Technical and Regulatory Approaches for Cleanup of Contaminated Groundwater at Test Area North at the Idaho National Laboratory

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Background

Operable Unit (OU) 1-07B contains the final remedy for the TSF-05 former injection well and surrounding groundwater contamination at the Test Area North (TAN) on the Idaho National Laboratory (INL) Site. In 1989, TAN was included on the National Priorities List and a remedial investigation/feasibility study was completed in 1995. The remedy selected in the Record of Decision (ROD) Amendment for the two-mile long trichloroethene (TCE) plume, consists of three parts: 1) in-situ bioremediation (ISB) for the "hot spot" (TSF-05 vicinity) restoration, 2) pump and treat for the medial zone, and 3) monitored natural attenuation (MNA) for distal zone restoration (see Figure 1). The comprehensive remedy also includes institutional controls and groundwater monitoring to ensure all components of the remedy are functioning properly. The subsurface geology at TAN is similar to most of the INL and is characterized by basalt flows with sedimentary interbeds, overlain by fine-grained sediments. There are two main interbeds at TAN, the P-Q interbed in the vadose zone at approximately 200 ft below ground surface (bgs) and the Q-R interbed in the saturated zone approximately 410 ft bgs, both of which consist of clay or silt that retards contaminant transport.

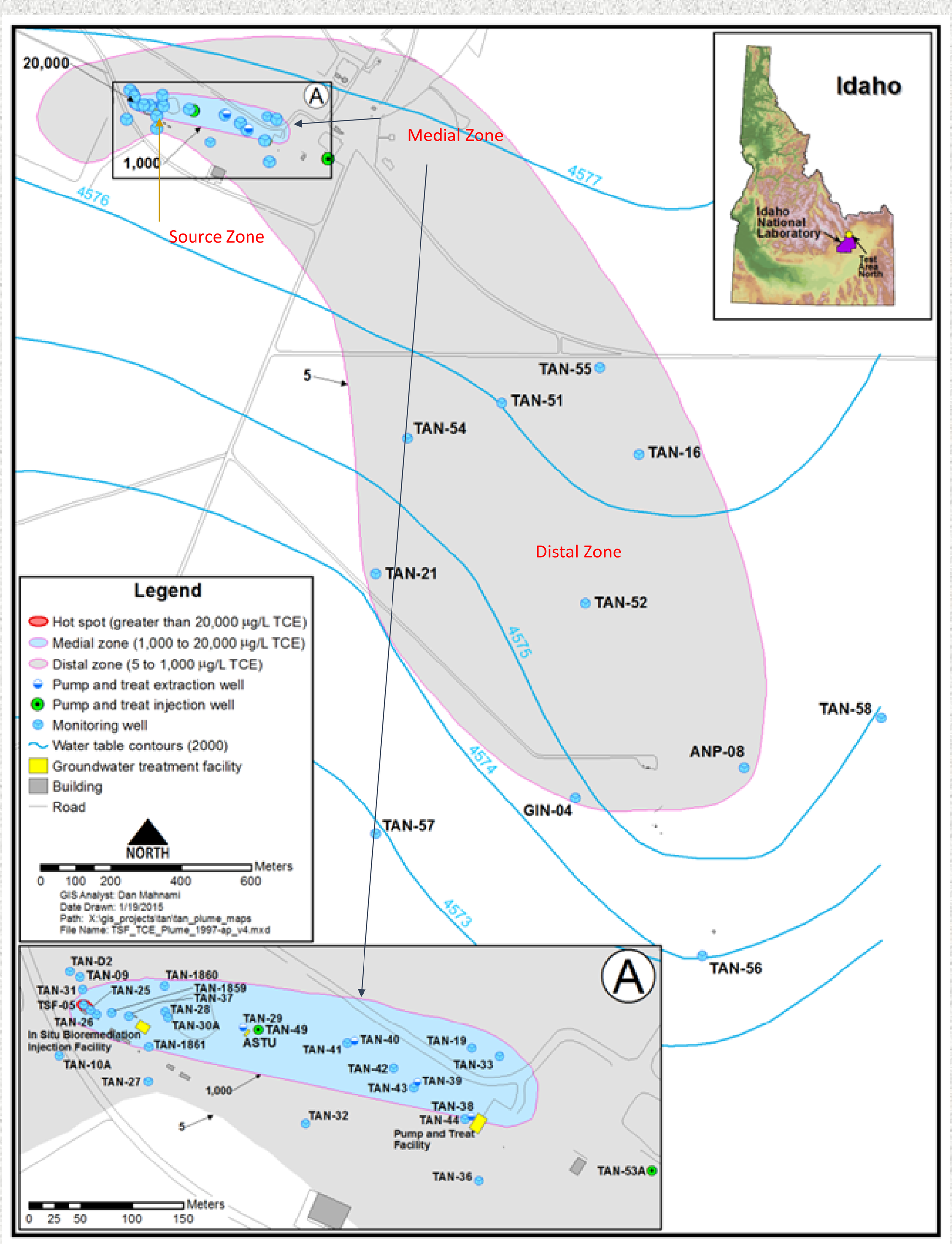

Figure 1. TAN Site Map with Three Plume Zones:

