

Approaches to Integrating Source and Plume Treatment Strategies for Long-Term Dilute Plume Management



Kent S. Sorenson, Jr., PhD,
PE

June 20, 2012

CDM
Smith

Presentation Overview

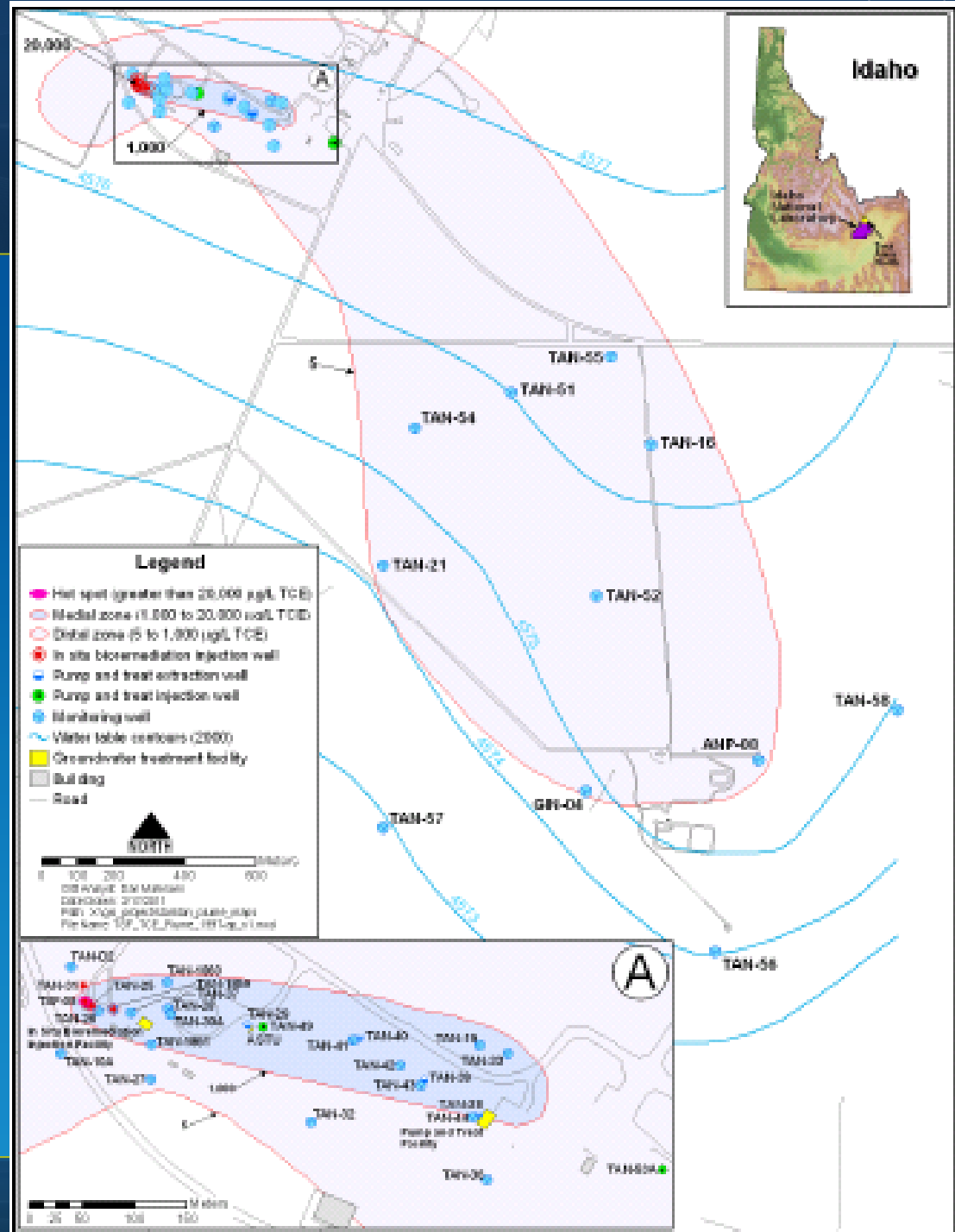
- Background
- Potential degradation mechanisms
- Strategies for technology integration

The background features a light blue gradient with several overlapping white circles of varying sizes. A thin white horizontal line runs across the middle of the image. On the right side, there is a vertical white line that intersects the horizontal line, creating a crosshair effect. The overall aesthetic is clean and modern.

BACKGROUND

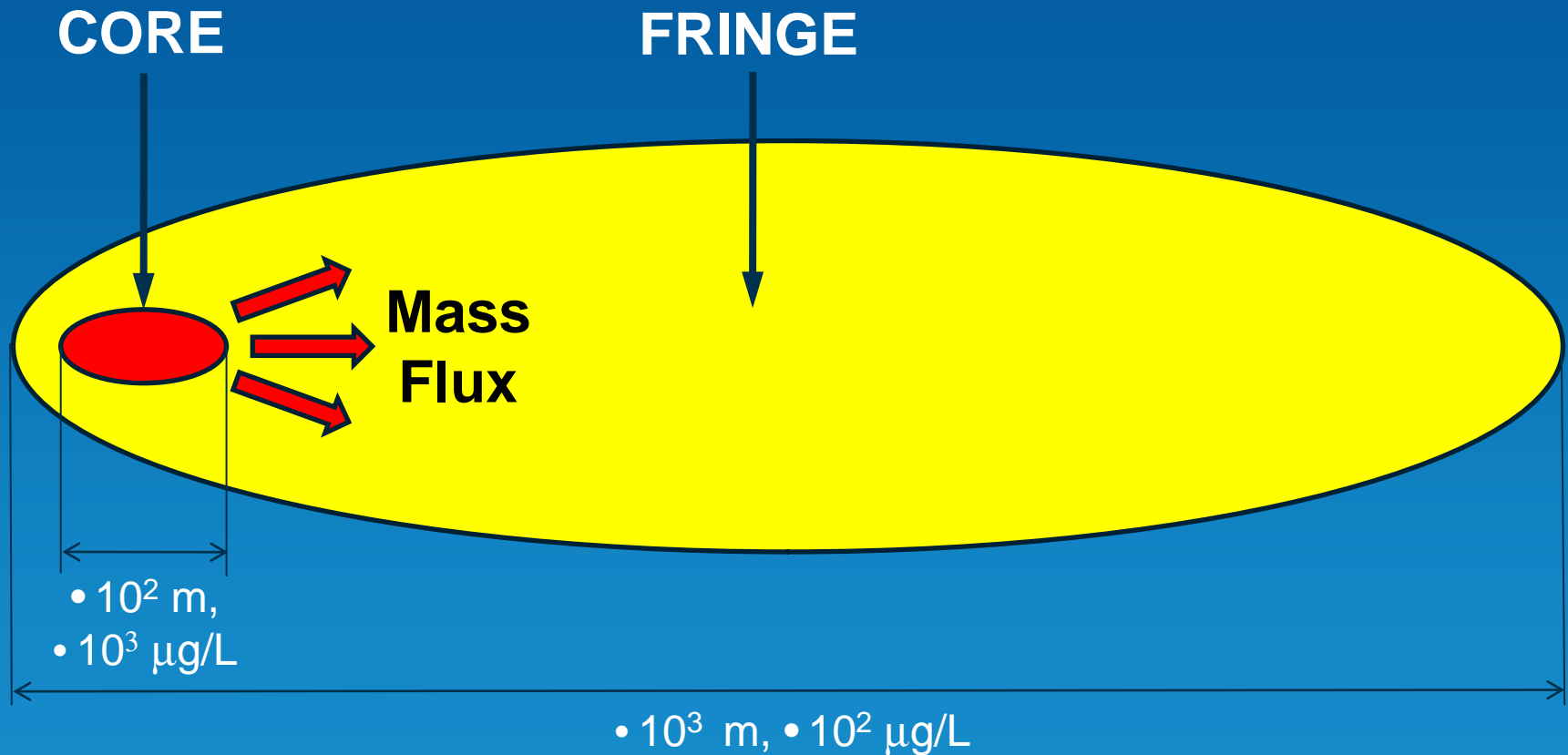
Test Area North

- 1.5-mi TCE plume
- 200 ft to water
- 200-ft contaminated thickness
- Sludge injection well at source
- 1995 ROD
 - Pump and treat
 - 100-year cleanup



Fringe and Core Hypothesis (Cherry, 1996)

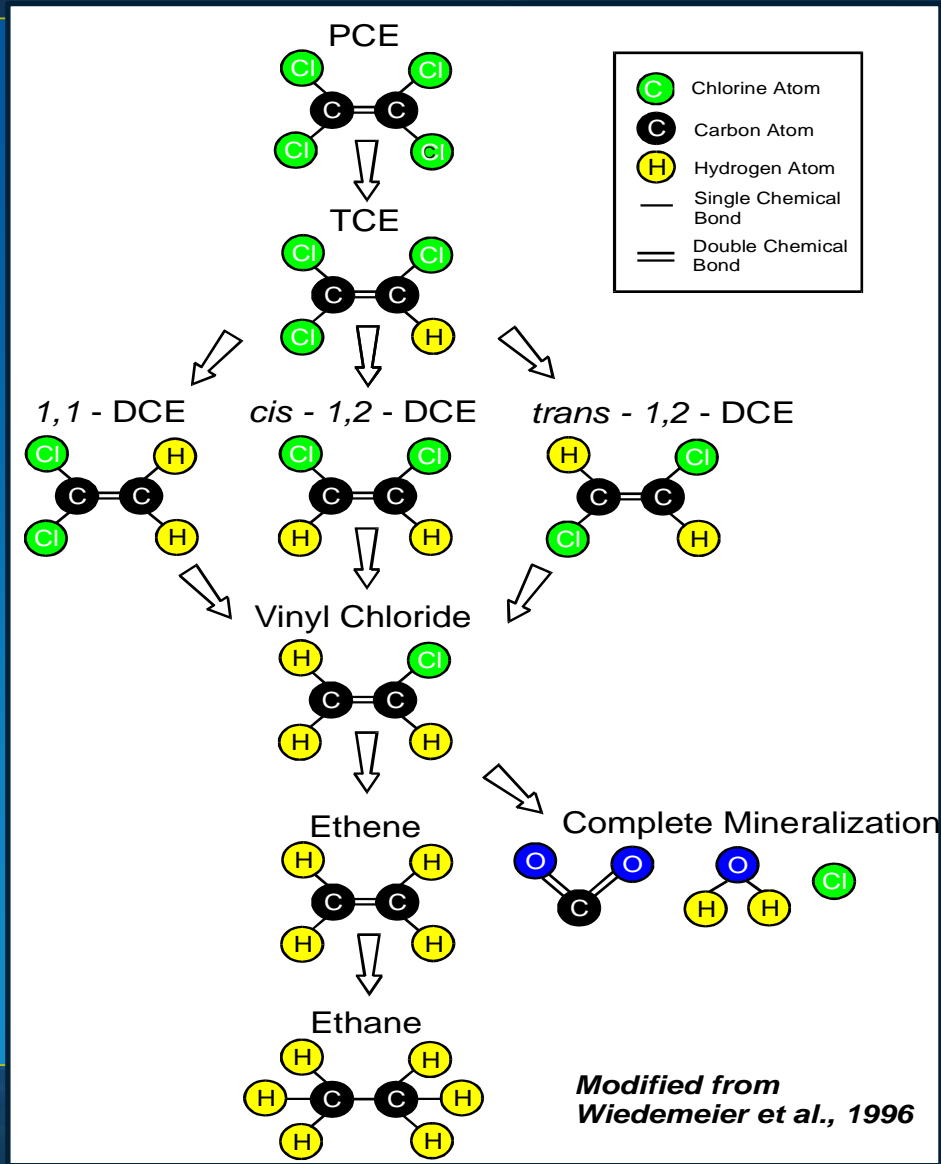
- Generic chlorinated solvent plume conceptual model



