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Triad Case Study: Marine Corps Base Camp Pendleton

Adrianne V. Saboya, Karen G. Collins, and Timothy Shields

ABSTRACT

The U.S. Navy Public Works Center (PWC) Environmental Department San Diego, California is home to the Navy west coast Site Characterization and Analysis Penetrometer System (SCAPS). SCAPS has been extensively used at several Navy sites since 1995 to provide real-time, high-density data sets. The United States Environmental Protection Agency's (EPA's) Triad approach provided an ideal framework for optimizing the use of the Navy SCAPS during a volatile organic compound (VOC) source investigation at Installation Restoration Site 1114 at Marine Corps Base Camp Pendleton. All three elements of Triad, systematic planning, dynamic work strategy, and use of real time measurement tools, were implemented to manage decision uncertainty and expedite the site management process. The investigation was conducted using the Navy SCAPS outfitted with a cone penetrometer), membrane interface probe and a direct sampling ion trap mass spectrometry detector which allowed for real- time collection of over 690 feet of continuous lithologic information and VOC concentration data. These data were used collaboratively with 24-hour turnaround EPA 8260B VOC groundwater results from temporary direct-push wells to support the conclusion of a limited source area. Implementation of the Triad approach for this investigation provided an expedited high-density data set and a refined Conceptual Site Model (CSM) in real time that resulted in cost savings estimated at $2.5 M and reduction of the site characterization and cleanup schedule by approximately 3 years. This project demonstrates how EPA's Triad approach can be applied to streamline the site characterization and cleanup process while appropriately managing decision uncertainty in support of defensible site decisions.

INTRODUCTION

The U.S. Environmental Protection Agency (EPA) is coordinating with other federal and state agencies to educate the environmental community in the implementation of the Triad approach to effectively manage decision uncertainty. In this effort, experienced practitioners are working with regulators to demonstrate how this approach can be successfully applied to specific sites. For the U.S. Navy Public Works Center (PWC), the process also incorporates promoting the integration of internal capabilities (i.e., the Site Characterization and Analysis Penetrometer System (SCAPS)) with the goal of conducting "better, faster, and cheaper" (Crumbling, et al 2003) environmental investigations and defensible site closures.

This article presents an example of the practical implementation of Triad concepts as applied by the Navy PWC to a volatile organic compound (VOC) groundwater investigation. This study focused on key Triad elements - systematic planning, dynamic work strategy, and collection of real-time measurements.

SITE BACKGROUND AND HISTORY

Marine Corps Base (MCB) Camp Pendleton is the primary Marine Corps amphibious training center on the west coast, located between Los Angeles and San Diego, California, and encompasses approximately 125,000 acres. The subject site (Installation Restoration (IR) Site

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1114) is located adjacent to the west and cross gradient of, IR Site 9, a former waste stabilization pond in the 41 Area (Exhibit 1). IR Site 9 is located in an area with minimal historic development restricted to dirt roads, the former waste stabilization pond, and a former grease disposal pit. The Base Master plan restricts site land-use to military training (Innis-Tennebaum Architects, Inc., 1990). The site vicinity is also part of a larger region reserved for habitat preservation. An area developed with housing and light industrial properties is located approximately ½ mile upgradient of the site.

