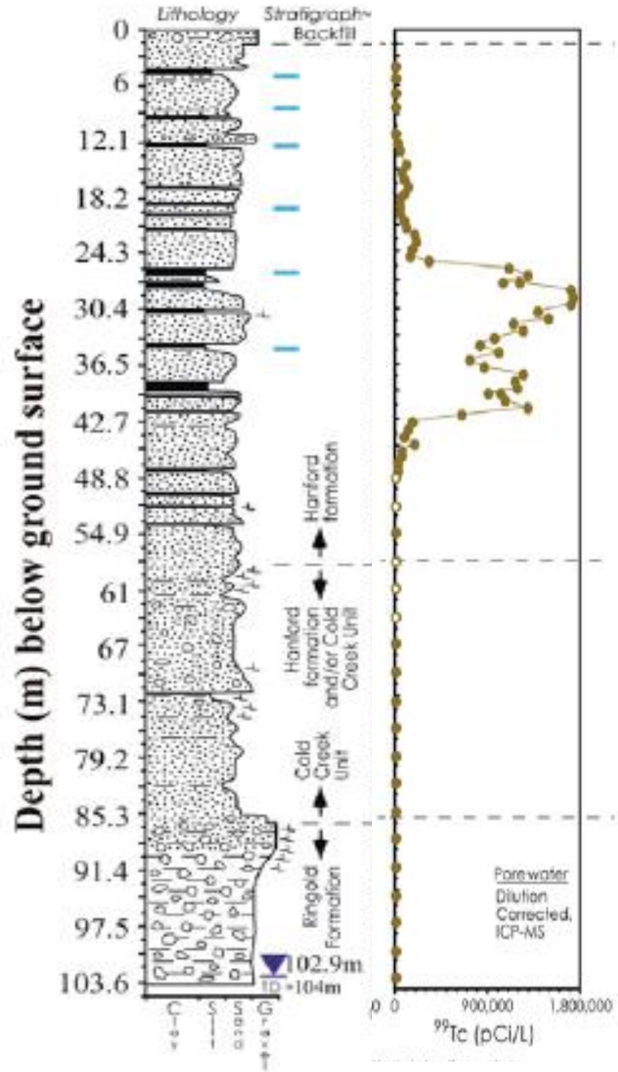


200 East Groundwater Plumes

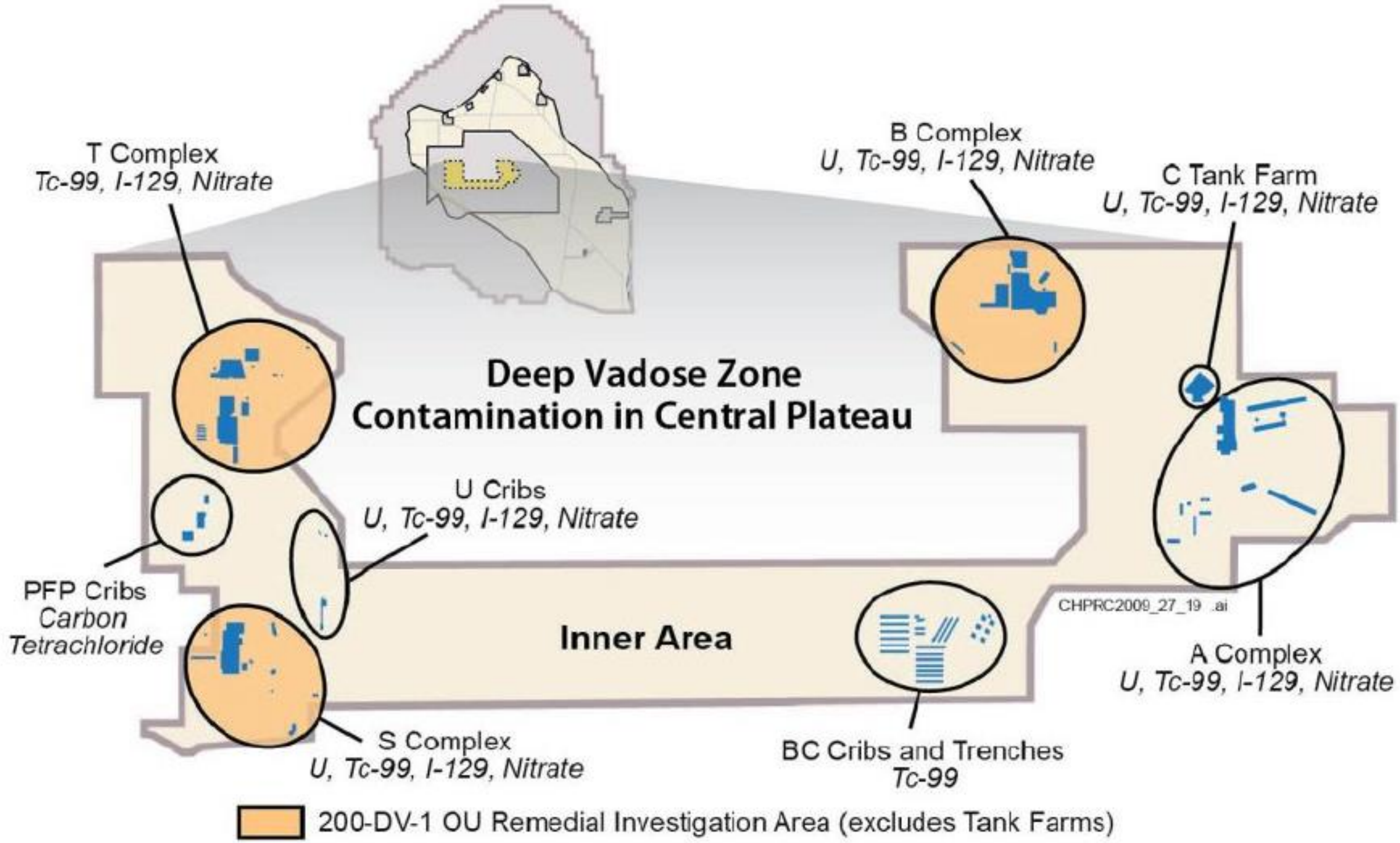
200 East Vadose Zone Transport



Not to Scale

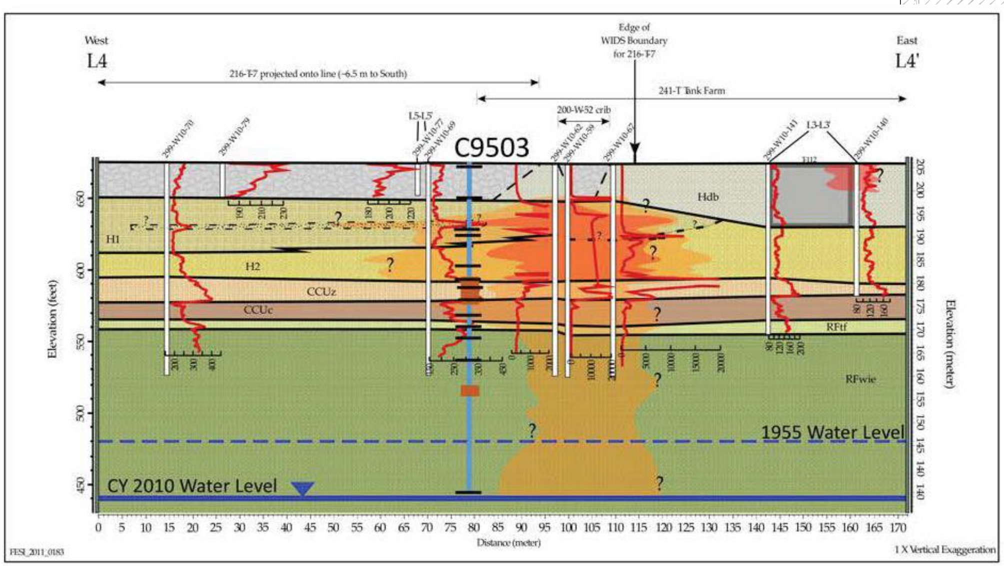


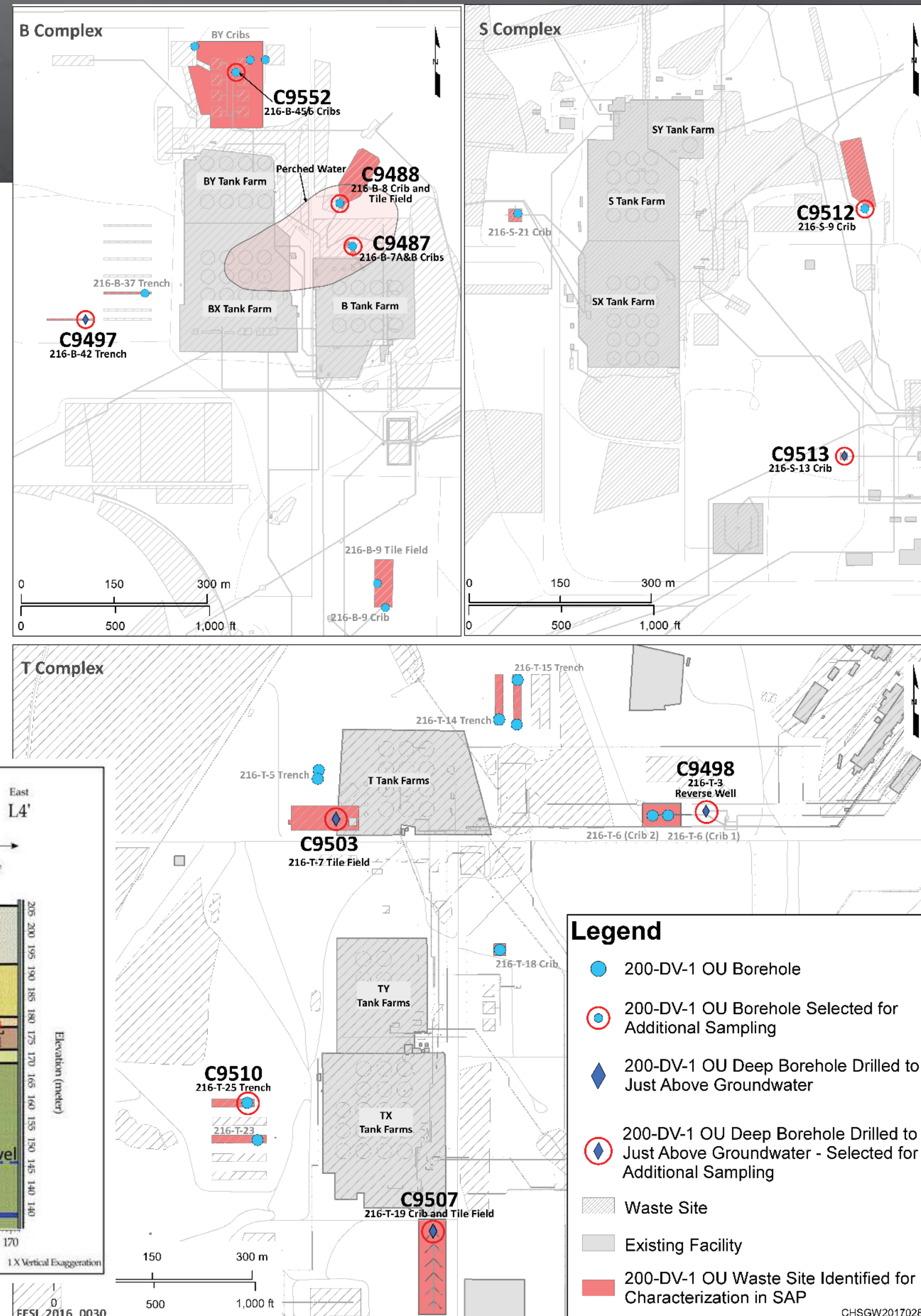
DV-1 Vadose Zone Operable Unit



DV-1 Sampling

- Laboratory testing for attenuation and transport processes
  - Based on EPA guidance for MNA of inorganic contaminants
  - Sequential extraction of COCs
  - COC leachability
  - Biogeochemical attenuation





Coupling Geophysical Monitoring and Predictive Simulation To Improve Estimates of Contaminant Flux to Groundwater