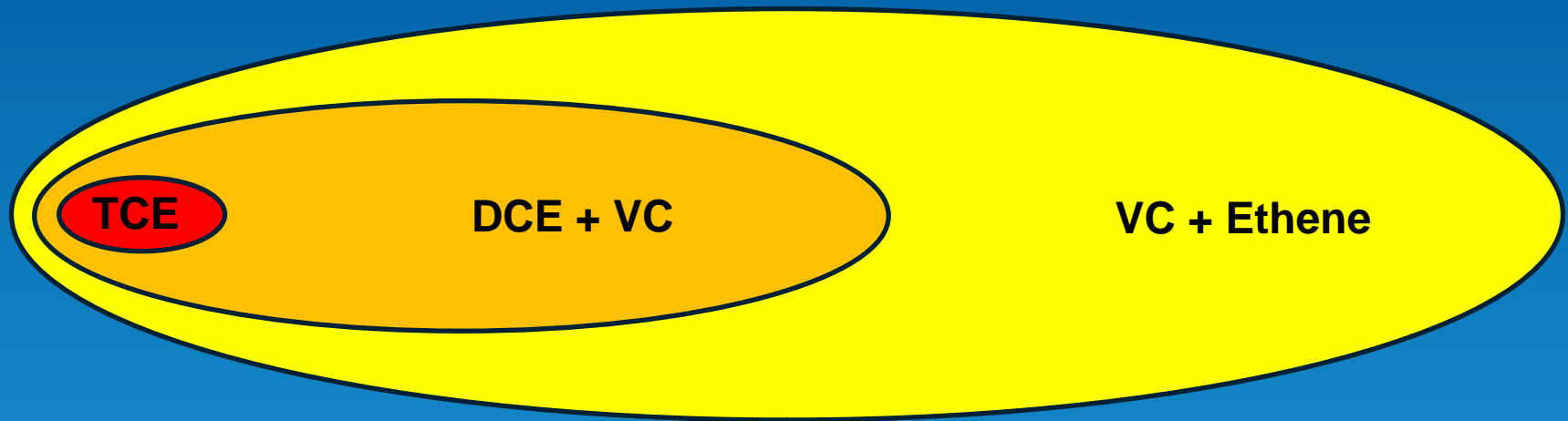
POTENTIAL DEGRADATION MECHANISMS

The background is a solid light blue color. It features several overlapping, semi-transparent circles of varying shades of blue, creating a layered, organic effect. A thin white horizontal line runs across the middle of the image, intersecting the circles. On the right side, there are some white circular outlines and a vertical white line, suggesting a grid or a diagrammatic structure.

