EXECUTIVE SUMMARY

This PITT Model and Design Report presents the design of four large-scale partitioning interwell tracer tests (PITTs) to be conducted during Phase V of the Dense Nonaqueous Phase Liquid (DNAPL) Source Delineation Project at Hill Air Force Base (Hill AFB), Operable Unit 2 (OU2). The design is accompanied by a PITT work plan, completed as part of the Dense Nonaqueous Phase Liquid Source Delineation Work Plan (SDWP). The PITTs to be conducted at OU2 represent the first known full-scale field application of this complex technology to characterize the DNAPL saturation and volume in a shallow groundwater aquifer. Although using PITTs to characterize DNAPL in the subsurface has been successfully demonstrated in five pilot-scale PITTs at OU2, this project seeks to significantly increase the scale at which PITTs can be applied.

OU2, located on the northeastern boundary of Hill AFB in Utah, was used from 1967 to 1975 to dispose of unknown quantities of chlorinated organic solvents from degreasing operations. These DNAPLs, primarily trichloroethene (TCE), were placed into two unlined disposal trenches underlain by an alluvial aquifer. This shallow unconfined aquifer is composed of a heterogeneous sand and gravel mixture, and is contained in a buried paleochannel eroded into thick clay deposits. A large volume of DNAPL remains in the subsurface, predominantly as a residual phase retained as ganglia by capillary forces in the aquifer's pore spaces. The DNAPL also exists as a mobile phase pooled in topographic lows on the surface of the clay aquiclude. A containment wall surrounds the main source zone area at OU2.

The focus of the source delineation project is to use the four PITTs to determine the volume and spatial distribution of DNAPL contamination in the shallow alluvial aquifer within the containment wall. The results of these PITTs will be used for technical and cost comparisons of remedial alternatives, i.e., soil vapor extraction, surfactant-enhanced aquifer remediation, and steam flooding. The information obtained from the PITTs can then be used in the design of the remedial action for the alluvium in the DNAPL source zone.

Conservative interwell tracer tests (CITTs) were conducted in each of the four PITT panels at OU2 as part of Phase III of the DNAPL Source Delineation Project. These tests were performed to obtain an understanding of how an induced-flow system behaves in each well array, and to provide calibration data for the numerical PITT design models. During each CITT, chloride tracer was injected into the central injection well and recovered by pumping from the two central extraction wells in each of the PITT well arrays. The method of first moment analysis was applied to translate and interpret the conservative tracer data into meaningful parameters such as swept pore volume, residence time, and longitudinal dispersivity. The calculated longitudinal dispersivities ranged from 6.4 feet (ft) to 37.8 ft. These values fall at the upper bound of published estimates, suggesting that the shallow aquifer is highly heterogeneous. Hydraulic conductivity estimates ranged from 17.1 ft/day (6.1×10^{-5} meters per second [m/s]) to 50.0 ft/day (1.8×10^{-4} m/s). The pore volumes swept during the CITTs ranged from 38,400 gallons (145 cubic meters [m^3]) to 53,000 gallons (201 m^3).

The successful implementation of field-scale PITTs requires the application of an engineering design strategy using careful and systematic modeling. UTCHEM, a three-dimensional, chemical compositional simulator developed at the University of Texas (Delshad, et al. 1996), was used to design the large-scale PITTs. The first step in designing each PITT was to update the UTCHEM simulation sub-models (well array models) used for the well field design with the information obtained during the installation of the PITT well field and the hydraulic testing activities.

The second step was to calibrate each sub-model to the corresponding CITT results. Once the model was calibrated, a number of sensitivity simulations were run to study the behavior of the tracers under different conditions and formulate a final design strategy. The results of these sensitivity studies were used to select the partitioning tracers and determine the duration of the tracer test as well as the mass of each tracer needed. These simulations were also used to determine the injection and extraction rates, the extraction well effluent tracer concentrations and the amount of tracer recoverable at the end of tracer test. Based on the results from the sensitivity studies, it was found that the major factor affecting the tracer test duration and estimation accuracy is the water table elevation. If a lower water table elevation is used, the duration of the tracer test can be reduced by a factor of almost two due to the elimination of tracer flow in the upper portion of the aquifer where DNAPL is not expected to be present. A smaller swept pore volume also means relatively larger retardation factors for the tracers with smaller partition coefficients, which in turn increases the estimation accuracy.