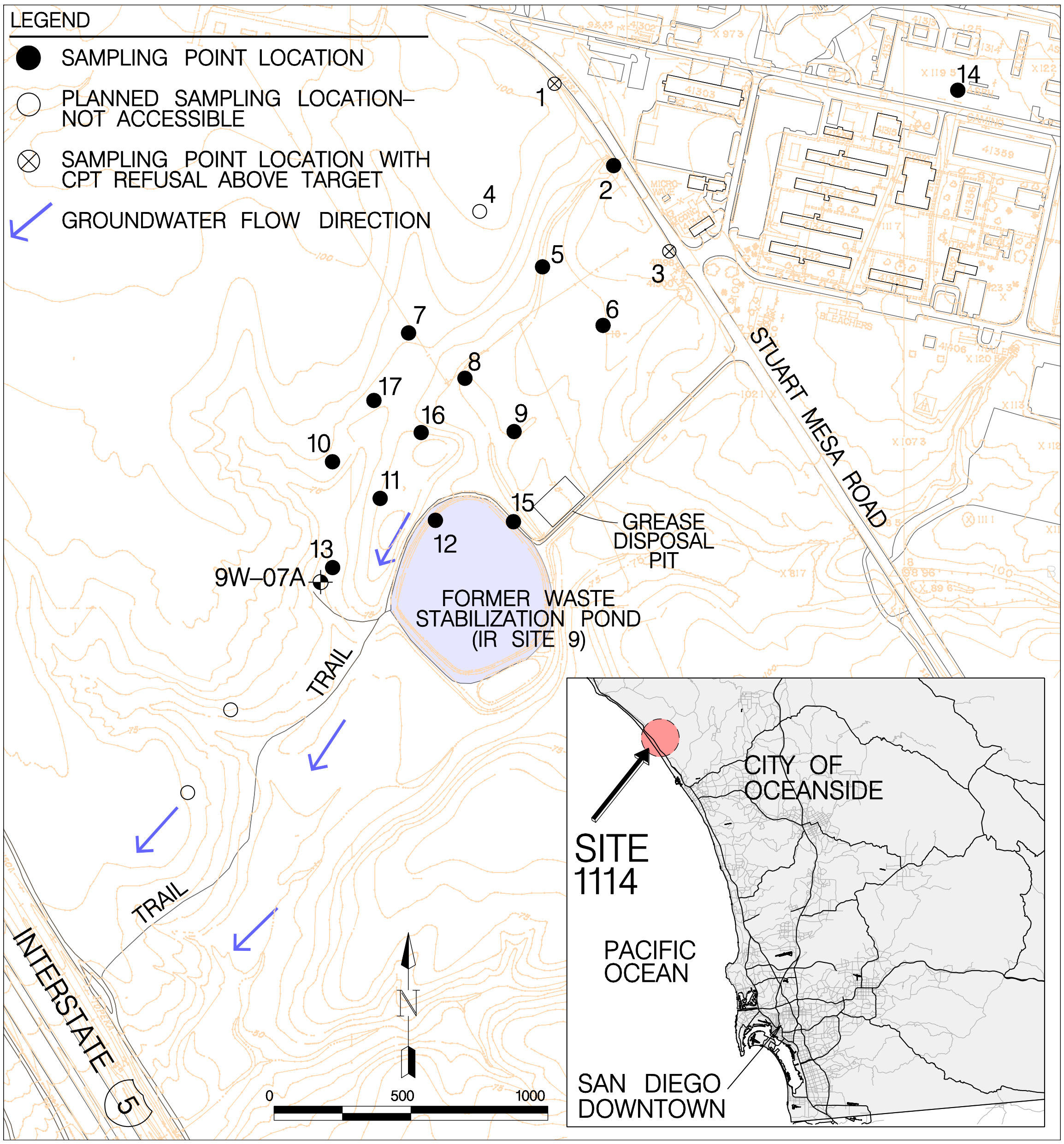

Exhibit 1. IR Site 1114 Map.

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The Record of Decision (ROD) for IR Site 9 documents the selection of monitored natural attenuation (MNA) as the remedy for groundwater, with effectiveness measured by long-term groundwater monitoring. The five-year review conducted to assess groundwater conditions indicated that tetrachloroethene (PCE) concentrations measured in one monitoring well identified as 9W-07A (Exhibit 1) increased steadily through time until they exceeded drinking water standards. The inconsistency of these results with the MNA prediction resulted in additional soil and groundwater sampling, which ultimately ruled out IR Site 9 as the source of PCE in groundwater (PWC, 2003). The suspected off-site source of VOCs detected in monitoring well 9W-07A was addressed as new IR Site 1114, designated in the 41 Area Arroyo. The boundaries of IR Site 1114 were defined based on results of the investigation discussed in this article.