Anaerobic Reductive Dechlorination



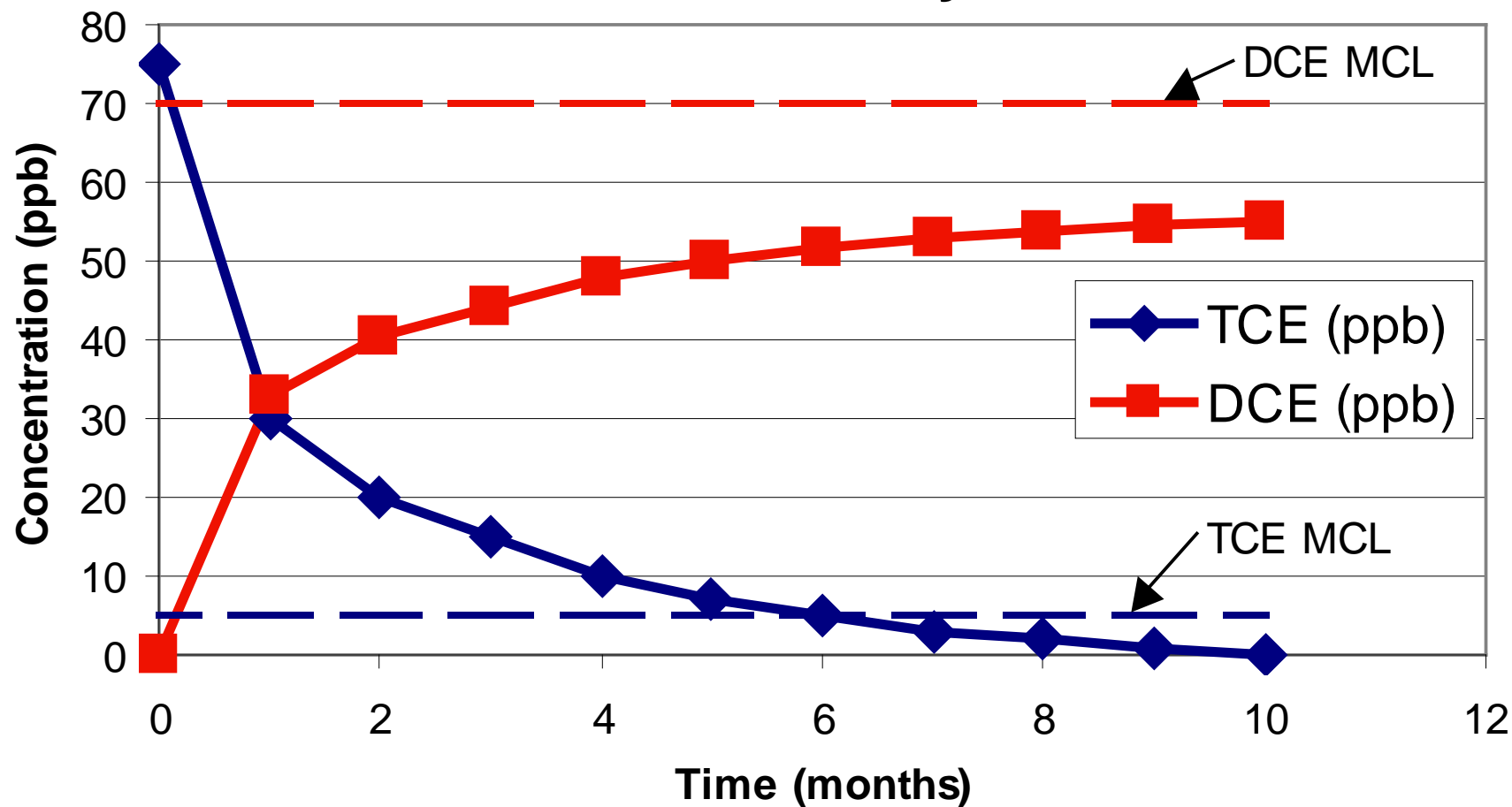
Anaerobic Reductive Dechlorination



Anaerobic Reductive Dechlorination

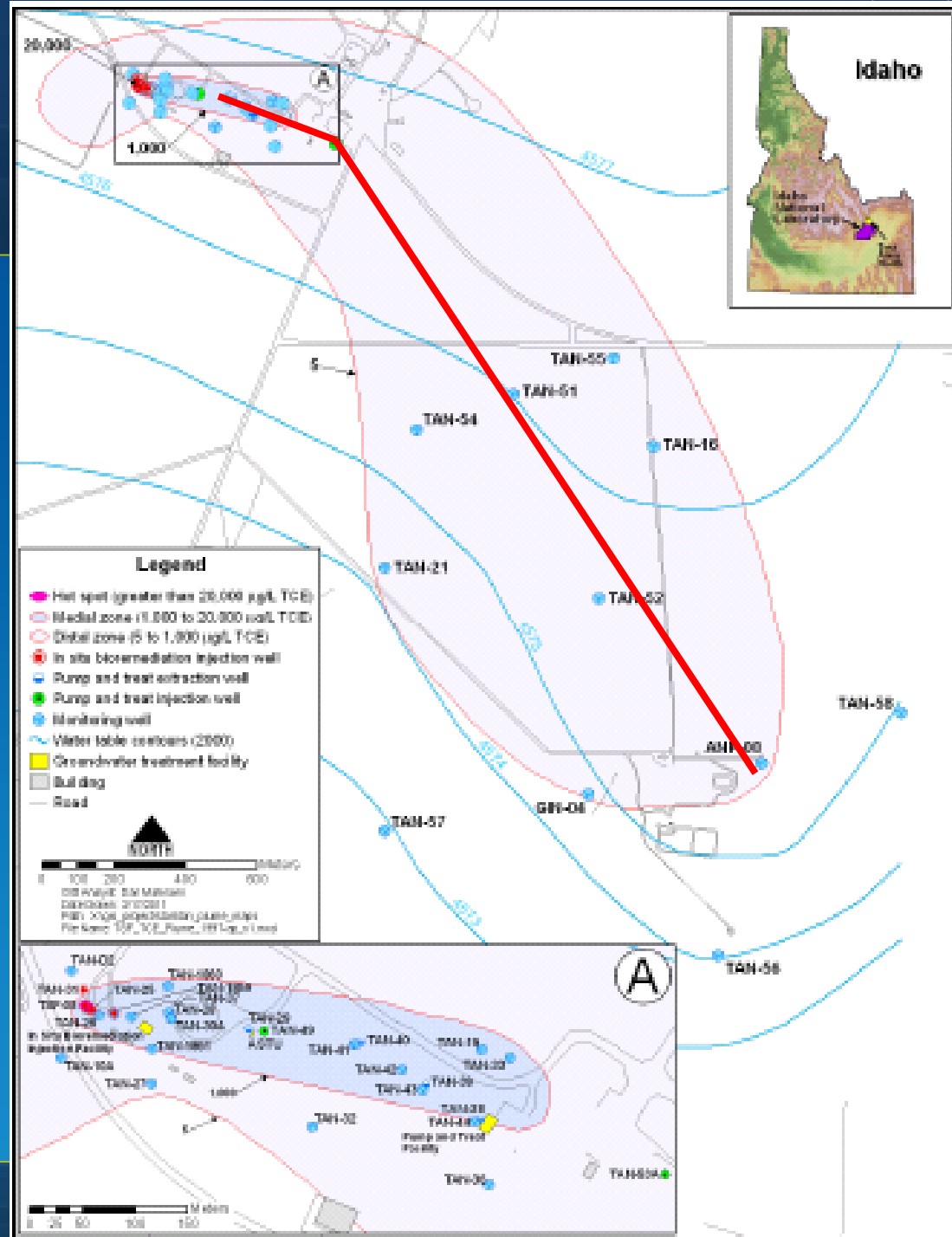
Anaerobic Reductive Dechlorination

DCE Stall Not Always Bad



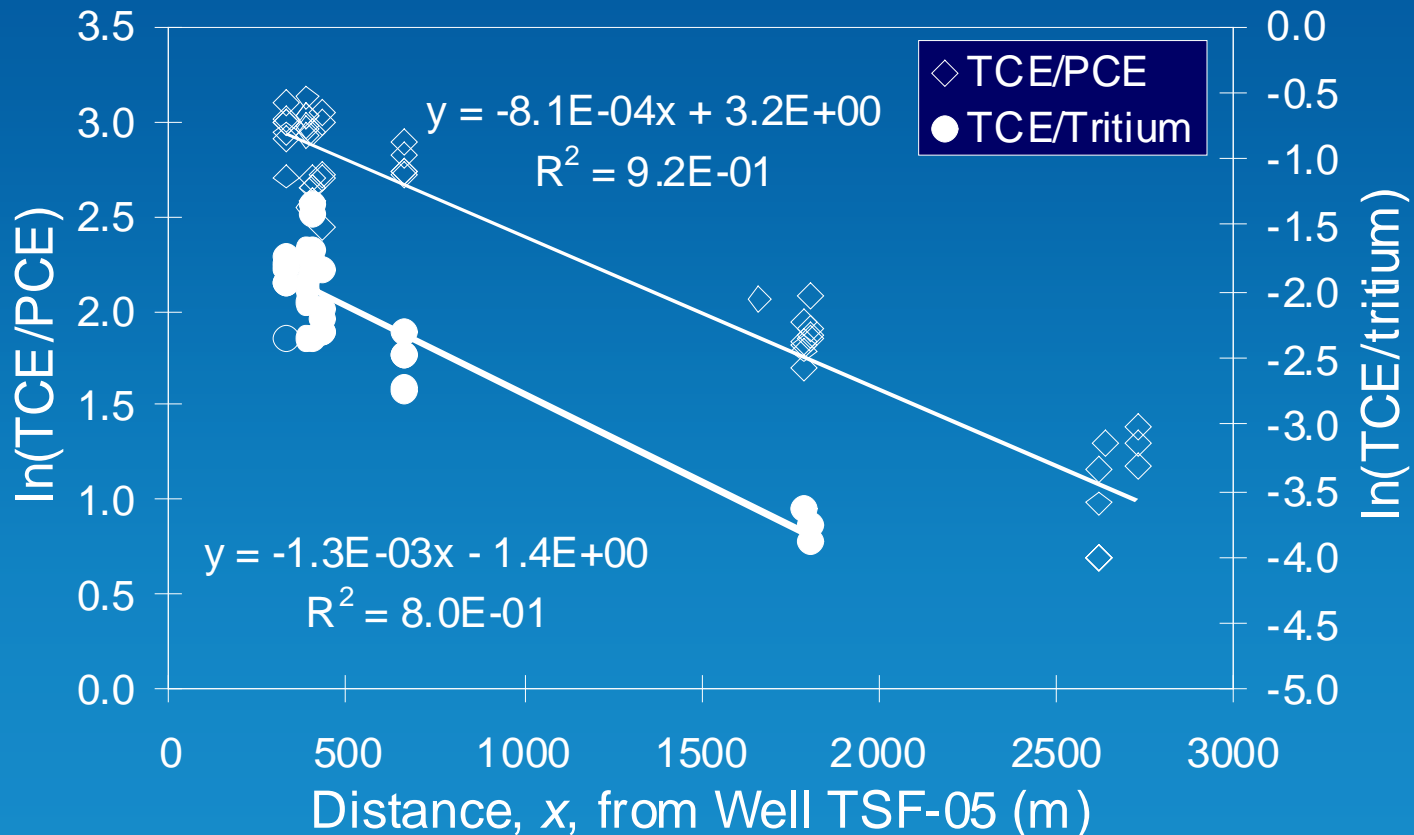
Aerobic Cometabolism

- Axial concentration ratios



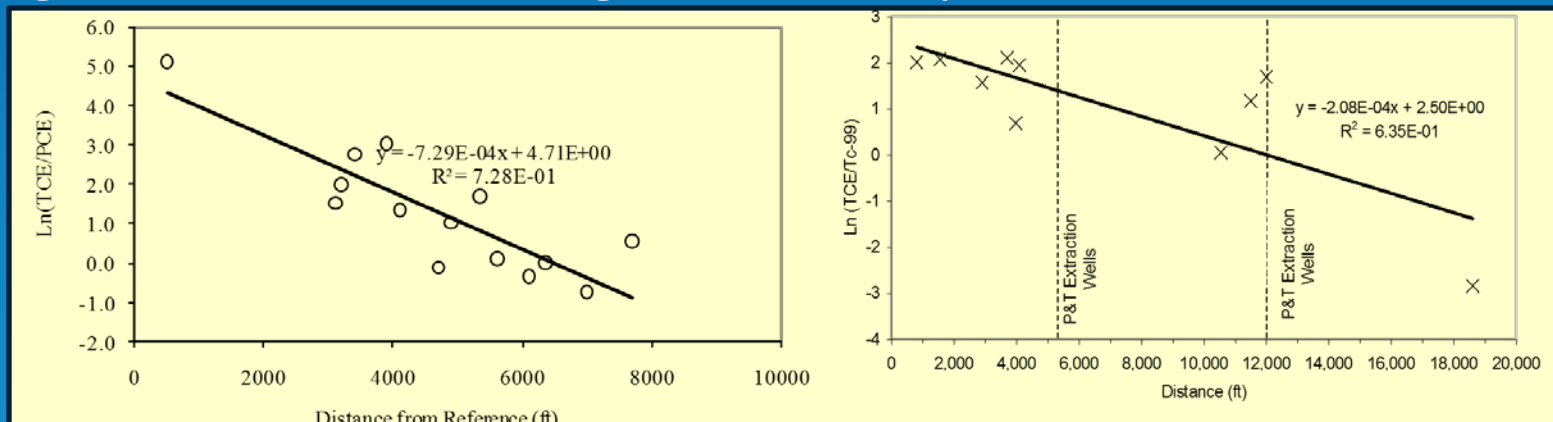
Aerobic Cometabolism

- Aerobic TCE degradation half-life: 12-15 years (^3H)
- Aerobic DCE degradation half-life: 8-9 years (^3H)



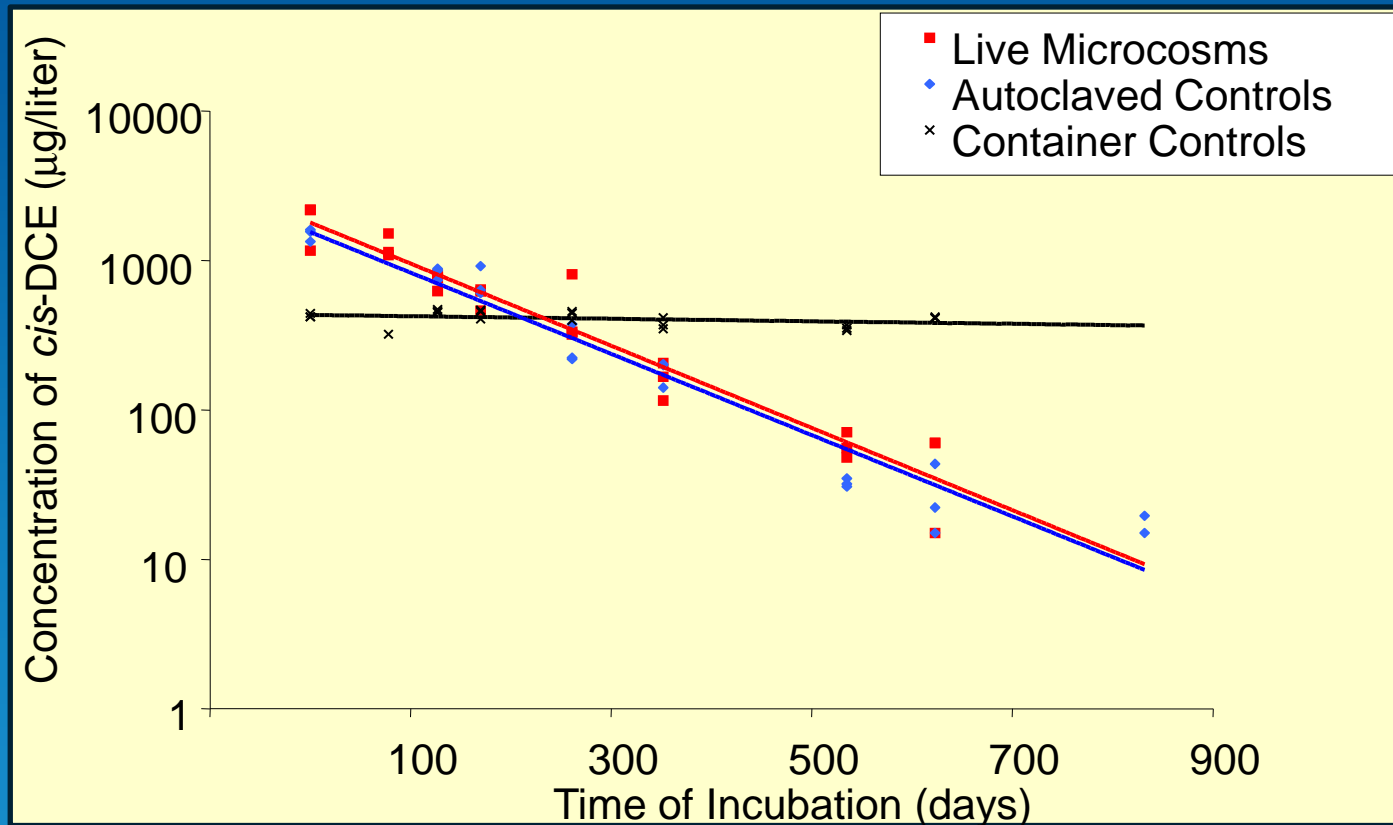
Aerobic Degradation

- 9 plumes evaluated at 4 DOE sites
 - Brookhaven National Laboratory
 - Paducah Gaseous Diffusion Plant
 - Savannah River Site
 - Rocky Flats
- Aerobic TCE degradation rates evident at 8 out of 9
- Degradation half-life range: 0.85 – 12 years




Biogeochemical Reduction by Iron Minerals

- Twin Cities Army Ammunition Plant
- TCE & DCE half-lives < 2.5 years




Biogeochemical Reduction by Iron Minerals

- Resources


 EPA
United States
Environmental Protection
Agency

EPA 600/R-09/115 | December 2009 | www.epa.gov/ada

Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water

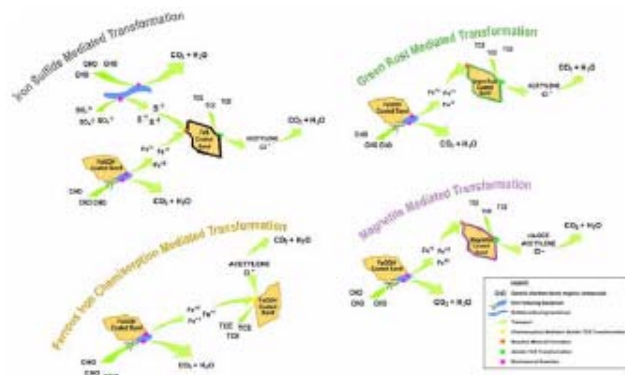


Office of Research and Development
National Risk Management Research Laboratory, Ada, Oklahoma 74820



Workshop on *In Situ* Biogeochemical Transformation of Chlorinated Solvents

February 2008



Legend:

