ENHANCED DNAPL RECOVERY FROM FRACTURED LIMESTONE AFP4, FORT WORTH, TEXAS

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Site Description And Background

Air Force Plant No. 4 (AFP4) is a government-owned, contractor-operated, aircraft manufacturing facility located approximately 7 miles west of Fort Worth, Texas. AFP4 became operational in 1942 and has been in continuous use up to the present. Throughout most of the plant's history, spent chemicals were disposed of in on-site landfills or were burned in fire training areas.

The Landfill No. 1 (LF1) and Landfill No. 3 (LF3) areas on the west side of AFP4 were used as waste disposal areas. LF1 covers approximately six acres and was used to dispose of general refuse, construction fill, and potentially hazardous waste. Oils and fuels were also dumped in shallow pits located within LF1 and burned. LF1 was closed in 1966 and the area was graded and paved for a parking area. The area is now referred to as the West Parking Lot and is shown below in Figure 1.

Site Conditions and Investigations

The water table aquifer in the LF1 and LF3 areas of AFP4 is composed of fill material and alluvium ranging from approximately 2 to 20 feet thick. Underlying the Terrace Alluvium and Fill is the Cretaceous Walnut Formation. The Walnut Formation is a light gray, 20- to 30-foot-thick fossiliferous limestone with interbedded clay layers. The top of the Walnut is generally weathered, fractured, and dry. The base of the Walnut is better cemented, less fractured, and appears to act as a confining unit, or barrier to vertical migration into the underlying Paluxy Formation, a regional aquifer. Figure 2 presents a cross section of the geology on the west side of AFP4.

During a 1996 drilling program to install groundwater monitoring and recovery wells in the deeper Paluxy Formation, water and DNAPL were encountered in the Walnut Formation. Several follow-up investigations conducted from June 1998 through June 2000 resulted in the installation of Walnut borings, wells, and piezometers (shown in Figure 1), followed by aquifer pumping and DNAPL recovery tests. Drilling results indicated that, in some places of the study area, the middle portion of the Walnut is saturated. The presence of DNAPL typically coincided with the occurrence of groundwater. The horizontal extent of DNAPL was not fully delineated. The aquifer pumping test results also indicated an area of the Walnut with interconnected drainage along fractures or clayey bedding planes. Figure 3 shows the drawdown at 505 minutes into the aquifer test, indicating areas where water and DNAPL are in communication most likely along bedding planes.

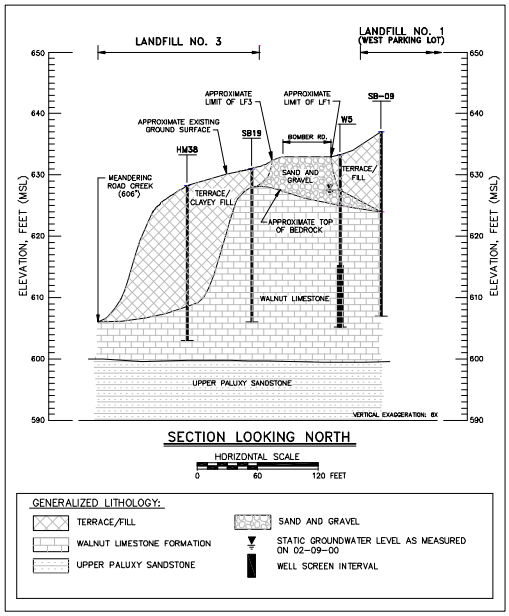

Figure 1 Location of LF1, borings, and wells.

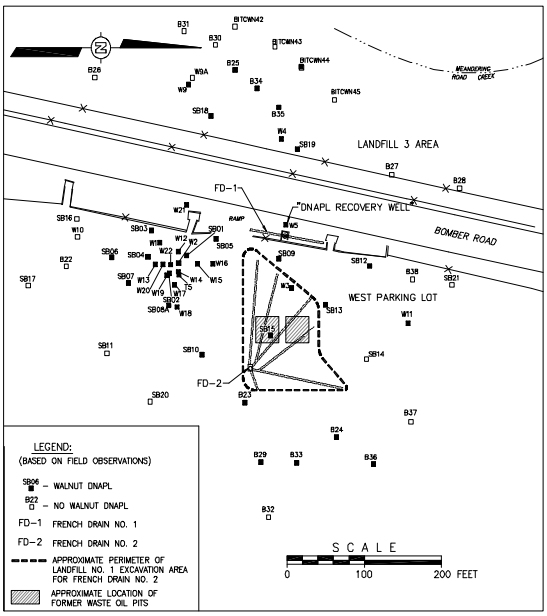

Figure 2 Cross section through LF1 and LF3.