OBJECTIVES

The IR Site 1114 investigation had two primary objectives:

1) The first objective was to identify potential source area(s) of target VOCs to groundwater. Target VOCs for the site are PCE and related degradation products trichloroethylene (TCE), dichloroethylene (DCE) and vinyl chloride (VC).

2) The second objective goal was to delineate the area where target VOCs exceed state or federal maximum contaminant levels (MCLs) in groundwater.

This investigation was conducted following the U.S. EPA's Triad approach, with the goals of streamlining the sampling, analysis, and data interpretation process to expedite decisions regarding site management and appropriate action.

OPTIMIZING THE INVESTIGATION USING TRIAD

Based on the project objectives, the key Triad elements including systematic planning, a dynamic work strategy, and use of real time measurement technologies were implemented in this investigation. A discussion of each of these elements as they were applied to this study is presented below.

Systematic Planning

Systematic planning is a central element of Triad, and is critical to maximizing project efficiency and effectiveness. The optimization strategy for this investigation involved an augmentation of EPA's seven-step Data Quality Objectives (DQO) planning process to focus on managing decision uncertainty rather than analytical uncertainty alone. Systematic planning involved defining project team roles and responsibilities, communication, decision-making logic, and a review of the preliminary CSM.

In an initial systematic planning meeting, the basic concepts of the Triad approach were presented, an experienced project team was created, and one agency point of contact was identified and given the authority to represent all other agencies. Agency partners and project team members on this project included representatives of the San Diego Regional Water Quality Control Board (RWQCB), U.S. EPA, California Department of Toxic Substances Control (DTSC), Navy Southwest Division (SWDIV), and the Navy PWC. The meeting set the stage for engaging stakeholders' participation and bringing consensus to project decisions, uncertainties, and the tools proposed to manage these uncertainties.

A preliminary CSM for IR Site 1114 was developed based on data gathered during previous investigations at IR Site 9, and available historical information such as maps, aerial photographs, and previous facility operations. Available information on the lithology beneath IR Site 1114 was limited to a single boring log from monitoring well 9W-07A, which indicated interbedded layers of silt, sandy silt, clay, and sand.

The preliminary CSM postulated that an upgradient release of PCE was migrating vertically from the source(s), most likely located in the upgradient developed area, until reaching a layer of less permeable sediments that would allow for lateral migration. Considering that PCE could potentially be present in dense non-aqueous phase liquid (DNAPL) or in dissolved phase, it became clear that this initial CSM was lacking the level of detail needed to understand geologic heterogeneities that are known to strongly influence the distribution of contaminants in the subsurface. With this understanding and as part of the CSM optimization strategy, a primary data quality objective was the lithologic characterization of the site.

PCE was identified as the primary compound of concern (COC) at the site, because it is the only contaminant detected at concentrations exceeding groundwater MCLs. In the systematic planning meeting, the team agreed that the MIP/DSITMS (membrane interface probe/direct sampling ion trap mass spectrometry) interface would be calibrated to detect and quantify PCE, TCE, and DCE. If at any time during the investigation other VOCs were identified, a new calibration curve including the unexpected analyte(s) would be generated. This adaptive aspect of the field analytical program, referred to as focused quality control (QC) using Triad terminology, allows for a more effective way to manage both analytical (allowing higher frequencies of QC samples) and sampling uncertainty (allowing an increase in data density).

Dynamic Work Strategy

To accomplish project objectives in support of the decisions that had to be made, the investigation was designed to occur in four linked phases during one field mobilization.

- **Phase I – Preliminary Assessment:** This phase involved the collection and interpretation of existing data, historical records, and general site information to identify potential source areas and support the preliminary CSM.