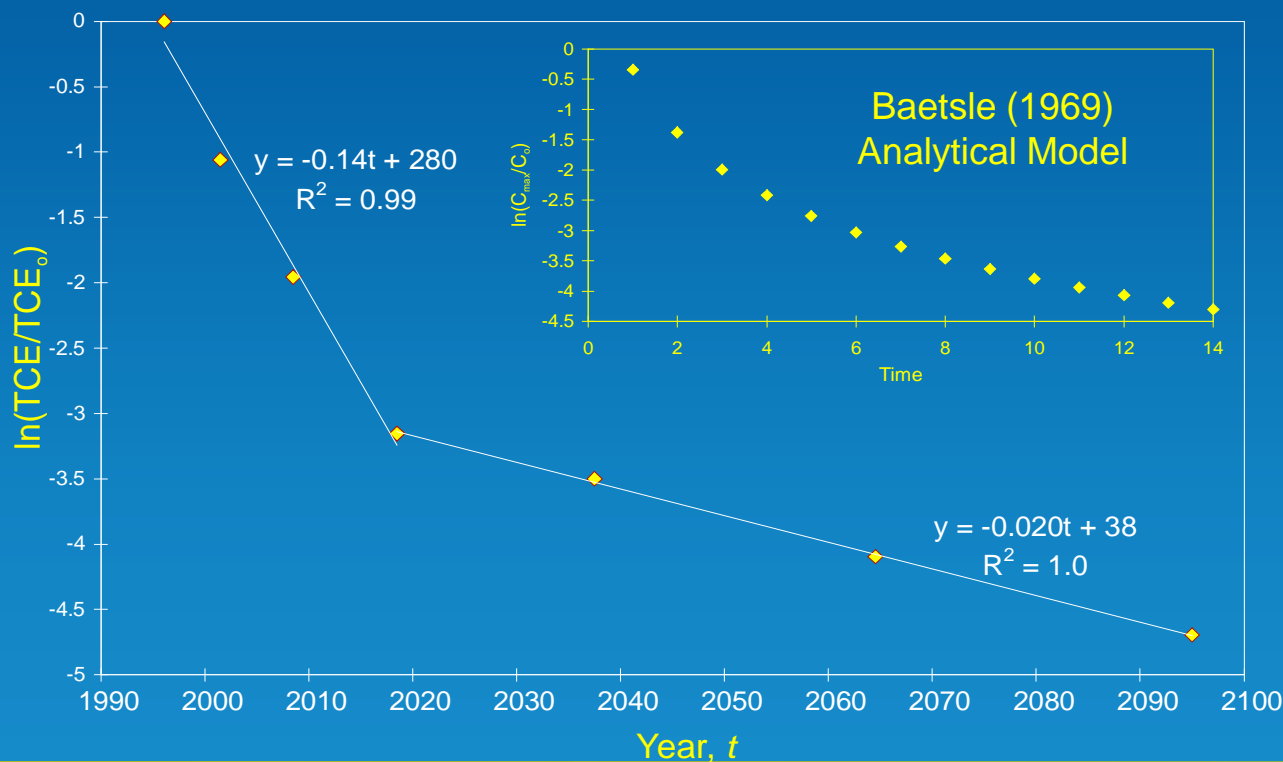
- Iron Minerals
- Organic Matter
- Iron(II) Species
- Iron(III) Species
- Iron(IV) Species
- Iron(V) Species
- Iron(VI) Species
- Iron(VII) Species
- Iron(VIII) Species
- Iron(IX) Species
- Iron(X) Species
- Iron(XI) Species
- Iron(XII) Species
- Iron(XIII) Species
- Iron(XIV) Species
- Iron(XV) Species
- Iron(XVI) Species
- Iron(XVII) Species
- Iron(XVIII) Species
- Iron(XIX) Species
- Iron(XX) Species

The background is a solid light blue color with several overlapping, semi-transparent circles of varying shades of blue. A thin white horizontal line runs across the middle of the image. On the right side, there is a vertical white line that intersects the horizontal line, creating a crosshair effect. The text is centered horizontally and positioned below the white line.

STRATEGIES FOR TECHNOLOGY INTEGRATION

Prerequisites

- Identification of intrinsic degradation mechanism
- Estimate of intrinsic degradation rate (separate from dispersion)
- Reasonable assurance of longevity of mechanism

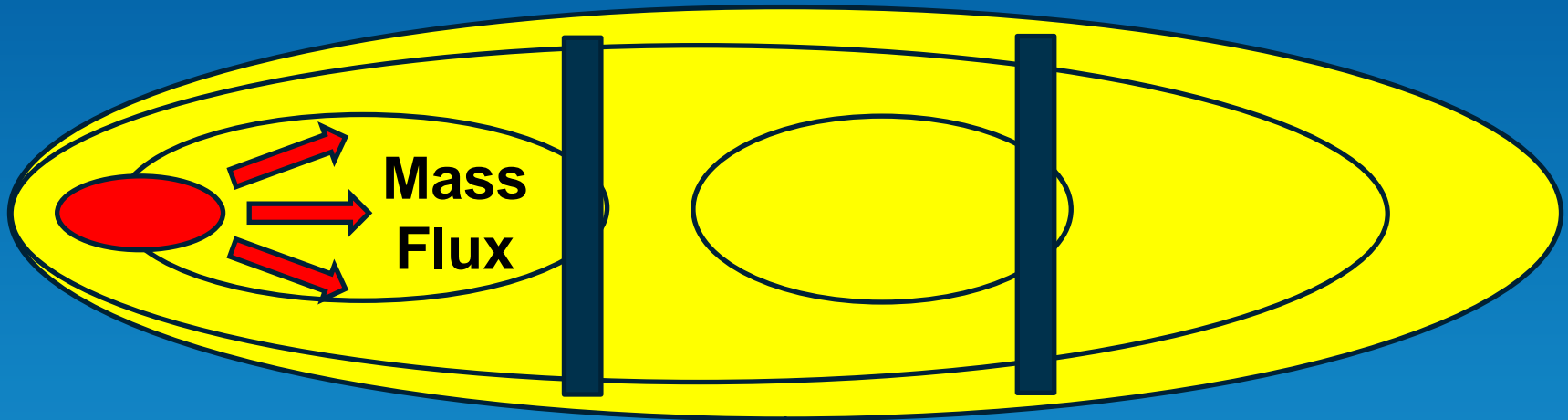


Fringe Types

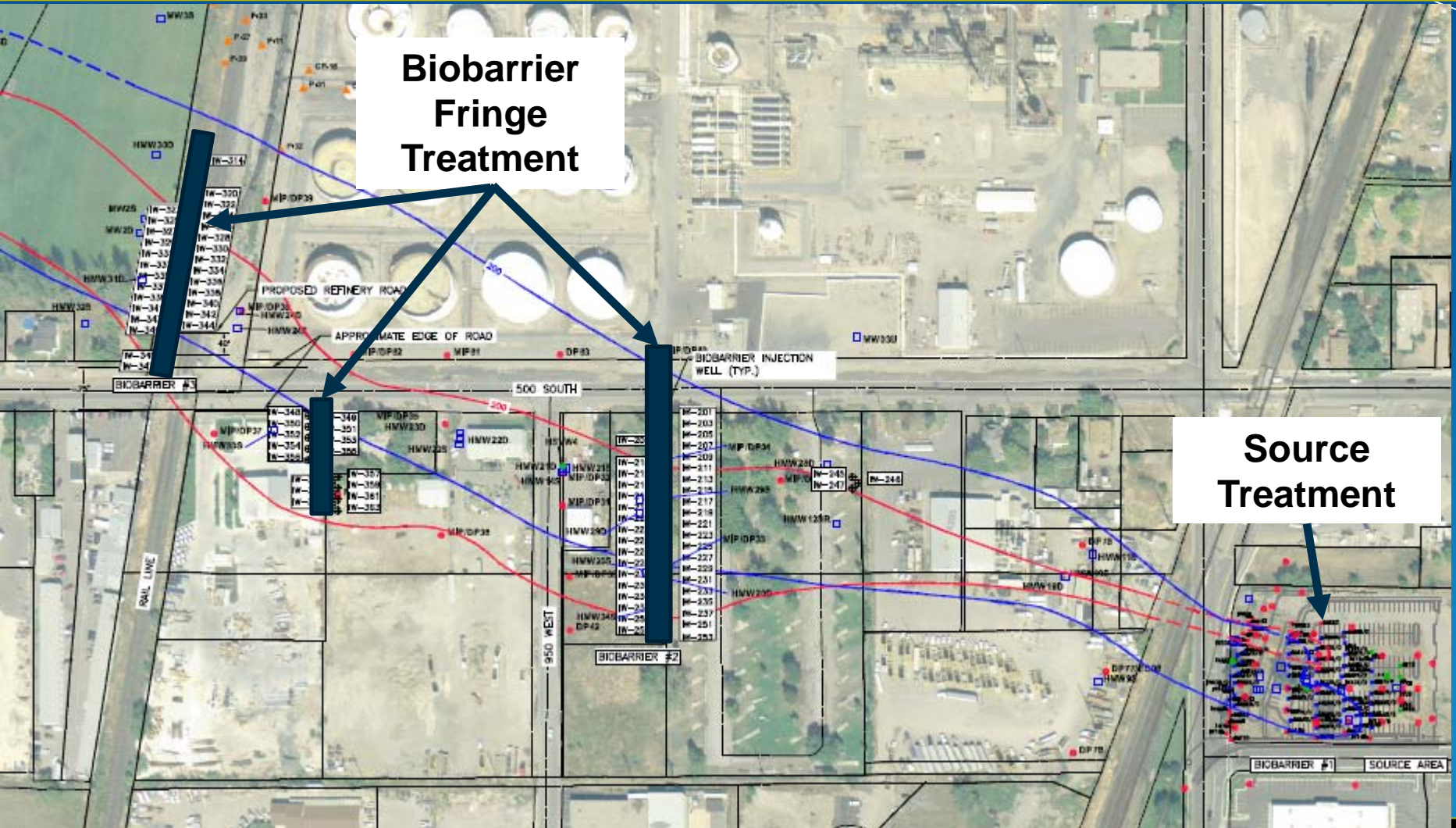
- Active Treatment Fringe (ATF)
 - Fringe Concentration $>$ MNA capacity
 - Bountiful
- Intrinsic Treatment Fringe (ITF)
 - Fringe Concentration \leq MNA capacity
 - TAN
 - Well 12A

Active Treatment Fringe

- Source removed/contained
- Active treatment required in fringe to meet cleanup goals



Bountiful/Woods Cross Superfund Site



Biobarrier Fringe Treatment

Source Treatment

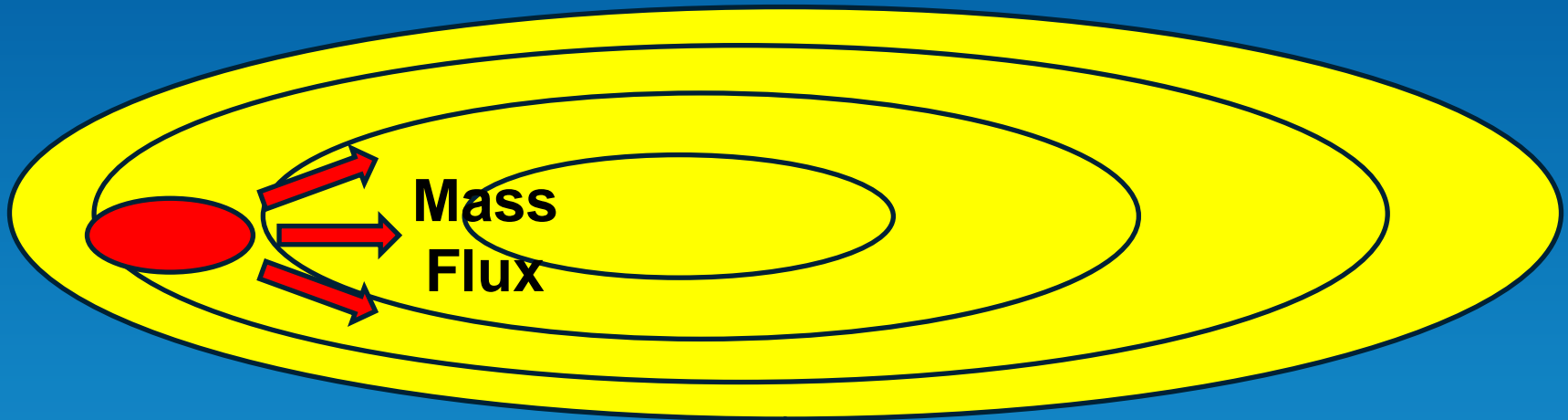
Bountiful (cont.)