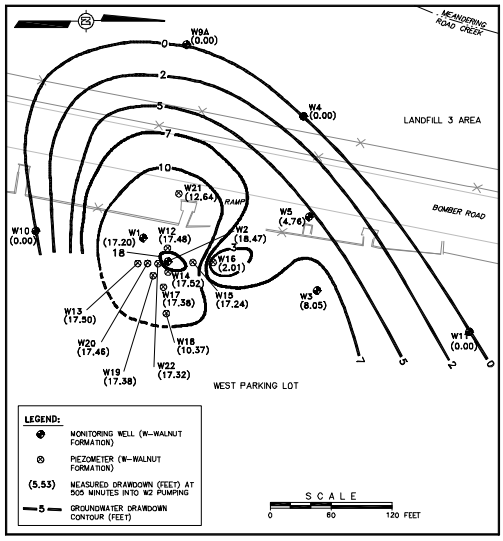

Figure 3 Walnut groundwater drawdown at 505 minutes into W2 pumping.

The amount of DNAPL in the Walnut wells ranges from discreet droplets to a maximum thickness of 18 feet (in Well W5). During June 2000, a series of DNAPL recovery tests were conducted in Well W5. At the time, 11 to 16 feet of DNAPL was measured in the W5 well screen and casing. Well W5 is a 4-inch-diameter stainless steel well with a wire-wrapped stainless steel screen installed from 17 to 27 feet below grade. The top of the Walnut at well W5 is 8 feet below grade.

The DNAPL pumping for the recovery test was done using a standard off-the-shelf Clean Environment Equipment (CEE) Model SPT 15 slow purge, bottom filling, bladder pump. The DNAPL was pumped at a low rate to avoid pumping groundwater. An electric compressor powered the SP15T pump. The DNAPL extraction flow rate was controlled using a CEE controller. Recovered DNAPL was discharged from the pump into a 5-gallon bucket and transferred to a new US DOT-approved 55-gallon drum. The tests resulted in the recovery of 85 gallons of DNAPL and 24 gallons of groundwater. The DNAPL recovered from each event was determined to be attributable to the storage capacity of the well casing plus the recharge from the Walnut Formation. The removal of water above the DNAPL prior to pumping was shown to increase the flow of the DNAPL into the W5 well from the Walnut Formation. By reducing the water column, the hydrostatic pressure in fractures near the well is

reduced, which results in increased DNAPL flow. The tests also showed that the removal of water or DNAPL from the Walnut Formation at W5 slightly increases DNAPL thickness in nearby offset wells.

DNAPL Recovery Program and Discussion of Results

In July 2001, a DNAPL recovery program was started in well W5. The general procedures used for DNAPL recovery consisted of initial groundwater removal (by bailing) to increase the DNAPL thickness in the well, followed the next day by DNAPL pumping using the low-flow CEE bladder pump system. Figures 4 and 5 shows W5 water and DNAPL thicknesses before and after water bailing prior to DNAPL pumping.

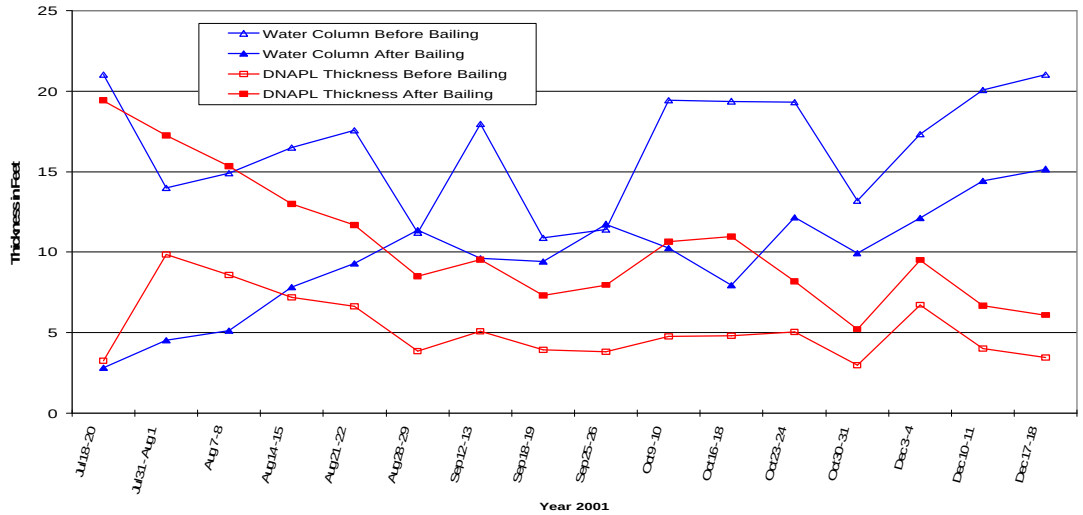

Figure 4 W5 water and DNAPL thicknesses before and after water bailing.

