Characterizing the Release and Discharge of a Contaminant Plume Using a Numerical Model, Environmental Tracers and Water-to-Vapor Diffusion Samplers

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Abstract: The source of contamination in a deep monitoring well near a creek was delineated using a numerical flow model, tritium/tritogenic helium environmental tracers and water-to-vapor diffusion samplers. This previously underdetermined source of contamination is believed to have generated a plume of contamination that has traveled over 1.5 miles and discharged to a local stream. The site, located in Florida, has a large unsaturated zone (100-ft.) that precluded more traditional approaches to characterizing contaminant plumes. Significant cost savings for site characterization are expected.

Volatile organic compounds (VOC's) including petroleum hydrocarbons consisting primarily of benzene, have been identified in a groundwater monitoring well that is screened at approximately 37 feet below mean sea level near a small creek at a United States Navy installation in Florida. The source of the contamination was subject to much uncertainty due to the absence of a nearby source of contamination that could hydraulically deliver the contamination at depth, the large number of potential sources of contamination located at the installation that are geographically distant, and the uncertainty of the flow paths caused by the influence of the creek. The identification of the source of contamination and its rate of movement is necessary to facilitate remedy of the contamination and predict timeframes associated with the cleanup of the plume. The approach used to answer these questions included constructing a numerical groundwater flow model coupled with a particle tracking program that could delineate the flow paths of the contamination, obtaining apparent ages of the contaminated water with tritium and its decay product (tritogenic helium), and using water-to-vapor diffusion samplers to identify potential discharge locations to the creek.

The origin of the contamination was identified through a model (Casey, C.C., 2000) that was constructed using the finite difference code MODFLOW (McDonald and Harbaugh, 1988; Harbaugh and McDonald, 1996) and particle tracking program MODPATH (Pollack, D.W., 1994). Backward particle tracking (figure 1) from the contaminated well terminated in the vicinity of a former underground fuel and waste storage tank area. Until the last decade when they were removed, ten steel tanks (circa 1943) that ranged in capacity from 24000 gallons to 750 gallons were used to store AVGAS and waste products at the fuel farm. The tanks were located in the 100-foot unsaturated zone of a sand and gravel plateau. Leakage through the unsaturated zone to the water table resulted in the accumulation of free product at the water table that has been subsequently removed. The tank farm is over 1.5 miles from the contaminated well near the creek and appears to be feeding a diving plume of contaminated groundwater. The total BTEX concentrations in nearby monitoring wells at the tank farm have been detected at concentrations of 32,700 ug/l.

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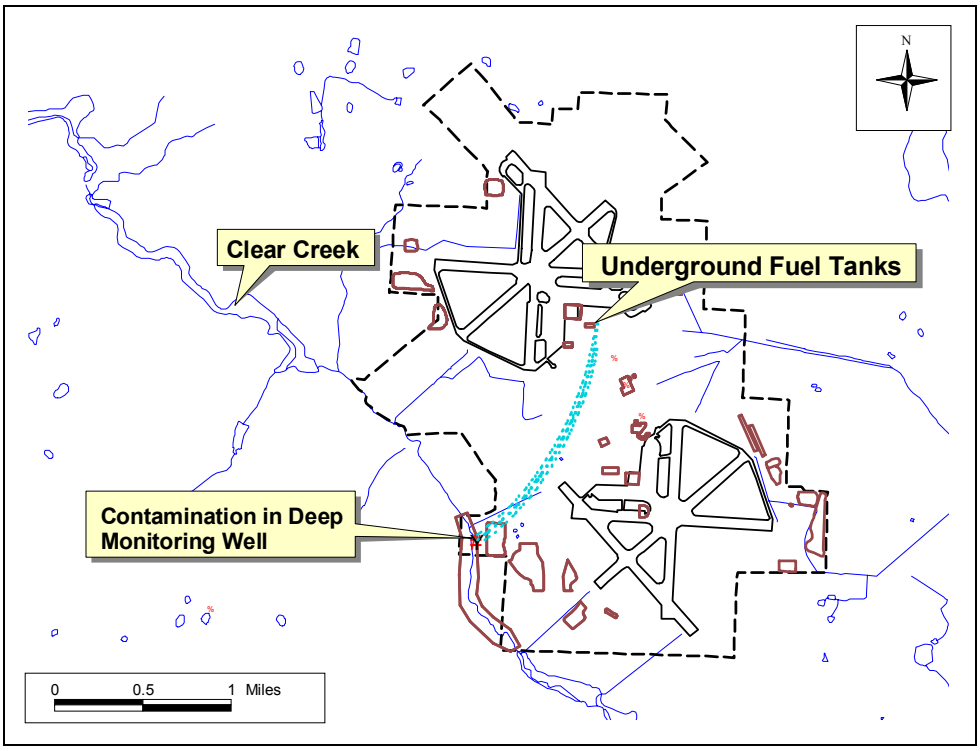

Figure 1. Backward particle tracking from contaminated deep well

The water was dated using the chemical isotopes tritium and its decay product tritogenic helium (Vroblesky, D. A., and Casey, C.C., 1999). Tritium is a radioactive isotope of hydrogen that was produced in the past through atmospheric testing of nuclear weapons and is found naturally in the atmosphere in much smaller amounts through the bombardment of N^{14} by cosmic rays (Plummer, L and others 1993). As it becomes incorporated into the water molecule of precipitation, it will follow the path of non-tritium containing water as it recharges the water table. The decay product tritogenic helium is lost to the atmosphere until the tritium containing water molecule is below the water table. As the tritium reaches the water table it moves downward with the water. The tritogenic helium is captured by the downward movement in the aquifer and moves with the tritium. An apparent age of the water since recharge is computed with knowledge of tritium, tritogenic helium and the decay rate. Two well clusters containing wells labeled as intermediate and deep wells near the creek were dated that were part of the path projected by particle tracking. Dating both wells in each cluster was conducted to ensure consistency in the ages relative to flow path length and projected time of travel. The two deep wells had ages that were 27 and 28 years since recharge. While the two intermediate depth wells were 20 and 24 years since recharge.

Water-to-vapor diffusion samplers were used to evaluate potential discharge along a 1500 foot section of the creek and floodplain. The samplers operated by diffusion of benzene, in this case, through a sealed polyethylene bag containing an uncapped 30-ml glass serum vial. After a period of two weeks, the samplers were recovered and a teflon-coated butyl-

rubber stopper was crimped over the bag onto the vial. A gas tight syringe was used to collect the sample for analysis on a gas chromatograph. Seventy-three samplers were deployed in the creek bed and floodplain sediment approximately 5 to 12 inches below the surface of the sediment. The samplers were retrieved two weeks later and analyzed with a gas chromatograph. Of the 73 samplers deployed, 23 had concentrations of benzene that ranged from 1.4 to 20.2 nM/20 ml (Vroblesky, D. A., Bradley, Paul M., and Casey, C.C., 1998).

Based on the results of the particle tracking analysis, apparent ages of water in the contaminated wells and water-to-vapor diffusion samplers, it appears contamination is emanating from the former underground fuel farm and discharges to the creek and its flooplain 1.5 miles away. The travel time for the contamination is probably greater than the 28 years estimated from the apparent ages of the water since the petroleum hydrocarbons are likely influenced by retardation factors to some degree. New wells have recently been installed to confirm this analysis. Substantial cost savings should be realized in terms of correct placement of wells that exceed 100 feet and are placed along the 1.5 mile flow path.

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