- Source flux stopped, downgradient biobarriers installed



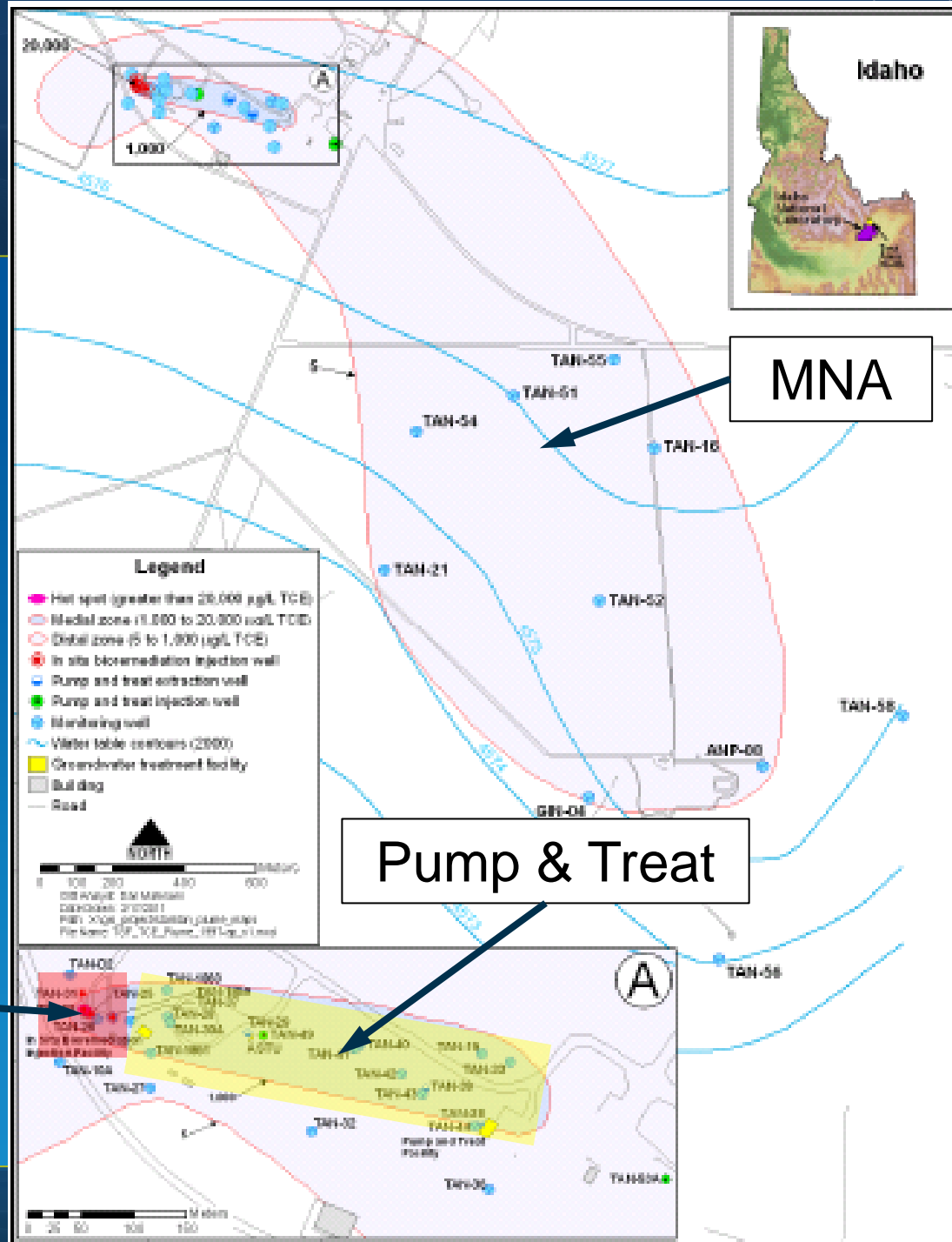
Intrinsic Treatment Fringe

- Source removed/contained
- Intrinsic degradation in fringe sufficient to meet cleanup goals