- **Phase II – Lithologic and Groundwater Investigation:** The intent of this phase of the investigation was to define lithology, provide sufficient analytical data to assess the lateral extent and vertical profile of dissolved VOCs, and guide data collection during the Phase III Focused Source Area Investigation. Three approximately 1,900-foot long sampling transects were planned running from well 9W-07A, where PCE has been consistently reported since 1992, to the upgradient developed area (Exhibit 1). Pre-determined sample locations were positioned at approximately 500-foot intervals along each transect, reflecting some of the logistical constraints to the dynamic nature of this investigation that were imposed by road access, sensitive habitat, and terrain. Given the extensive site area (approximately 325 acres), these sample locations were designed to provide data density adequate to support the Focused Source Area Investigation.

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Groundwater samples were analyzed with 24-hour turnaround time using U.S. EPA Method 8260B by a mobile laboratory unit located close to the site. The expedited turnaround time on these results allowed for near real-time decision-making. In order to comply with the Navy's internal directives, ten percent verification groundwater samples were submitted to a fixed laboratory (the Navy Environmental Laboratory at North Island) for VOCs analysis using U.S. EPA Method 8260B.

- **Phase III – Focused Source Area Investigation:** Upon evaluation of the results from Phases I and II, Phase III was planned to assess the area adjacent to, and upgradient of, monitoring well 9W-07A for potential VOC sources. Phase III employed the Navy SCAPS, equipped with a modified CPT and a MIP paired with an on-board DSITMS. The CPT and MIP/DSITMS can rapidly acquire nearly continuous lithologic and VOC concentration data.

- **Phase IV – Installation of Permanent Monitoring Wells:** This Phase was designed as a contingency phase for the installation of permanent groundwater monitoring wells, if necessary. Based on data generated during Phases II and III, and as agreed by the regulatory authorities, Phase IV was not conducted.

Data from each phase was used to guide subsequent phases of investigation, resulting in a collaborative data set comprising multiple lines of evidence.

Real-Time Measurement Technologies

Based on the target contaminants (VOCs), and the need to obtain data in support of real-time decisions, the following tools were selected:

- **CPT**: This technology was selected to provide real-time continuous lithologic data. Specifically, the CPT was used to determine sand layers correlating to the screened interval of monitoring well 9W-07A and to identify other potential preferential migration pathways. Data from CPT logs were used to determine the optimum screened interval for adjacent temporary direct-push wells. The field technical team incorporated the CPT data into an evolving CSM.

- **Temporary Direct Push Wells:** Selection of this technology for groundwater characterization allowed the design, construction, sampling, analysis and destruction of temporary wells within one week, yielding a site-wide and cost-effective data set. Groundwater samples collected from temporary direct push wells were submitted for 24-hour turnaround 8260B VOC analysis.

- **Global Positioning System (GPS):** A differentially corrected GPS in carrier-phase mode was selected to collect spatial data in real time during the investigation. The field technical team used GPS elevation measurements to correct the CPT data for topographical variations between push locations.

- **24-Hour Turnaround Time EPA 8260B:** Groundwater samples were analyzed by EPA Method 8260B using a gas chromatograph/mass spectrometer (GS/MS) with method reporting limits equal to 1 microgram per liter (µg/L) and a target list of analytes consistent with the standard VOC list reported by most laboratories. Data generated from these analyses were intended to guide the location of MIP/DSITMS direct pushes for the Phase III Focused Source Area Investigation.

- **MIP/DSITMS:** The MIP is a permeable membrane device designed for the subsurface assessment of VOCs. A thin Teflon film membrane is impregnated into a stainless steel screen on the face of the probe. This membrane is heated to 100 – 120 degrees Celsius, leading to quick diffusion of VOC contaminants across the membrane and into the helium carrier gas, which flushes the back of the membrane and transports the contaminants to the above-ground DSITMS detector.