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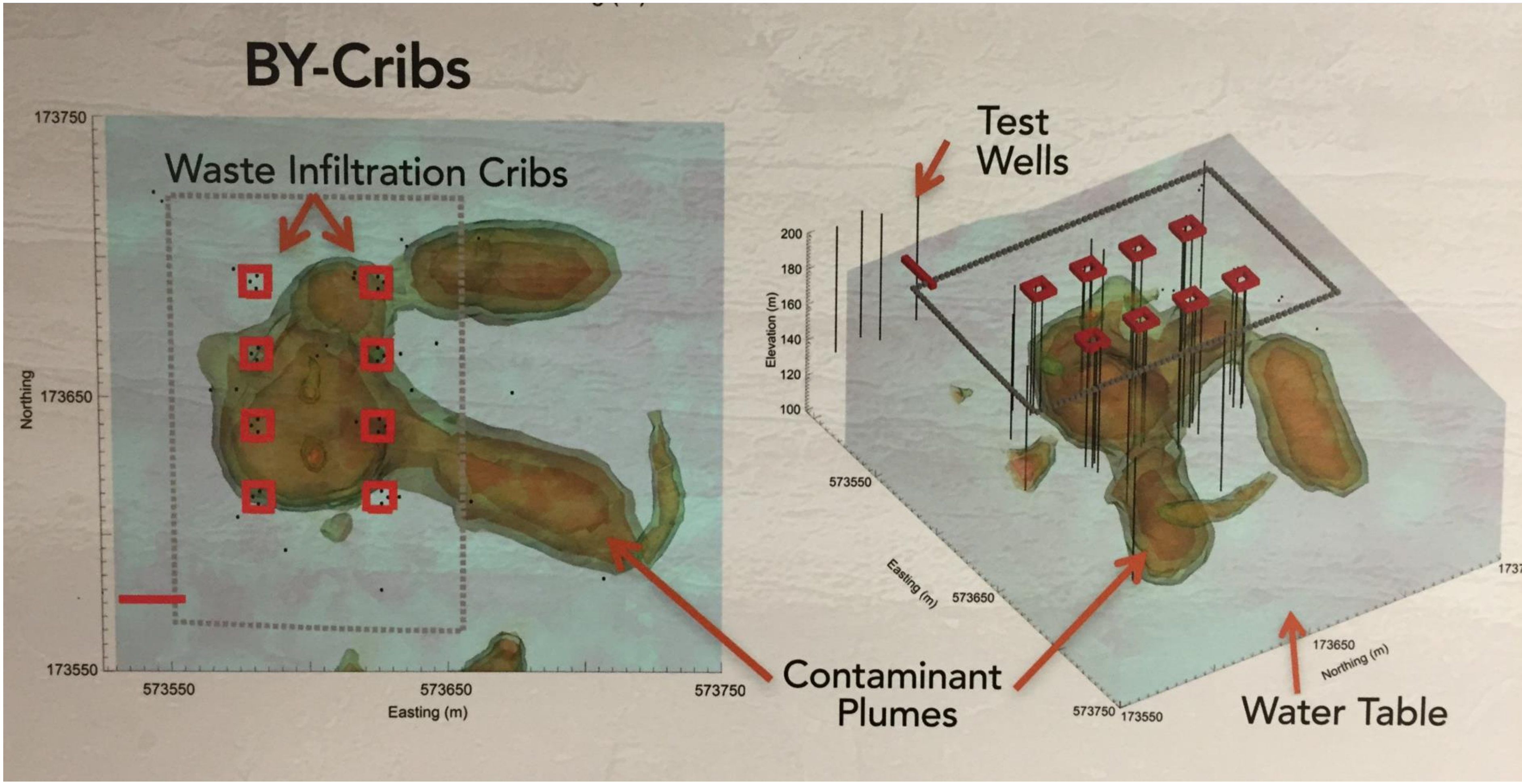
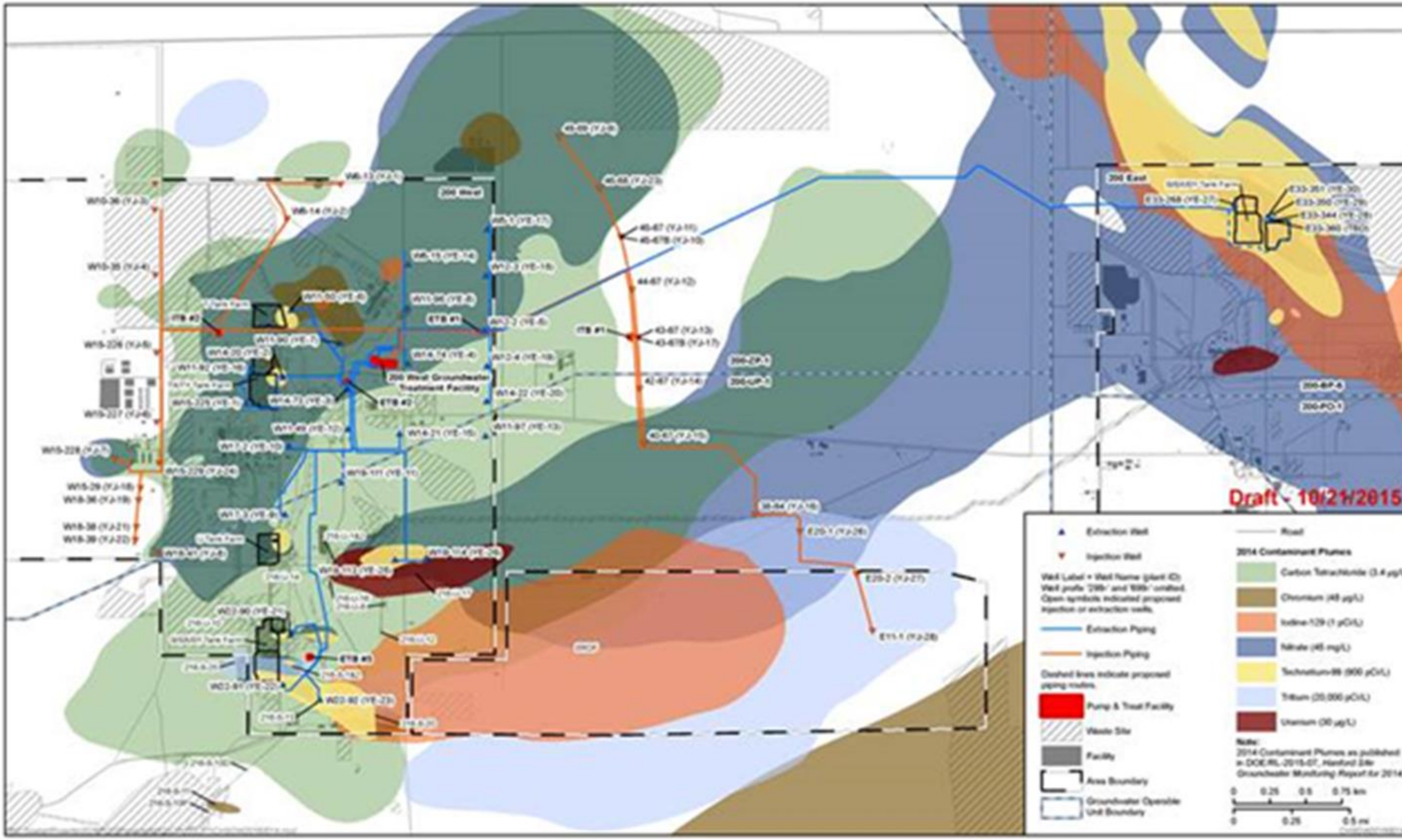