Test Area North, OU 1-07B

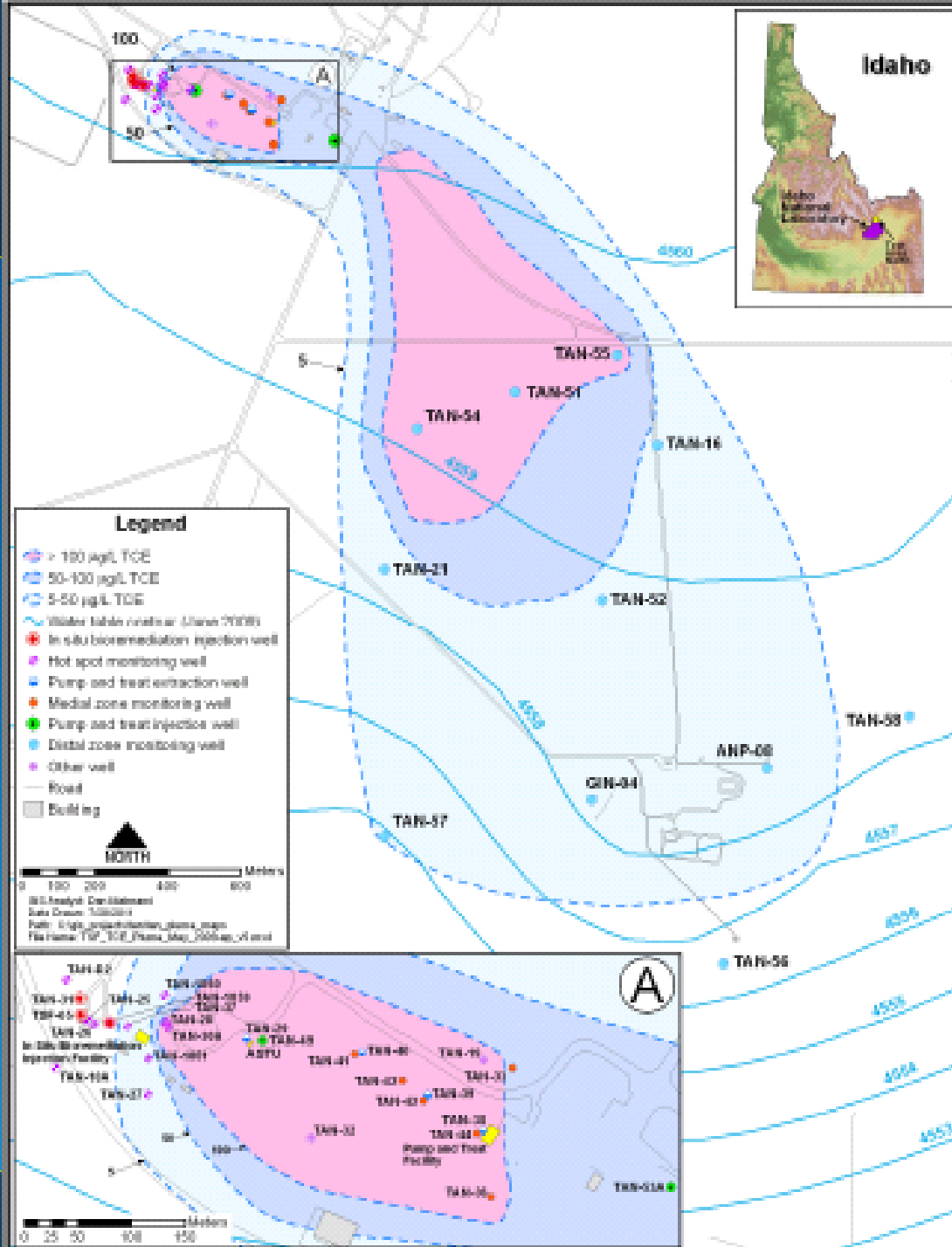
- 1997 TCE Distribution



Bioremediation

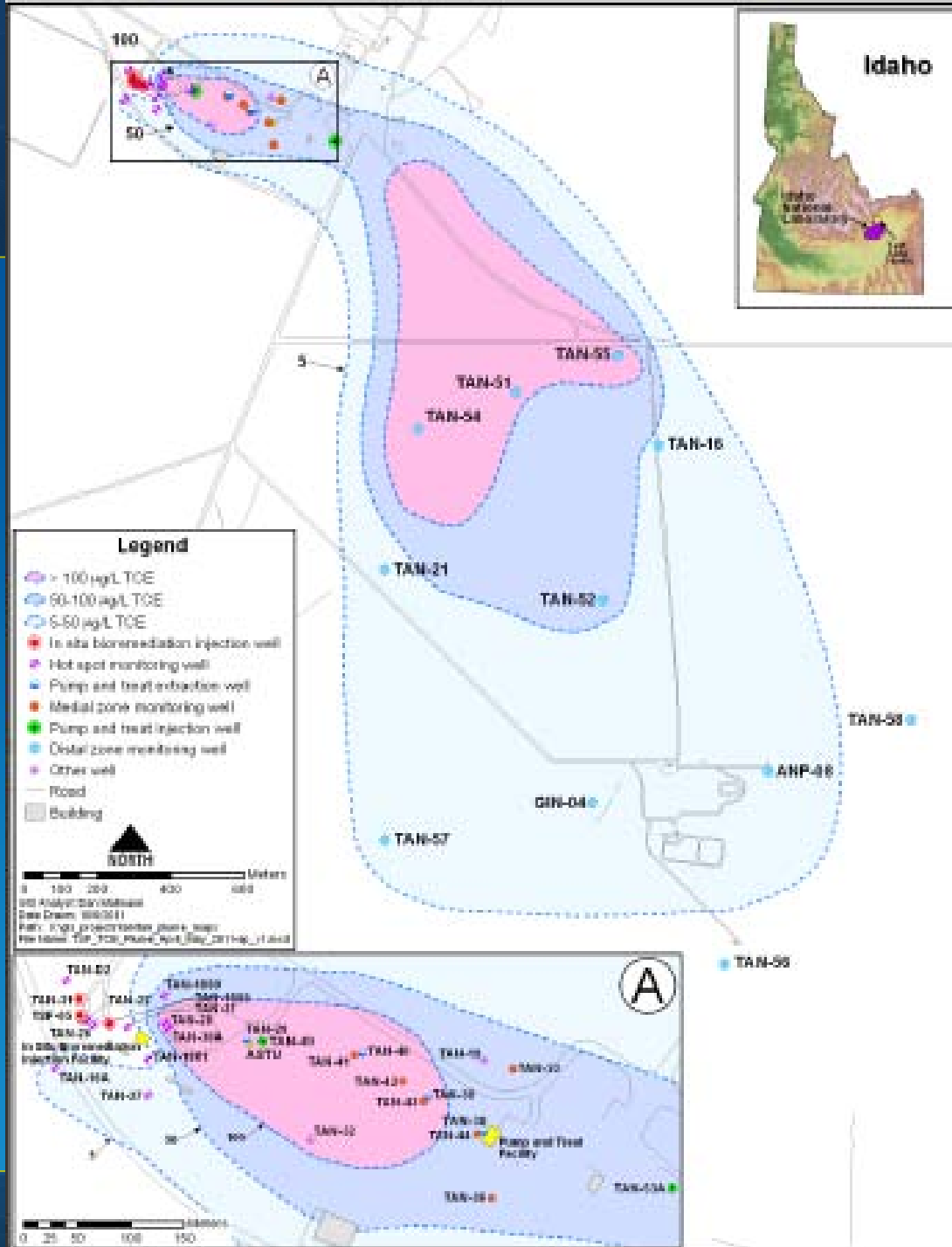
Test Area North, OU 1-07B

- 2009 TCE Distribution



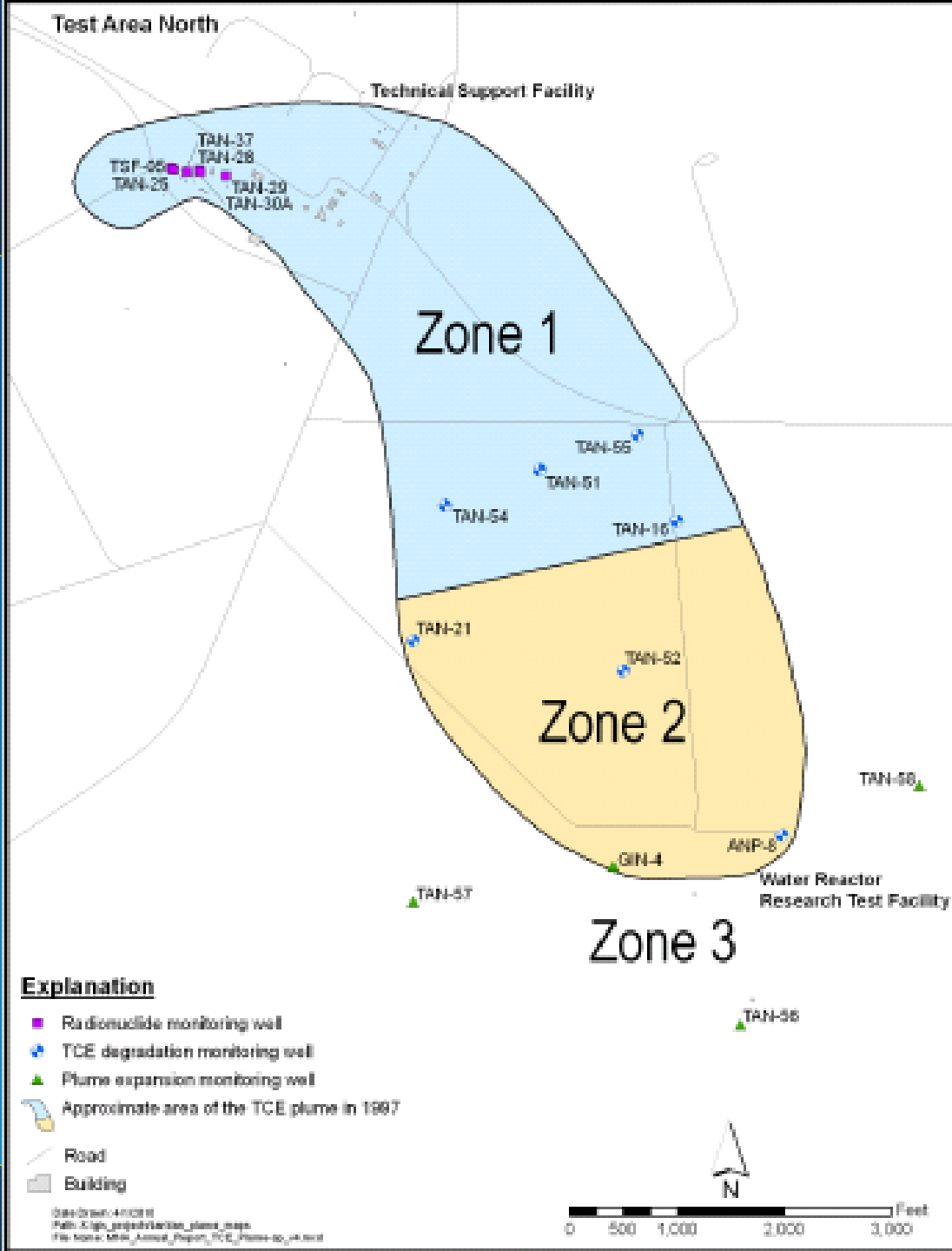
Test Area North, OU 1-07B

- 2011 TCE Distribution



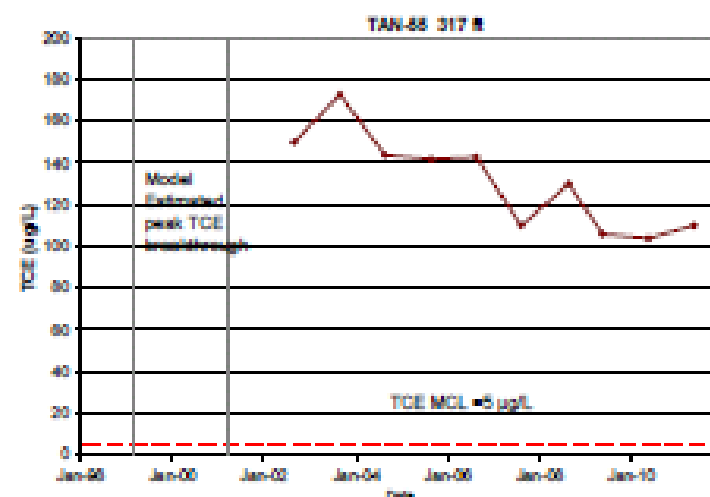
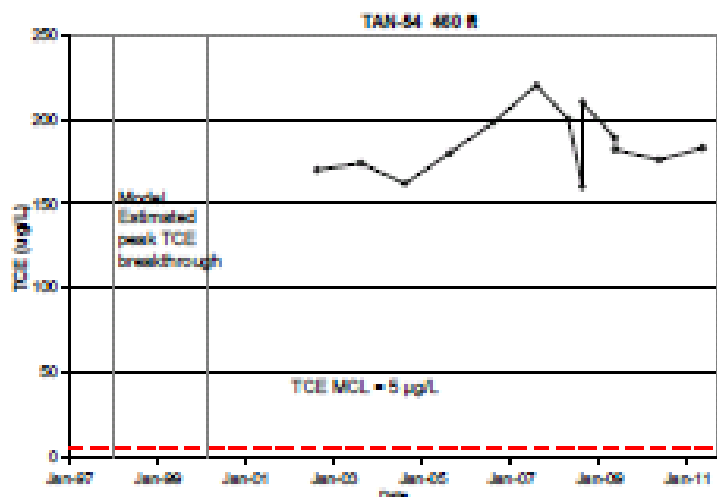
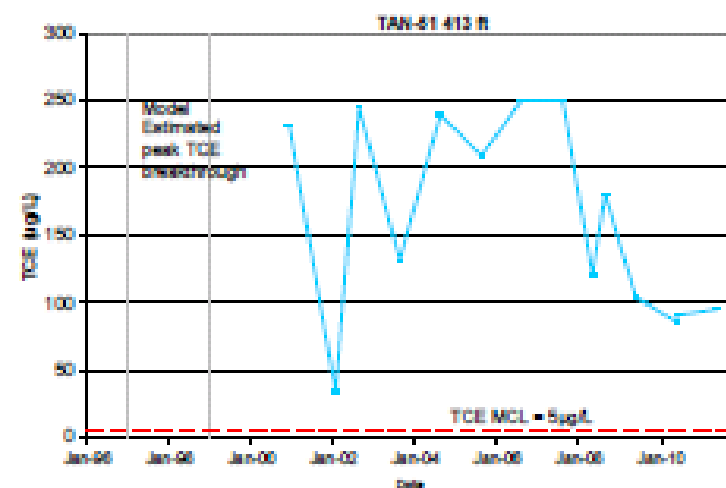
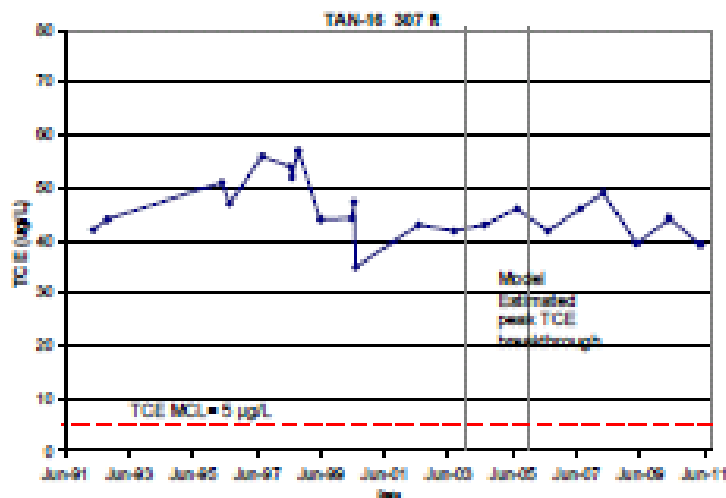
Test Area North, OU 1-07B

- MNA performance monitoring



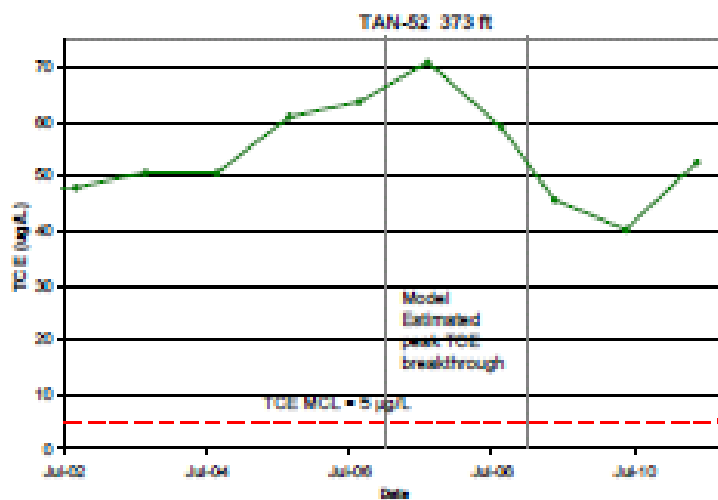
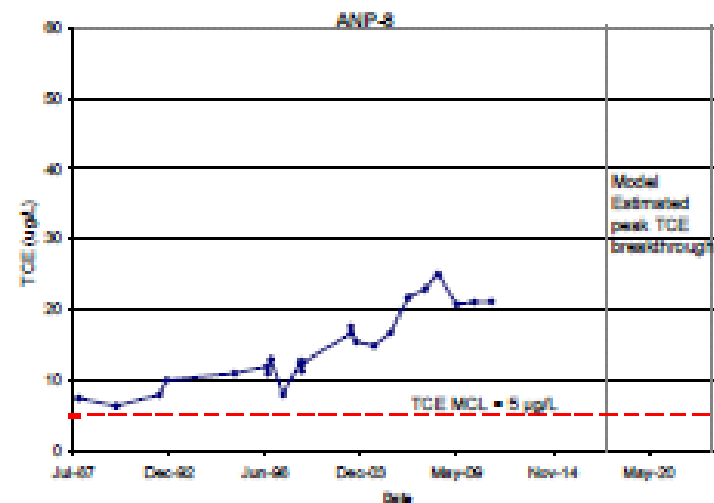
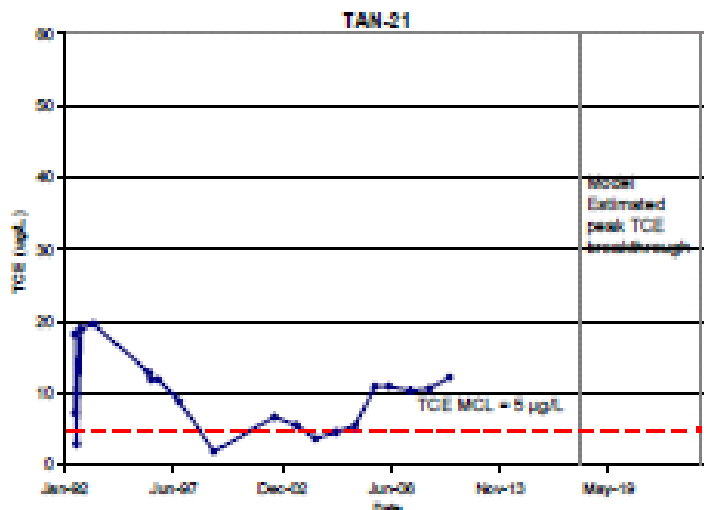
Test Area North, OU 1-07B