  The DSITMS, which evaluates in-situ concentrations of VOCs in real-time, was selected as the detector for the MIP. Based on experience at other sites, a nominal detection limit of 200 part per billion (ppb) for the MIP was used for systematic project planning. The MIP/DSITMS, incorporated with a lithologic CPT sensor, enabled the identification of contaminant distribution and migration pathways in real time.

These real-time measurement technologies yielded a combined data set that was used collaboratively to provide a refined understanding of the distribution of PCE in the subsurface. The use of collaborative data sets was an essential element in the weight of evidence approach employed during this investigation.

FIELD ACTIVITIES

In addition to the typical field mobilization activities (including well permits, utility clearance, and conducting GPS survey of planned sample locations), some additional mobilization tasks were conducted. These included the establishment of the field technical team, construction of dirt access roads, establishing an Internet file transfer protocol (FTP) site for the communication of field data and project decisions, and conducting a field survey to identify ecologically sensitive, off-limit areas in coordination with MCB natural resource staff.

Dirt roads were constructed to provide access to proposed sample locations. Because the site comprises endangered species habitat, road construction required review and approval by a base biologist, vernal pool specialist, archeologist, and ornithologist. Several road routes were revised as a result of this environmental review. In addition, the project schedule was reviewed to ensure that fieldwork would not conflict with nesting seasons, which preclude work between August and February.

SCAPS was used to collect CPT data at thirteen locations (locations 1 through 3 and 5 through 14 on Exhibit 1). The CPT data was corrected for topographic variations and incorporated into the evolving CSM. Roads to proposed location 4 and two locations downgradient (not numbered on Exhibit 1) from well 9W-07A were muddy and inaccessible during the investigation. Pushing in several locations was very difficult, requiring cycling and an increase in factory pre-set push power standards.

Twelve temporary direct push wells were constructed during Phase II. The field technical team used the real-time CPT data to design the temporary direct-push well adjacent to the CPT push location. Based on this evaluation, one depth-discrete groundwater sample was collected from each temporary direct push well. Each temporary well was constructed with a five-foot screen.

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Groundwater samples were collected using the low-flow sampling technique, with the exception of one sample, which was collected using a bailer due to low groundwater yield.

Exhibit 2 presents a summary of screened intervals and groundwater quality data for each temporary direct push well. The wells were designed to sample sand layers that would be probable preferential pathways to the screened interval of monitoring well 9W-07A, as well as to evaluate the vertical extent of the contamination. Temporary wells were not completed at proposed locations 1 and 3 due to shallow refusal. Two differently screened temporary wells were constructed at locations 11 and 13 to assess discrete lithologic units identified by the adjacent CPT logs.

	Elevations (feet above mean sea level)			**Groundwater Sample Analytical Summary (micrograms per liter)**		
Well Identifier	**Surface**	**Top of Screen**	**Bottom of Screen**	**PCE**	**TCE**	**DCE**
Well 2	98.2	41.2	36.2	<1	<1	<1
Well 5	84.0	47.0	42.0	<1	<1	<1
Well 6	86.1	42.1	37.1	<1	<1	<1
Well 7	87.1	27.1	22.1	<1	<1	<1
Well 8	78.6	30.6	25.6	<1	<1	<1
Well 9	77.2	43.2	38.2	<1	<1	<1
Well 10	83.4	49.4	44.4	<1	<1	<1
Well 11A	89.7	34.7	29.7	<1	<1	<1
Well 11B	89.7	28.7	23.7	<1	<1	<1
Well 12	78.1	21.1	16.1	<1	<1	<1
Well 13A	69.8	44.8	39.8	**54**	**4.6**	<1
Well 13B	69.4	38.4	33.4	**17**	<1	<1

Exhibit 2. Summary of screened intervals and groundwater quality data for temporary wells.