Primary Mode of Groundwater Treatment

200-ZP-1 Pump and Treat – Big Picture

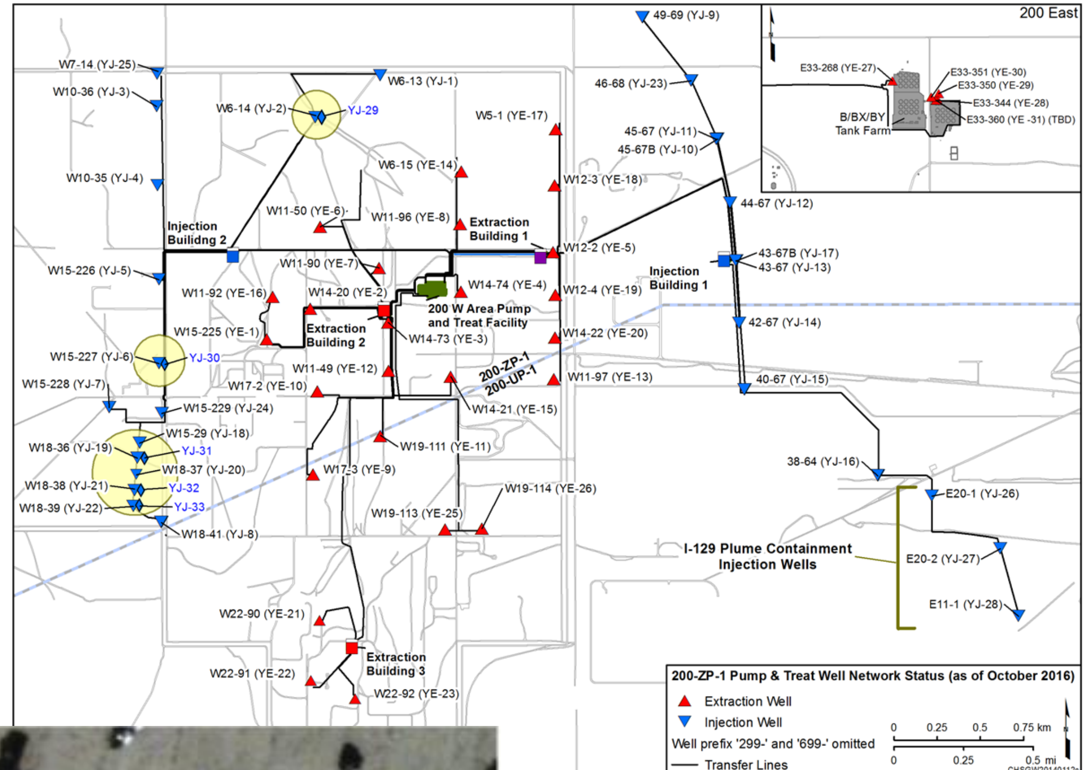


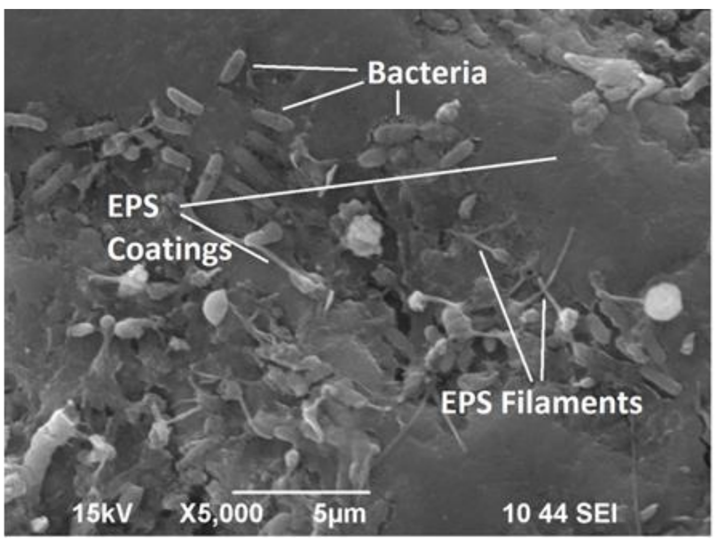
Pump and Treat Performance

- Pump and Treat
  - 200 West Area Groundwater Treatment Facility
  - DOE's Largest system for treating groundwater at Hanford
- Hydraulic containment
  - I-129
- Groundwater treated*
  - 3.84 billion gallons
  - 11,563 kg Carbon tet.
  - 1,273,260 kg NO_3
  - 269 kg Cr(VI)
  - 6.72 curies Tc-99
  - 92.5 kg U