Hot spot near TSF-05 >20,000 ug/L TCE

Medial zone 1,000 to 20,000 ug/L TCE

Distal zone 5 to 1,000 ug/L TCE

Objectives

The ROD Amendment assumed Cs-137 and Sr-90 would attenuate without treatment through sorption and decay to meet the remedial action objectives (RAOs) for all Snake River Plain Aquifer wells to be below MCLs by 2095. The Operable Unit 1-07B RAOs are listed in Table 1 below:

Contaminant	Historical Maximum	Cleanup Level
TCE	32,000 μg/L	5 μg/L
Cis-1,2-DCE	7,500 μg/L	70 μg/L
Trans-1,2-DCE	3,900 μg/L	100 μg/L
PCE	110 μg/L	5 μg/L
Sr-90	1,880 pCi/L	8 pCi/L
Cs-137	2,150 pCi/L	119 pCi/L

Table 1. TAN Groundwater Contaminants and Cleanup Levels

Note: Cs-137 MCL is now 200 pCi/L (corresponds to 4 mrem/yr dose limit)

Approach

ISB injections of carbon sources (as electron donors) started in 1999 into TSF-05 near the hot spot to stimulate naturally occurring anaerobic bacteria to degrade VOCs. ISB has used sodium lactate, whey, emulsified vegetable oil, and sodium lactate with volatile fatty acids. Depth to groundwater at TSF-05 is approximately 234 ft bgs. Typical amendment injection rates are approximately 22-33 gal/min.