- Zone 1



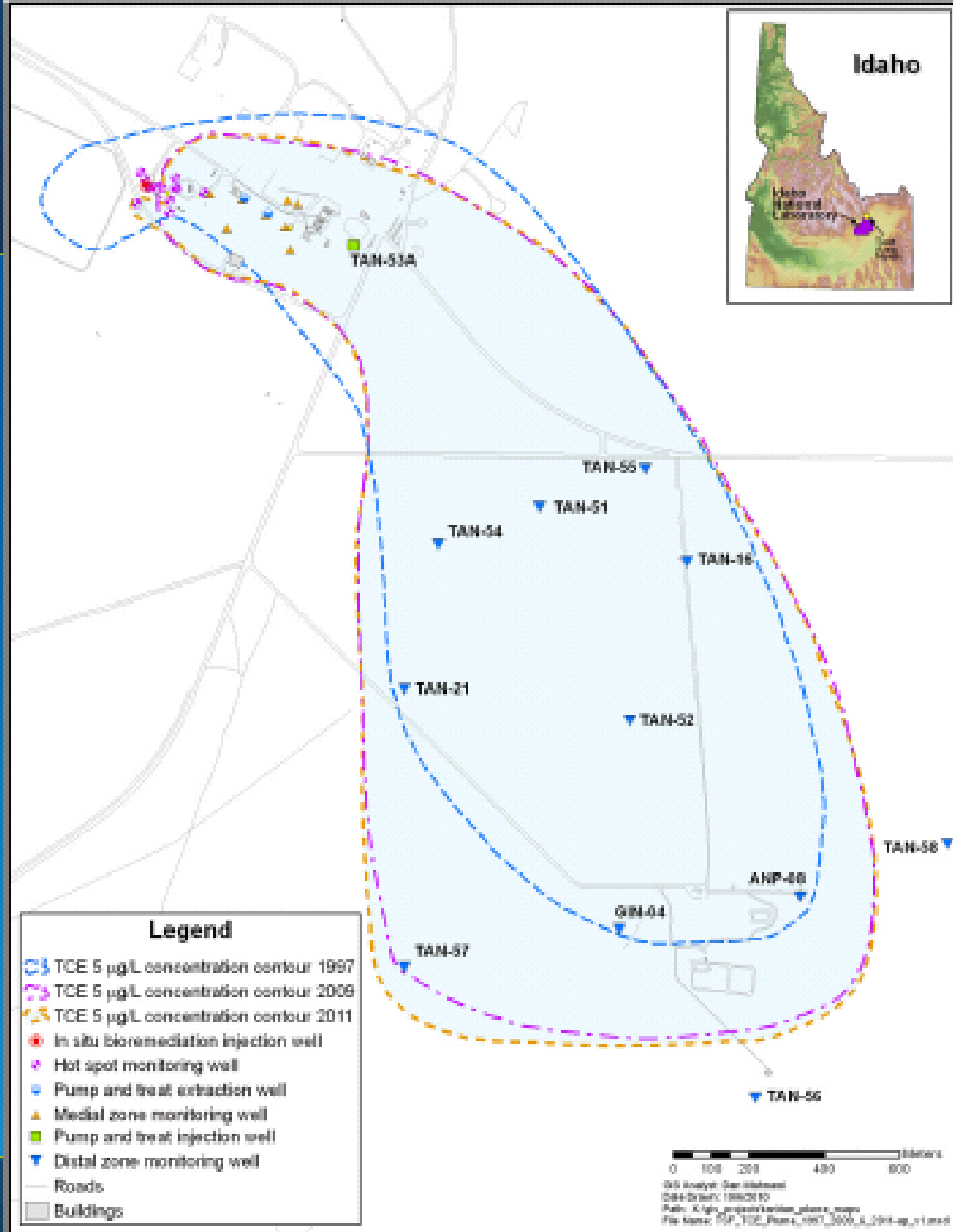
Test Area North, OU 1-07B

- Zone 2



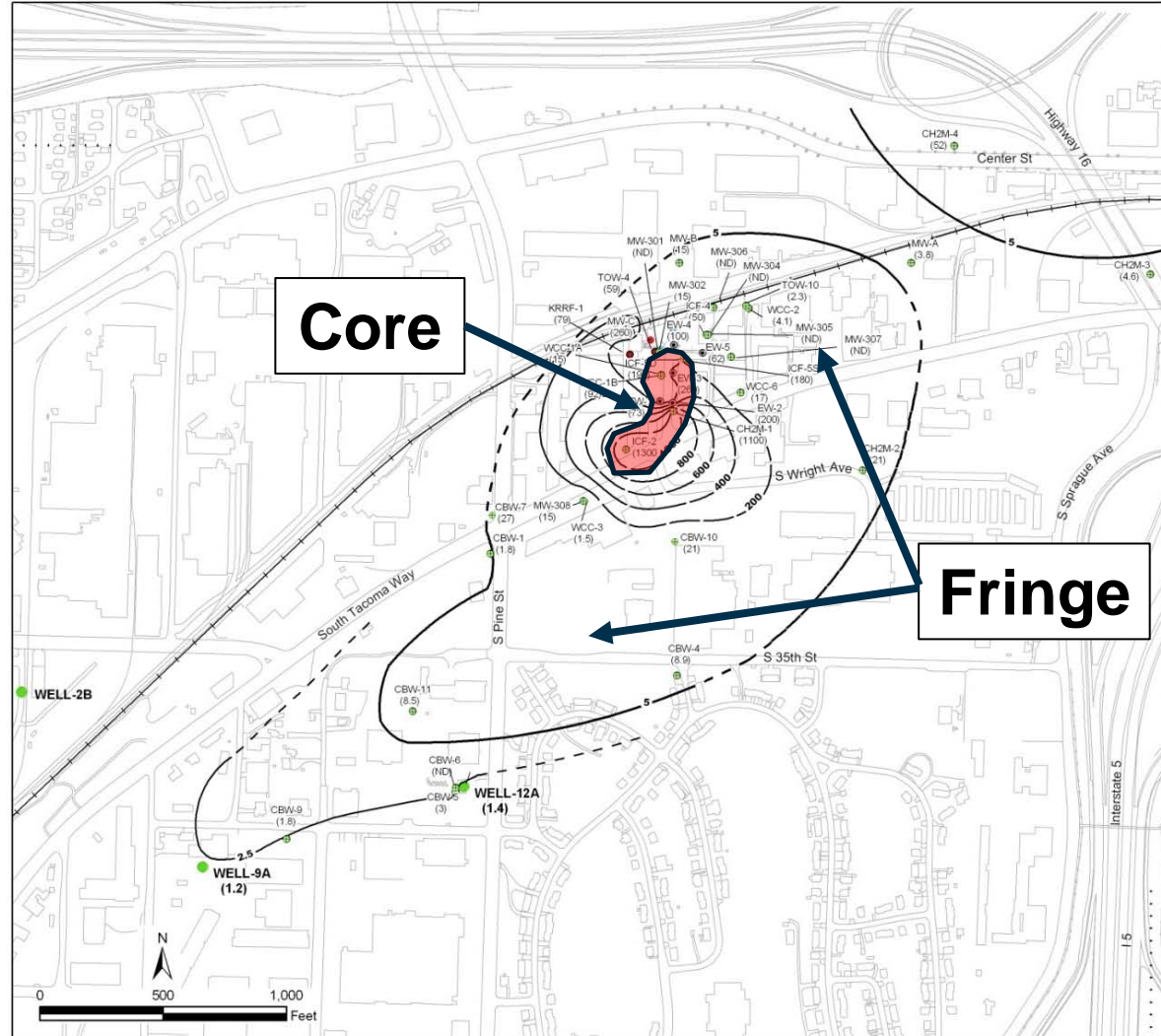
Test Area North, OU 1-07B

- Zone 3
 - Up to 30% temporary plume expansion allowed
 - Actual expansion 8.5% to 15%
 - Performance appears right on track!