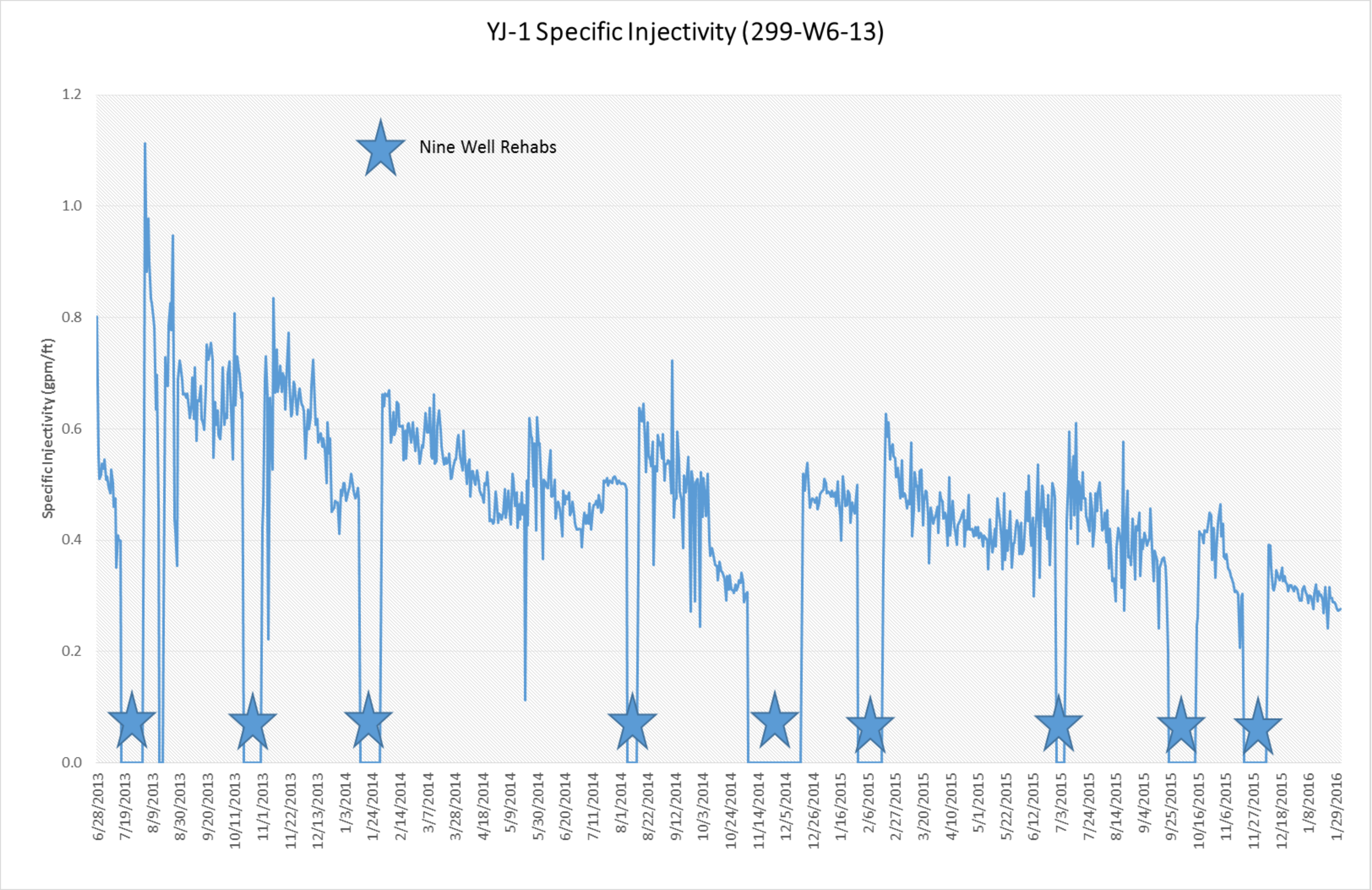
* Through April 2017

200 West Pump and Treat Well Network





Adverse Effects of Well Fouling on Injectivity



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Radioiodine at Hanford

Iodine Inventory in Hanford Waste

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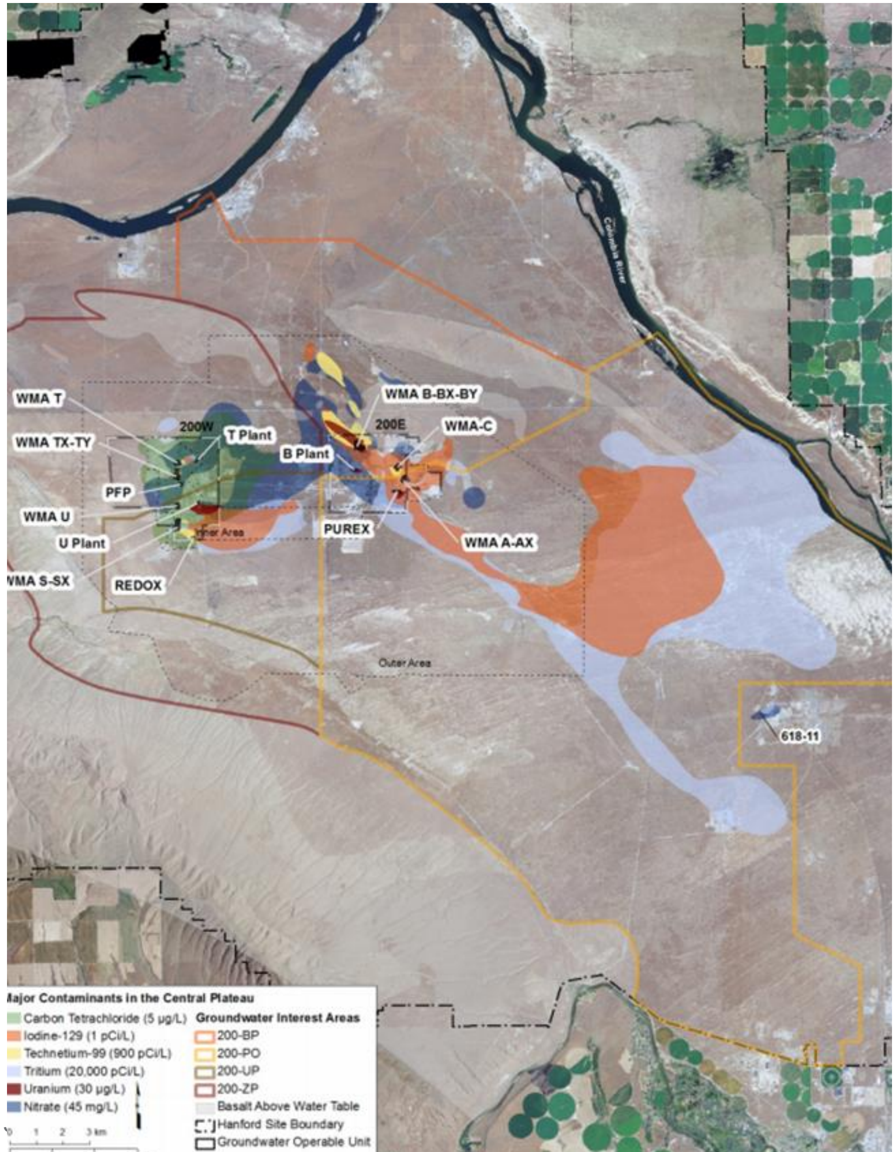
I-129 Inventory Category	Estimate	Discussion and References
Total generated by production reactors	49.4 Ci	Based on calculation using the 2002 ORIGIN2 fuel activity estimate (Watrous et al. 2002). This estimate is well known and based on fuel irradiation histories.
Stored in single-shell and double-shell tanks	29.0 Ci [(a)]	Best Basis Inventory (BBI) obtained from the Tank Waste Information Network System (April 23, 2015) (https://twins.labworks.org/twinsdata/default.htm). Significant uncertainty remains with this estimate.
Discharged to liquid disposal sites	4.7 Ci	From Hanford's Soil Inventory Model (Corbin et al. 2005). Uncertainty estimates were developed for individual waste sites that ranged from 20% to almost 400%.
Released to the atmosphere	Unknown	Estimates of magnitude of these potential releases are not available. This remains one of the main uncertainties limiting development of a true mass balance for Hanford ^{129}I.
Captured by offgas absorbent devices	Unknown	Devices known as "silver reactors" were used to capture iodine at chemical separations plants (PUREX, B-Plant, T-Plant, and REDOX). The ^{129}I inventory captured in this manner is not known. Some of these devices remain at the canyon facilities and some are in solid waste burial grounds.

(a) The BBI underwent a significant update in 2004 (Higley et al. 2004), which reduced the tank inventory estimate from 48.2 to 31.8 Ci based on improved models of separations processes. This change removed the previous conservative assumption that essentially all of the ^{129}I sent to the separations plants exited those plants in waste streams sent to tank farms. Subsequent revisions to the BBI have replaced generic estimates for specific waste streams with sample-based estimates from the tanks.

Iodine-129 Contamination at Hanford



- ^{129}I is found in two separate plumes in the 200 Area of Hanford Site
- These plumes cover >50 km^2; ~3.5 pCi/L (DWS: 1 pCi/L)
- ^{127}I concentrations are approximately 200 times higher than ^{129}I
- Hydraulic containment is the current remedial action
- Treatment technologies are unavailable; are complicated by the geochemistry (alkaline, oxygenic) of groundwater at Hanford site; ^{127}I competes for reactants added for remediation