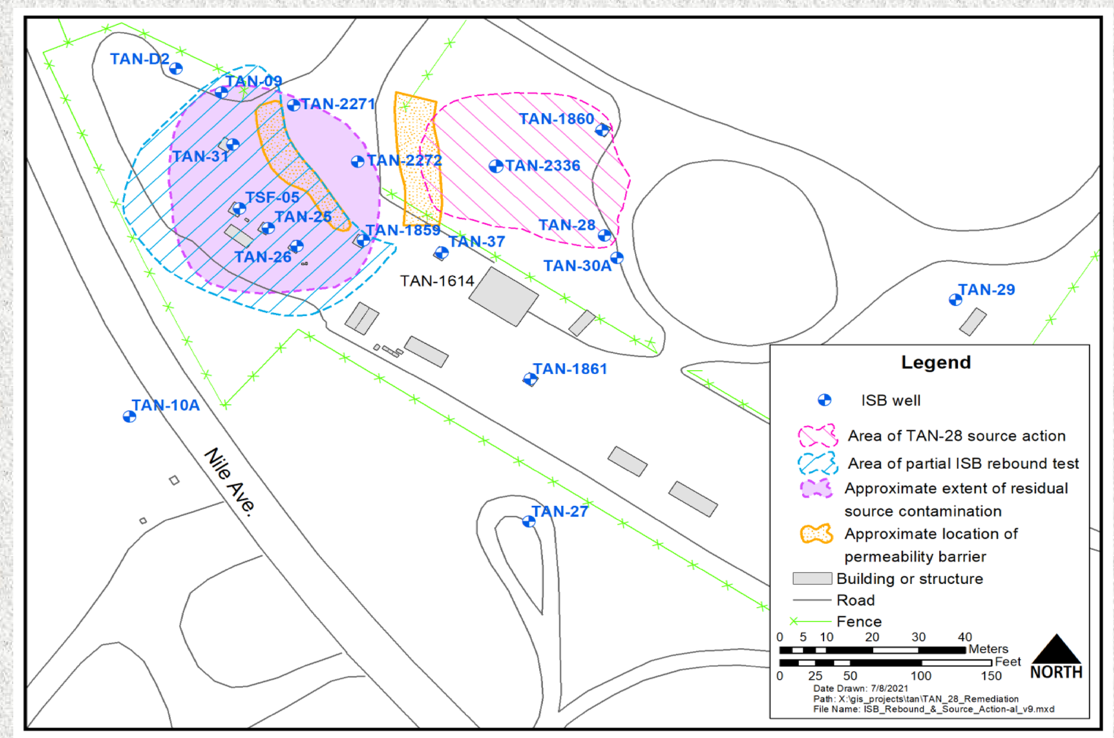

Figure 2. ISB Monitoring Well Locations and Area of TAN-28 Source Action

Site Activities

After more than a decade of injecting ISB amendments into the fractured basalt aquifer near TSF-05, ISB transitioned into a rebound test in July 2012. The effectiveness of ISB in reducing the residual source in the aquifer will be evaluated as background redox conditions are re-established. The ISB injection strategy for the remaining TCE source area has been modified because the spread of the ISB amendment has been hindered by low-permeability zones near TAN-28 (see Figure 2). Monitoring well TAN-2336 was installed in 2021, and recently a transducer was installed within TAN-29 to determine if injections into TAN-2336 and TAN-37A were affecting water levels within TAN-29. A pump and treat facility (NPTF) is operated as needed to mitigate the migration of TCE downgradient into the distal MNA area. The NPTF has run nearly continuously from 2002 to 2025 and has currently treated more than 937 million gallons of groundwater. TCE data from the MNA portion of the plume is compared to model output to determine if the remedy is on track to meet the RAOs and plume expansion is monitored.

Results and Discussion

Data collected in support of MNA for the distal part of TCE plume indicate that VOC concentrations in most wells are trending consistent with MNA groundwater flow models. TCE concentrations in most of the medial zone wells are significantly lower than historical averages (Figures 3 and 4).

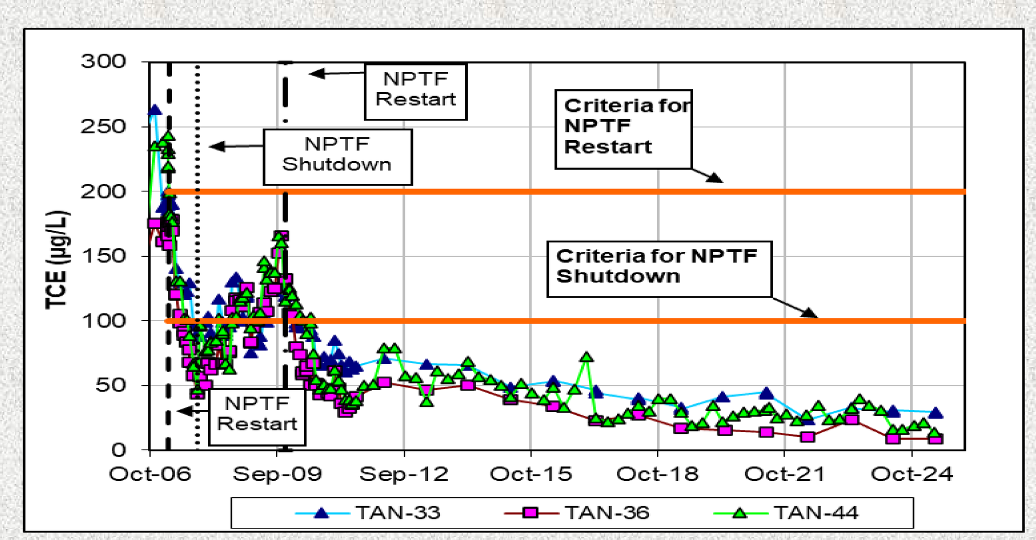

Figure 3. TCE Concentration Flux to the Distal Zone, as Estimated by Sample Data from TAN-33, TAN-36, and TAN-44