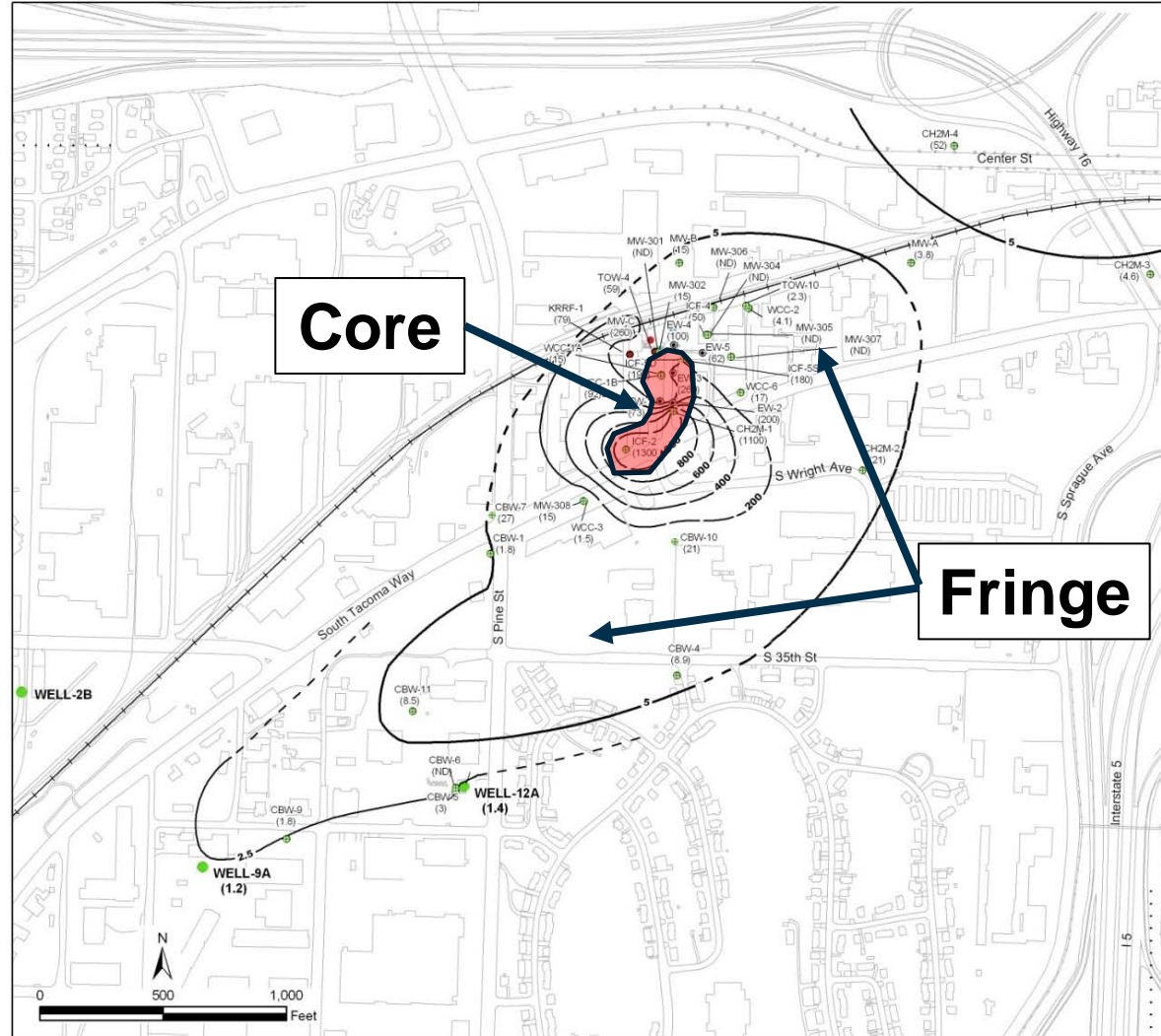
Well 12A Superfund Site

- Tacoma water supply
- Significant residual source material
- Large, dilute plume
- Estimated intrinsic degradation limit: 300 $\mu\text{g/L}$



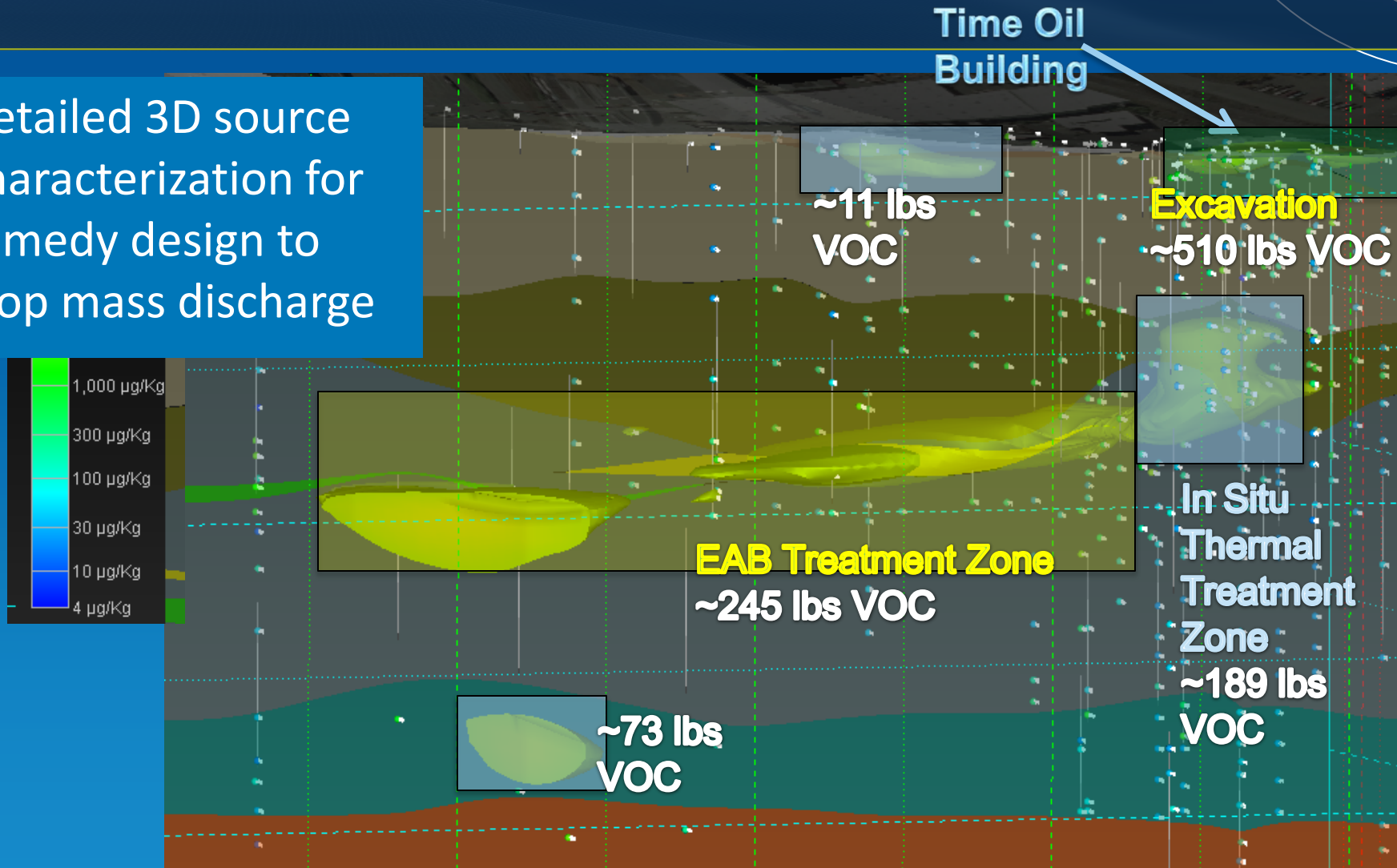
Well 12A Superfund Site

- RAOs:
 - 90% mass discharge reduction from core
 - ARARs at designated points of compliance
 - Determine if MNA can meet ARARs in fringe



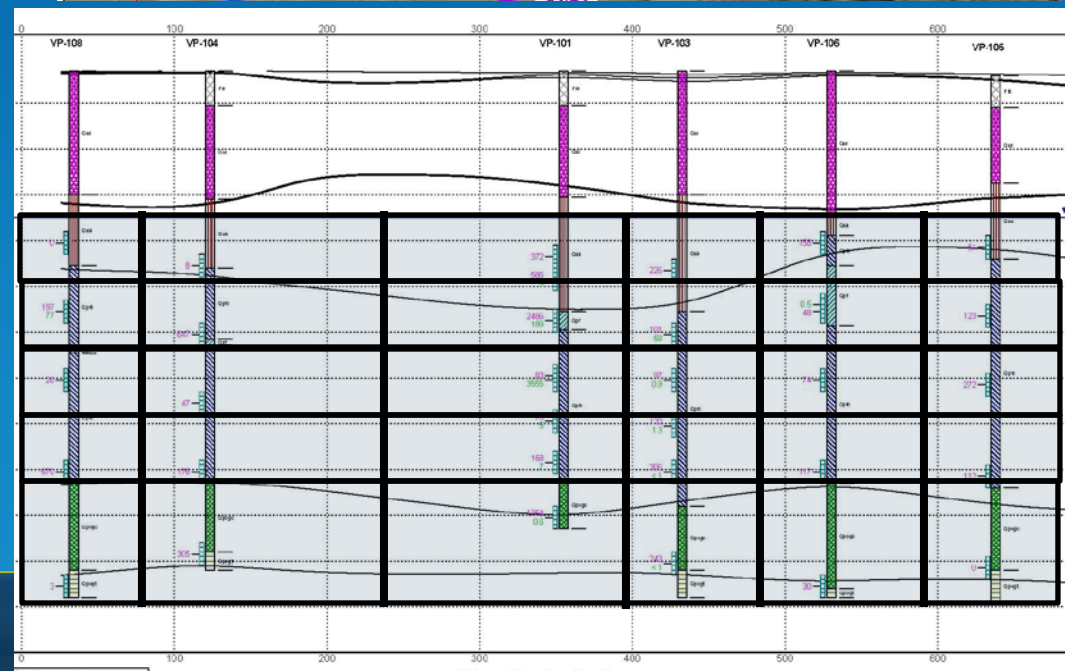
Well 12A Superfund Site

- Detailed 3D source characterization for remedy design to stop mass discharge



Well 12A Superfund Site

- Performance monitoring transects established for source treatment
- MNA evaluation and performance monitoring underway



Acknowledgments

- Kira Lynch (EPA)
- John Wilson (EPA)
- Sam Garcia (EPA)
- Lee Nelson (Idaho National Laboratory)
- Tamzen Macbeth (CDM Smith)
- Nathan Smith (CDM Smith)

References

- Baetsle, L.H. 1969. "Migration of Radionuclides in Porous Media." In: A. M. F. Duhamel (Ed.), *Progress in Nuclear Energy Series XII, Health Physics*, pp. 707-730. Pergamon Press, Elmsford, NY.
- Cherry, J. A. 1996. "Conceptual Models for Chlorinated Solvent Plumes and Their Relevance for Intrinsic Remediation." In: *Symposium on Natural Attenuation of Chlorinated Organics in Ground Water*, pp. 29-30. Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, EPA/540/R-96/509.
- DOE. 2012. *Annual Report for the Final Groundwater Remediation, Test Area North, Operable Unit 1-07B, Fiscal Year 2011*. DOE/ID-11464, Revision 0. 81 pp.
- EPA. 2009. *Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water*. EPA 600/R-09/115. December.
- ESTCP. 2008. *Workshop on In Situ Biogeochemical Transformation of Chlorinated Solvents*. February.
- Ferrey, M. L., R. T. Wilkin, R. G. Ford, and J. T. Wilson. 2004. "Nonbiological Removal of cis-Dichloroethylene and 1,1-Dichloroethylene in Aquifer Sediment Containing Magnetite." *Environmental Science & Technology*. 38(6):1746-1752.

References (cont.)

- Koelsch, M., R. C. Starr, and K. S. Sorenson, Jr. 2005. "Assessing Aerobic Natural Attenuation of Trichloroethene at Four DOE Sites." Proceedings of the Waste Management 2005 Conference, Tucson, AZ.
- Lee, M. H., S. C. Clingenpeel, O. P. Leiser, R. A. Wymore, K. S. Sorenson, Jr., and M. E. Watwood. 2008. "Activity-Dependent Labeling of Oxygenase Enzymes in a Trichloroethene-Contaminated Groundwater Site." *Environmental Pollution*. 153(1):238-246. 2009.
- Sorenson, K. S., Jr., L. N. Peterson, R. E. Hinchee, and R. L. Ely. 2000. An Evaluation of Aerobic Trichloroethene Attenuation Using First-Order Rate Estimation. *Bioremediation Journal*, 4(4):337-357. 2000.
- Wymore, R. A., M. H. Lee, W. K. Keener, A. R. Miller, F. S. Colwell, M. E. Watwood, and K. S. Sorenson, Jr. 2007. "Field Evidence for Intrinsic Aerobic Chlorinated Ethene Cometabolism by Methanotrophs Expressing Soluble Methane Monooxygenase." *Bioremediation Journal*. 11(3):125-139. 2007.