Current Conditions Related to Iodine Speciation at Hanford

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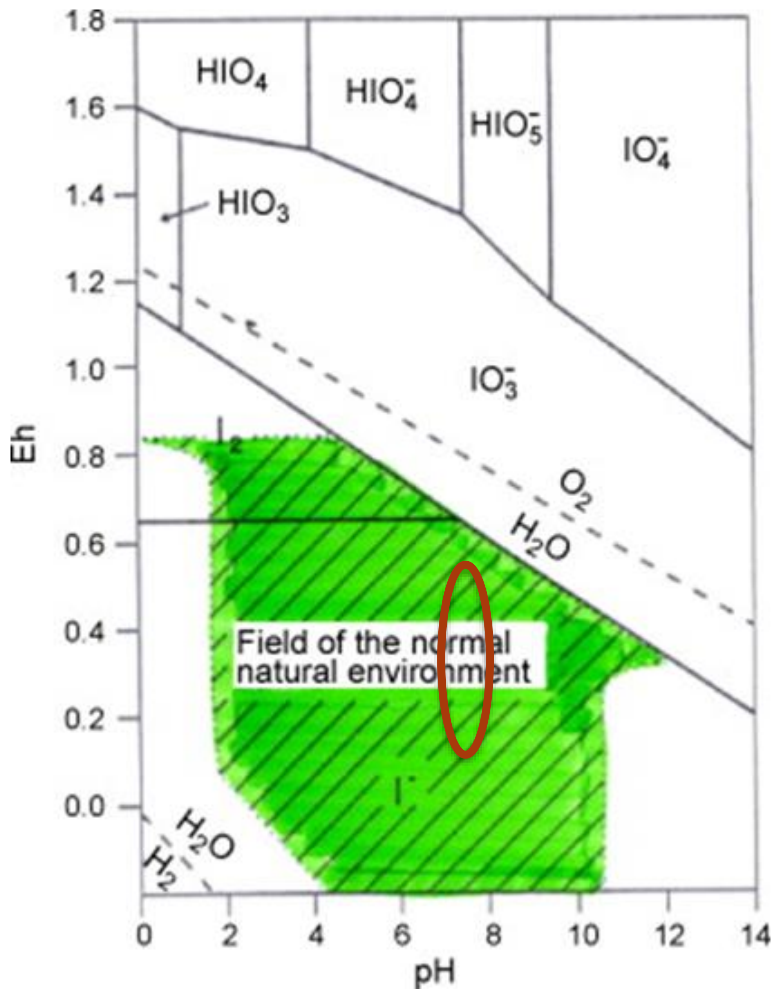
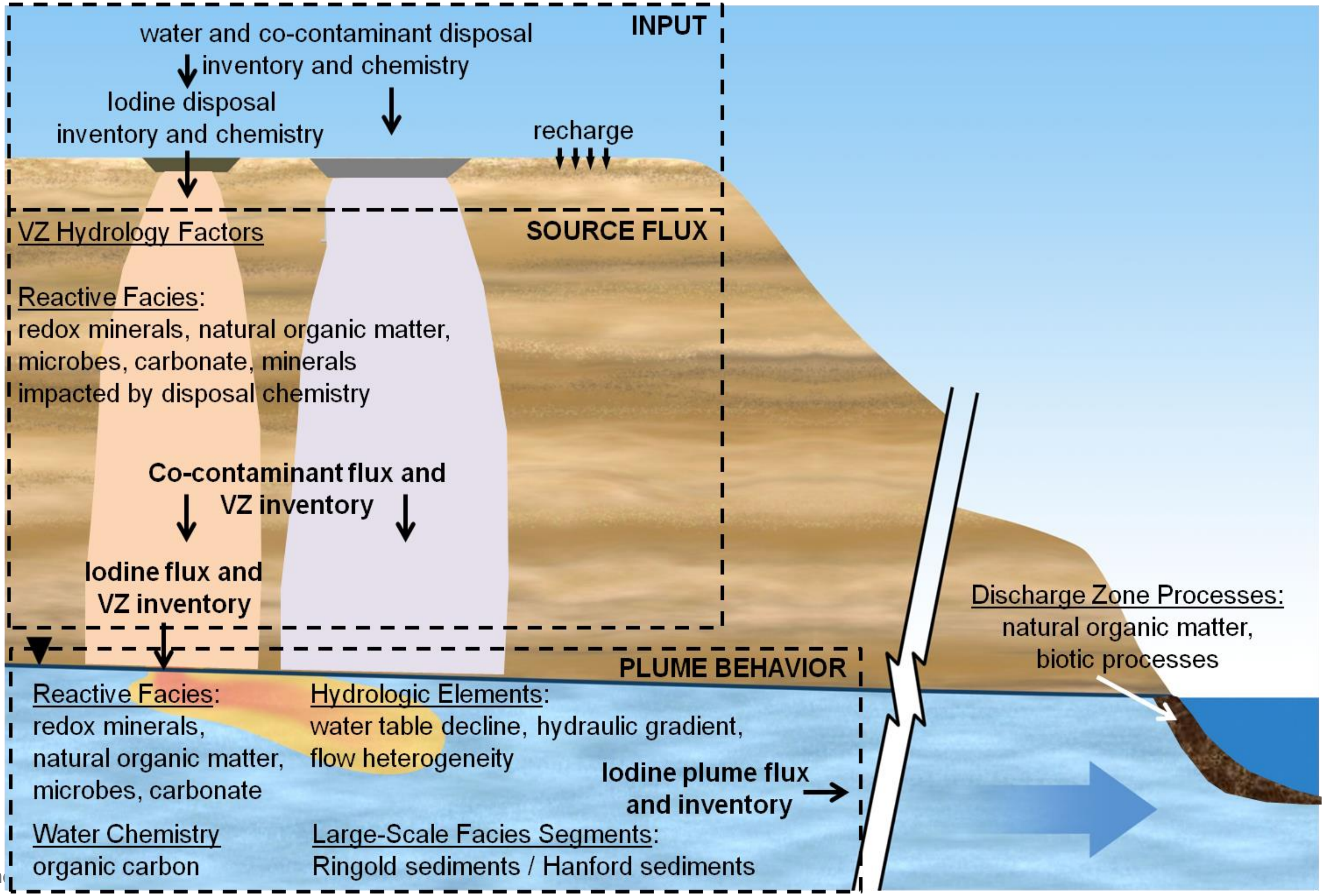
- Speciation at 200 Area:
  - Iodate (IO_3^-) is the prevalent form of iodine, 70.6%
  - Iodide (I^-) , 3.6%
  - Organo-iodine, 25.8%