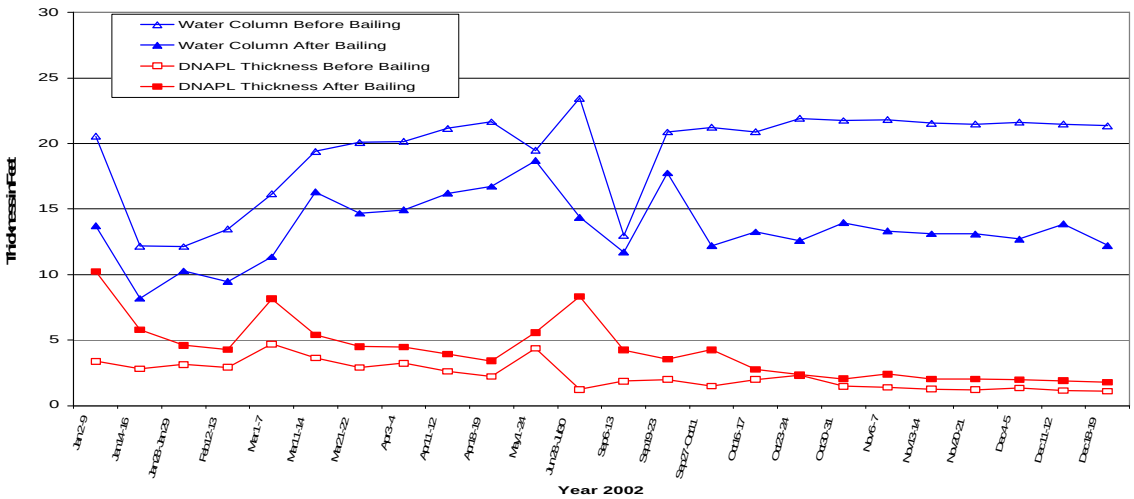

Figure 5 W5 water and DNAPL thicknesses before and after water bailing.

From July 2001 through December 2001, DNAPL thickness measured before and after water bailing declined. During this period, pumping events were being conducted weekly (when practical). During November 2001, water bailing and DNAPL pumping was suspended to see if recoverable DNAPL thickness would increase under static conditions. Following the suspension of activities, the thickness showed a slight increase in early December, and then quickly decreased after activities resumed.

Beginning in January 2002, the number of water bailing events prior to pumping, and the time intervals between water bailing and DNAPL pumping were varied to evaluate and optimize conditions for maximum DNAPL recovery. The frequency and timing of events were based largely on volumes of fluid recovered, and the observed responses to water bailing and DNAPL pumping over time, while maintaining the goal of maximizing DNAPL recovery. During 2002, W5 water thickness increased and DNAPL thickness decreased. This could

indicate a possible depletion of free-flowing DNAPL in the Walnut surrounding Well W5. DNAPL thickness are monitored in offset wells to determine if DNAPL is mobilized during pumping. DNAPL and groundwater removal may cause DNAPL migration.

Figure 6 shows monthly and cumulative recovery of groundwater and DNAPL from Well W5. At the end of December 2002, 470 gallons (approximately 6,110 pounds of TCE) of DNAPL and 910 gallons of water have been recovered from Well W5. The cost to recover each pound of DNAPL ranged from $10 to $20 per pound. Weekly DNAPL recovery was done using simple, off-the-shelf equipment, a field technician for a maximum of one 8-hour shift per week (to do water removal, DNAPL recovery, and thickness measurements), and disposal of one drum of waste per month by incineration. This compares well to enhanced recovery projects where recovery costs may exceed $1,000 per pound. Initial direct DNAPL removal from the Walnut has resulted in an inexpensive mass removal. AFCEE may conduct additional characterization activities in LF1 and LF3. Additional enhanced source area removal actions may be conducted in the future.

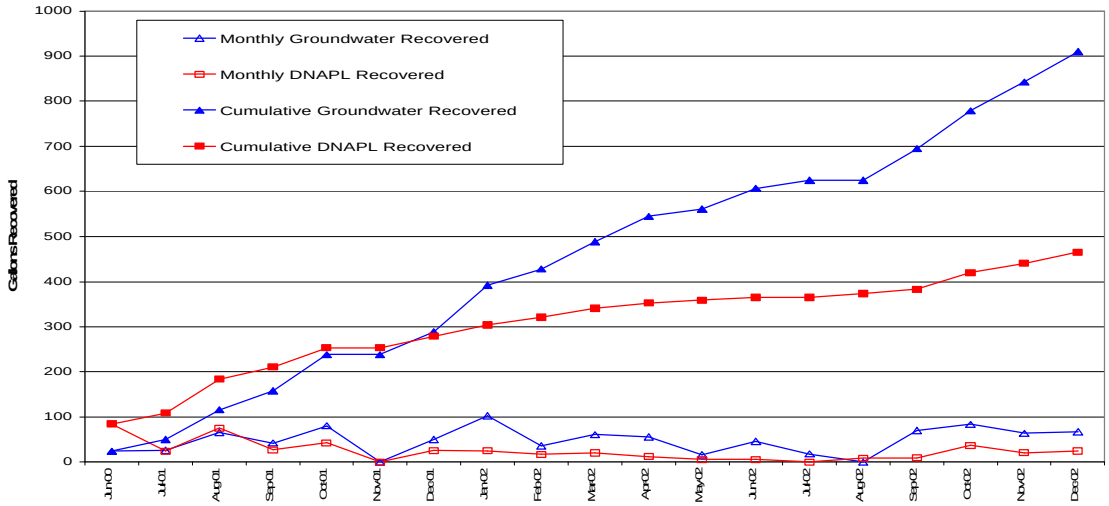

Figure 6 Groundwater and DNAPL recovery from Walnut Well W5.

REFERENCES

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