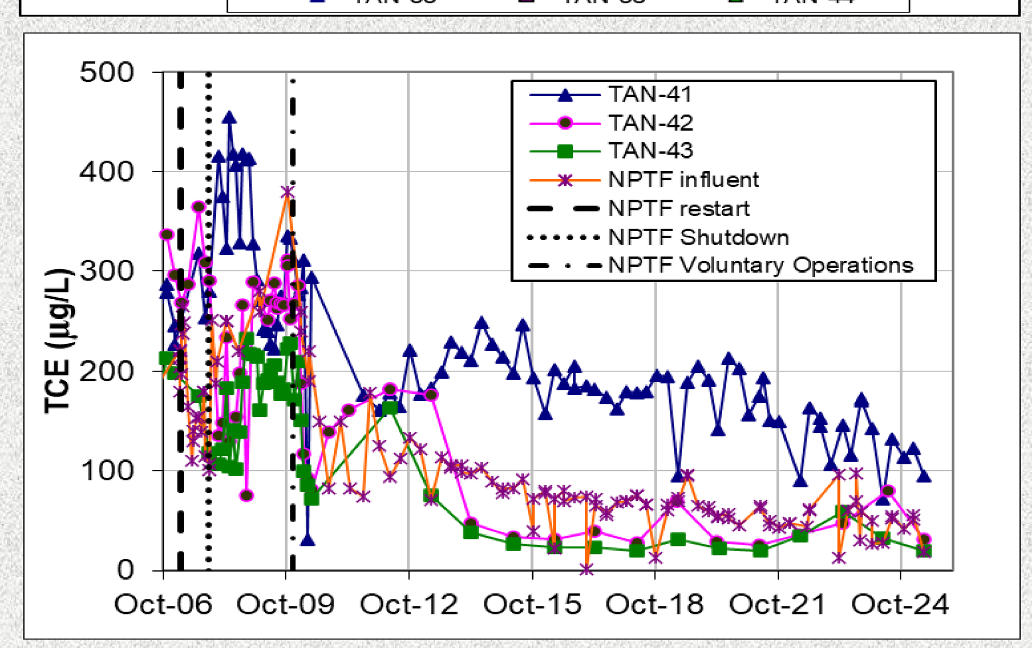

Figure 4. Medial Zone TCE Concentrations in NPTF Influent and Monitoring Wells TAN-41, TAN-42, and TAN-43

Sr-90 and Cs-137 concentrations near the hot spot, as shown in Figures 5 and 6, are generally declining since the start of the rebound test.

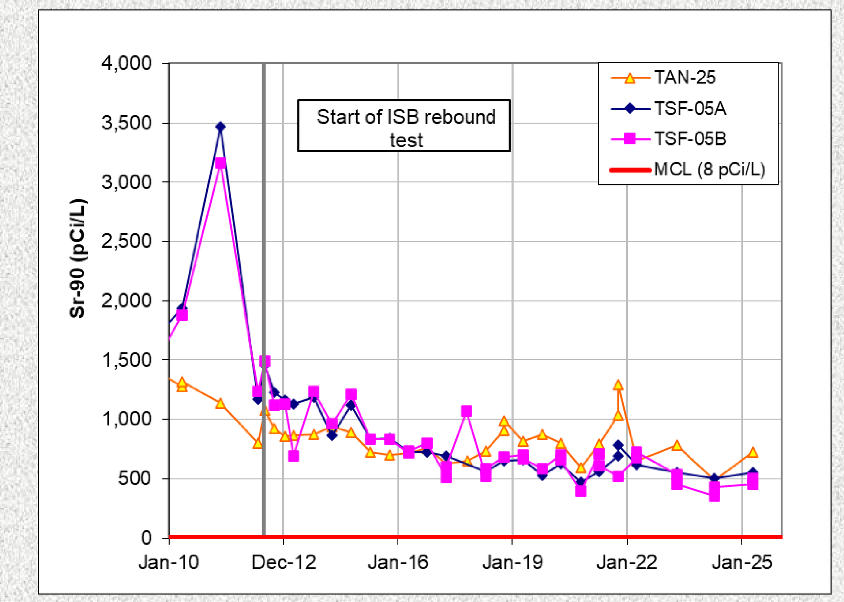

Figure 5. Sr-90 Concentrations in TAN-25, TSF-05A, and TAN-TSF-05B

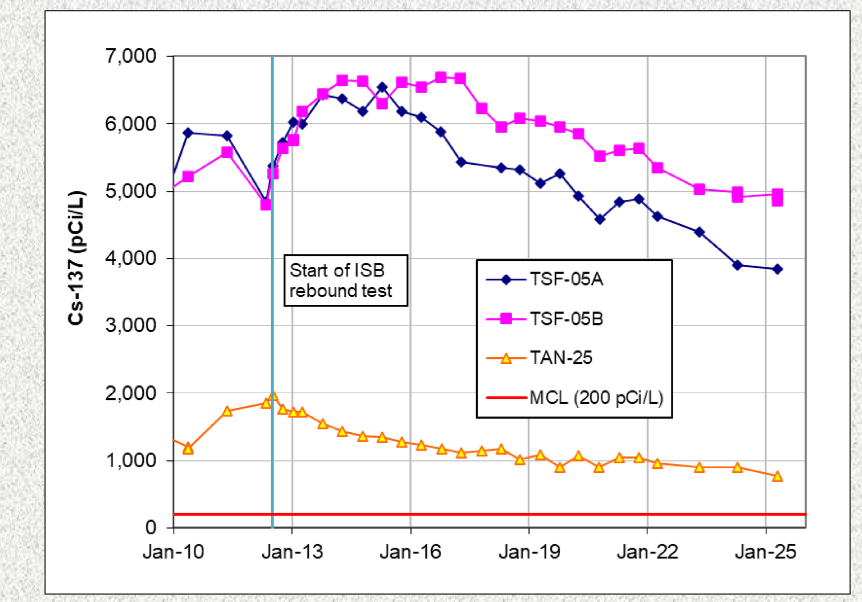

Figure 6. Cs-137 Concentrations in TAN-25, TSF-05A, and TSF-05B

TCE concentrations within TAN-29 are currently the highest within the TAN facility, ranging from 248 ug/L to 365 ug/L (Figure 7). Iron and methane data collected recently show that previous injections into TAN-1860A and TAN-2336 have shown an impact on the TAN-28 TCE source, as concentrations have been below 1 ug/L TCE.