- ***Speciation is significant because based on chemical thermodynamics, the dominant species should be iodide***



From: Hou et al. 2009

Conceptual Model



Biogeochemical Processes Controlling Fate and Transport of Iodine in Hanford Groundwater

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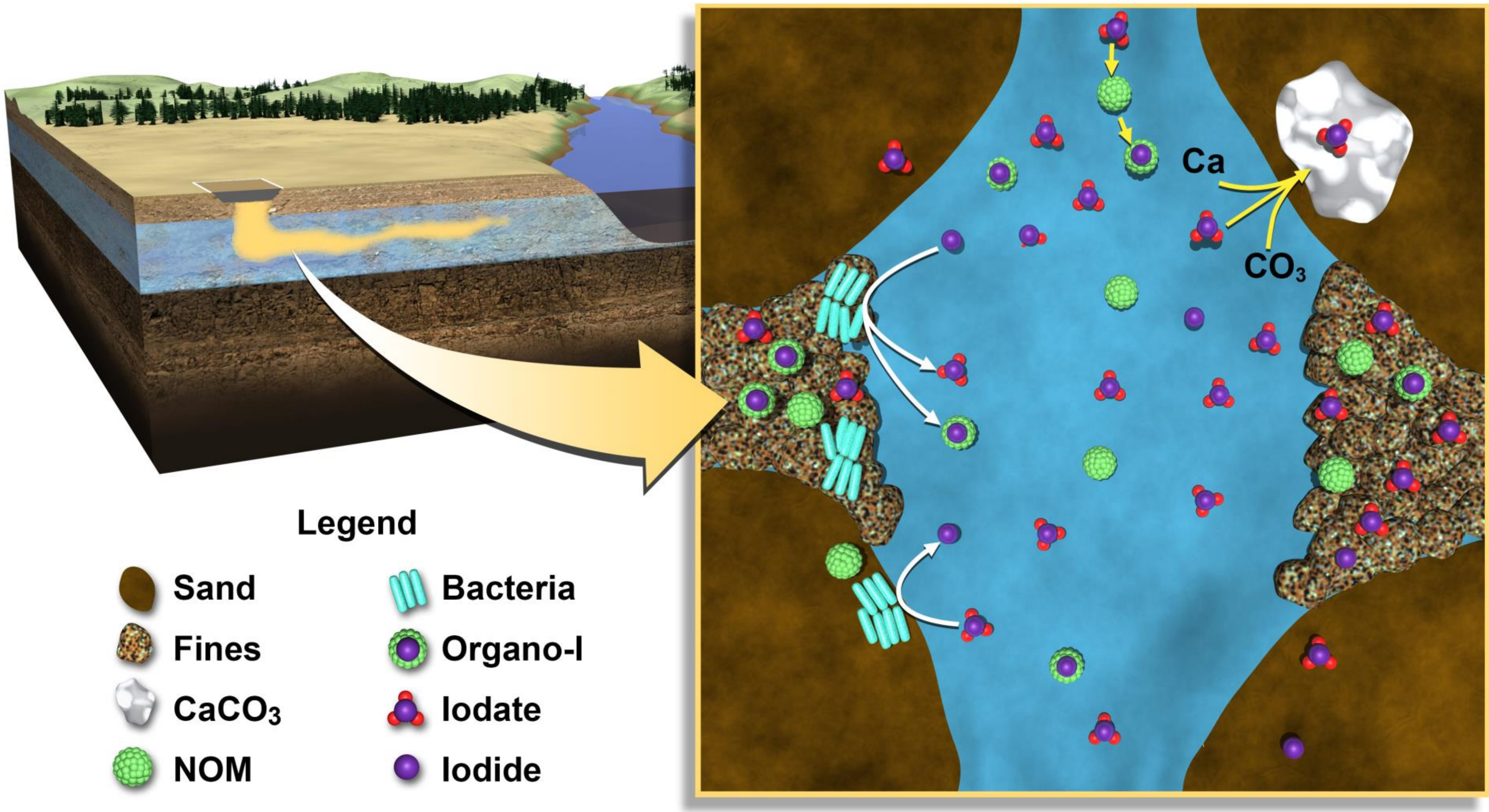