In general, the results of the modeling indicate that the tracer test duration (including waterflood) will range from 24 to 27 days. The expected tracer concentrations in the tail of the response curves range from 0.1 milligrams per liter (mg/L) to 5 mg/L, depending on the individual extraction well and the PITT test zone. The predicted swept pore volumes range from 57,500 gallons (218 m^3) for PITT1 to 150,000 gallons (567 m^3) for PITT3. Tracer recoveries are predicted to be greater than 90 percent for each of the four tests. Based on the PITT simulation and laboratory results, the tracers chosen for the PITTs include 2-propanol, 3-methyl-3-pentanol, 2-ethyl-1-butanol, 1-hexanol, 1-heptanol, and 2-ethyl-1-hexanol. Bromide, a conservative ion tracer, is added to the tracer suite as a backup for the nonpartitioning alcohol 2-propanol. The individual tracers in the suite are chosen on the basis of their partitioning coefficients given the travel time across the zone of interest for a particular PITT. Tracers will be injected at concentrations ranging from 350 mg/L to 1000 mg/L depending on the solubility of the particular tracer.

The PITTs will be conducted sequentially, beginning with PITT1 and ending with PITT4. Once a PITT has been completed in a well array, the injection-extraction setup will be moved to the next PITT panel and the field operations will be repeated. There will be an approximately 10-day period between PITTs to allow for maintenance on the Source Recovery System (SRS) and to set up the next PITT. Tracers will be mixed hydrodynamically and injected inline, eliminating the need for tracer mixing, storage tanks, and the associated plumbing and recirculation pumps required for batch processing. A wastewater tank will, however, be required to collect the fluids purged during the sampling process. A high-density polyethylene (HDPE) liner will be installed around the tracer mixing equipment and the waste tank to provide secondary containment for any potential spills or leaks. PITT samples will be acquired with a mobile automatic sample collection system.

Each PITT will begin with source water injection and simultaneous extraction until a steady state forced-gradient flow field is established in the test zone. During each PITT, the flow rates in the injection and extraction wells will be held constant throughout the entire test. The total injection rate specified is 15 gallons per minute (gpm) for PITT1 and PITT4 and 16 gpm for PITT2 and PITT3. The total specified extraction flow rates range from 15 gpm for PITT1 to 24 gpm for PITT2 and PITT3. Monitoring wells will be operated throughout injection/extraction operations at a low flow rate (90 milliliters per minute or less) to minimize perturbations to the flow field in the test zone.

Each PITT will consist of injecting a fixed slug of tracer into the aquifer, followed by several days of continuous source water injection (post-water flush) to transport the tracers across the zone of interest. During each test, injection and extraction pressures, rates, and volumes will be monitored to ensure that these parameters are maintained according to the test design. Fluid levels will be monitored electronically and manually to verify that hydraulic control over the test zone is maintained. Tracer concentrations will be monitored by periodically sampling the effluent of each extraction well, ground-water monitor wells, and the injectate. Volatile organic compound (VOC) concentrations will be monitored by periodically sampling the effluent streams from the extraction wells and the ground water monitor wells. Samples will be shipped to Onsite Laboratories in California for analysis using SW-846 Method 8260B. In addition to the tracer alcohols, the target analytes will include TCE, tetrachloroethene, and 1,1,1-trichloroethane.

The PITT well field effluent will be diverted to the SRS for treatment, after which it will be pumped to the Hill AFB Industrial Wastewater Treatment Plant (IWTP). Once a PITT has been initiated, it is imperative that injection/extraction operations continue uninterrupted until the tracer mass has been recovered at the extraction wells. For this reason, an effluent treatment contingency plan has been formulated in the event that some or all of the PITT well field effluent can not be treated at the SRS. This contingency plan utilizes a temporary HDPE pipeline installed in the PITT well field to allow effluent to bypass the steam stripper if necessary. If a bypass is required, effluent will instead be pumped directly into T105, the SRS's treated water tank, for discharge to the IWTP. Since there are six extraction wells, the well field plumbing will be configured so that the total amount of effluent can be diverted in 1/6 increments to the bypass line if needed. If a partial diversion is required, effluent would be first diverted from the outside (wing) wells, since these wells have lower VOC and alcohol concentrations than the center extraction wells. Under a partial bypass scenario, the diverted water would then diluted with treated water in T105 prior to discharge to the IWTP.

This PITT Model and Design Report is divided into three main sections and nine appendices. The first section describes the site-specific information obtained for the PITT design and modeling tasks during the PITT well field construction and hydraulic testing during Phase III of the project. The second section of this report describes the numerical modeling process used to design each of the PITTs. The third portion of the report consists of the PITT work plan. The work plan describes the design specifications for each PITT, and outlines the logistical and operational requirements for conducting the tracer tests. Finally, Phase V specific addenda to the project Health and Safety Plan, the Sampling and Analysis Plan, and the Quality Assurance Project Plan are attached to this report as appendices.