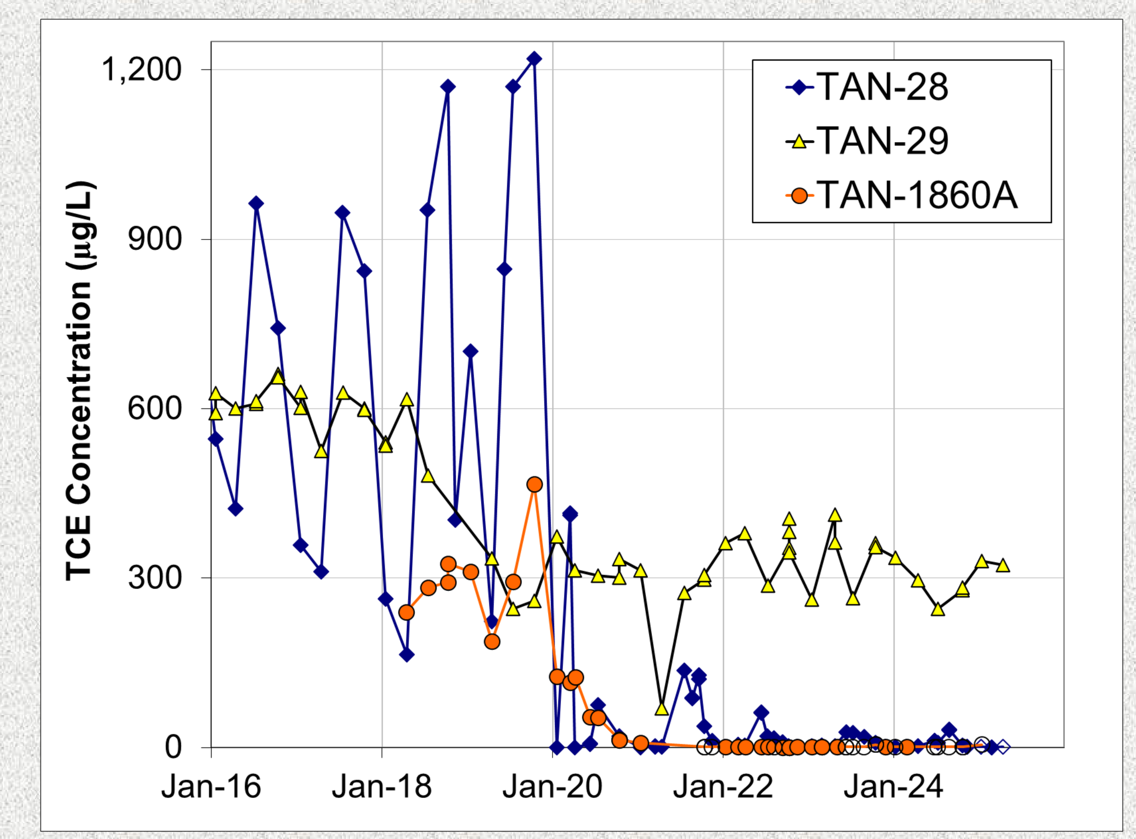

Figure 7. TCE Concentrations for Monitoring Wells Associated with the TAN-28 TCE Source Action.

Lessons Learned

A flexible technical and regulatory approach to monitoring the three remedy components is necessary because it may take more time to restore background redox conditions within the ISB area and to fully assess source treatment. Treatment of the remaining TCE source has been difficult because ISB injections do not always penetrate into areas of low flow. The contrast between fast flow and low flow zones illustrates the unpredictable nature of flow within fractured basalt. TCE data from the MNA portion of the plume compared to model output suggests that the remedy is on track, but areas with lower transmissivity may require more time than model predications to meet the RAOs. The location of the institutional control boundary and potential receptors must be considered as well as overall plume expansion. Further, the selection of ISB amendment must consider potential mobilization of radionuclides because the introduction of cations from the ISB amendment can mobilize radionuclides.

Acknowledgements

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