Supporting Data and Research Needs (Addresssing Data Gaps in CM

- Environmental Data
  - Species distribution across plume
  - Organo-iodine compounds
- Evaluation of transformation reactions
  - Biotransformation - Rates
  - Abiotic transformation - Rates
  - Fate of reaction products
  - Effect of co-contaminants
  - Precipitation
- Fate and transport parameters
  - Fate of reaction products
  - Effect of co-contaminants
  - Precipitation
- Effect of vadose zone recharge

Remedy Evaluation Process

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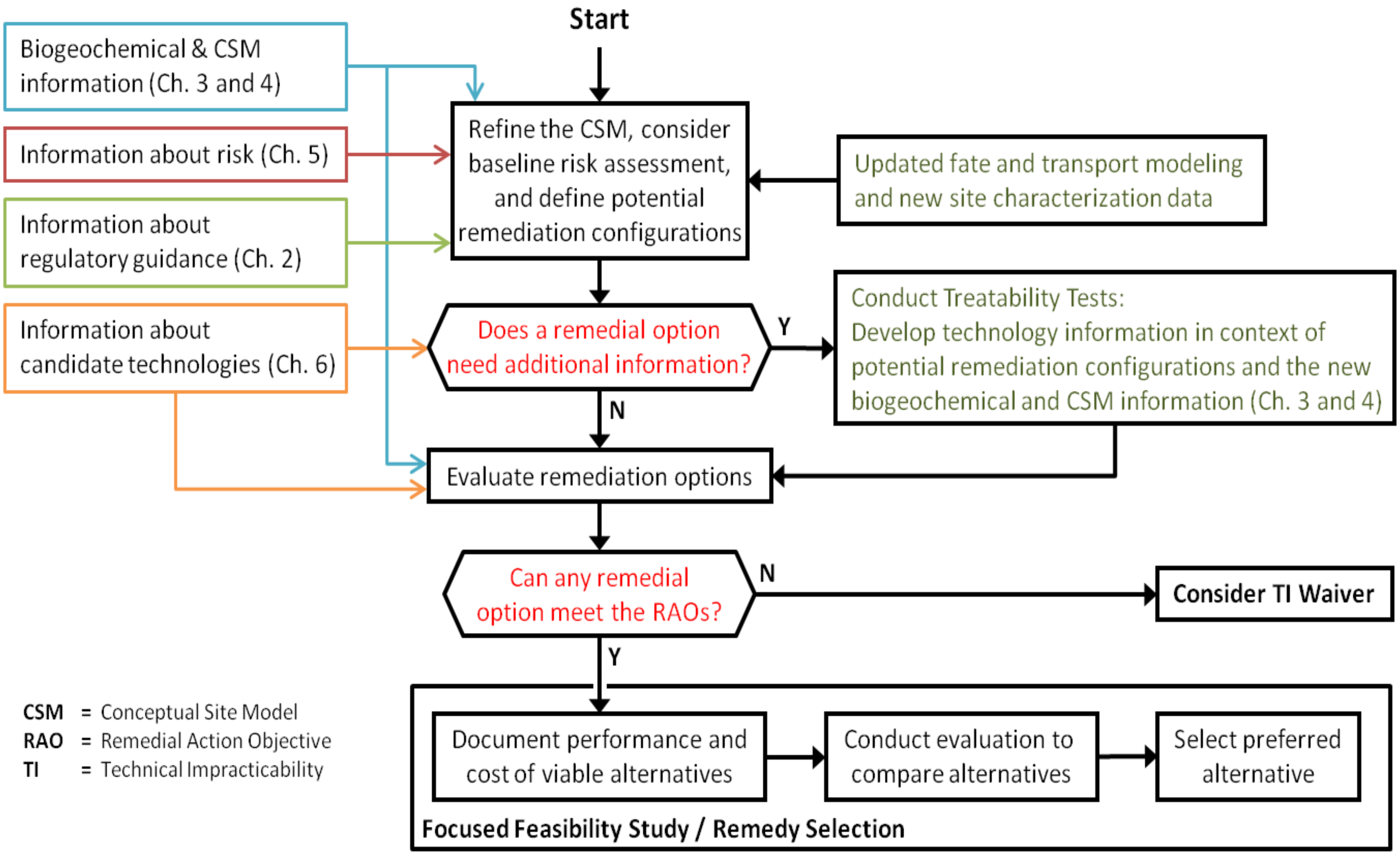

CSM = Conceptual Site Model
RAO = Remedial Action Objective
TI = Technical Impracticability

Acknowledgments

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Thank You for Your Attention

Questions?

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