Thirteen SCAPS MIP borings were advanced, twelve at locations southwest of Stuart Mesa Road (locations 5 through 13 and locations 15 through 17), and one (location 14) located northeast of Stuart Mesa Road in a topographic low area that collects runoff from the tank maintenance facility (Exhibit 1). Because the calibrated detection limit of the new MIP probe was relatively high, a non-critical data point was selected as the first MIP push (location 5). Detection limits at subsequent locations was 250 ppb. In accordance with the adaptive nature of Triad, the number of MIP measurements was increased in density at key areas of interest, including location 13 adjacent to monitoring well 9W-07A, and near the water table subsequent to identifying the contaminant concentration pattern at location 11.

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QUALITY ASSURANCE (QA)/QUALITY CONTROL (QC) PROCEDURES

Given the dynamic nature of the investigation, a number of quality assurance measures were implemented to monitor conformance with the established framework for making real-time decisions. Unlike traditional investigations, real-time review of analytical results is essential to support an accurate refinement of the CSM. This strategy offers an opportunity to implement immediate corrective action and adjust the QC scheme, as necessary, to support defensible decision-making. The QA process was also designed to incorporate open and ongoing communication between the technical team members and the regulatory oversight agencies during field activities.

One key element of the field QA process involved the review of QC measurements in near real-time to ensure that field decisions were being made based on effective data. While the QC measurements for the EPA Method 8260B employed traditional fixed laboratory routines, the QC strategy for the MIP/DSITMS focused on managing uncertainties in the data that could directly impact field decisions. Instrument stability and reproducibility checks were performed daily by conducting instrument calibration and running calibration check standards and blanks throughout the day. The frequency of the QC checks was adaptive in nature and a function of the analytical performance in the context of an evolving CSM. For example, an excessive number of unexpected non-detects would result in a higher frequency of calibration checks at lower concentrations to control analytical uncertainty within the lower range of the calibration curve. Comparison of data generated from the MIP/DSITMS with CPT logs and groundwater quality data from temporary direct push wells provided another QC check by combining knowledge of subsurface heterogeneity with potential instrument response variability.

Quality control measures associated with samples analyzed by EPA Method 8260B included the analyses of laboratory control samples (LCS), matrix spike (MS) and matrix spike duplicates (MSDs), surrogate spikes, field duplicates, method blanks, and field blanks. Quality control sample results were evaluated in conjunction with sampling procedures and the evolving CSM to determine overall data quality and whether data usability goals had been met. The evaluation was documented in data quality review forms and integrated with the daily summary reports for posting on the project FTP site.

REAL-TIME DATA MANAGEMENT TOOLS

Initial systematic project planning proceeded from a preliminary CSM that predicted VOC concentrations in groundwater would increase towards the direction of the developed areas upgradient of well 9W-07A. The initial CSM also predicted that the dissolved contamination would be migrating along preferential pathways consisting of thin sandy layers, perhaps representing old stream channel deposits. In anticipation of a complex migration pattern, the project team planned to use the three-dimensional data-visualization modules in the Groundwater Modeling System software package to maintain and present the evolving CSM and the collaborative data sets. Data would be processed on board the SCAPS truck in near real-time, and posted on the FTP site each night.

However, as the investigation progressed and the vast majority of the contaminant data was non-detect, it became clear that computerized data visualization was not needed to support project decisions. The data management methods were adapted to simply and effectively meet the needs of the decisions. During the Phase II Groundwater Investigation, CPT printouts were used as a base figure to design the screened intervals for the temporary direct push wells. The well design was documented by hand drawing and notating the CPT logs. The logs were then scanned each night and posted to the FTP site for review by the project team and regulators. During the Phase III Focused Source Area Investigation, MIP/DSITMS data (nearly all non-detect), was compared to the Phase II CPT logs, and the findings were documented and communicated to the project in the daily narrative report, posted to the FTP site at the conclusion of each field day.

Effective implementation of the Triad approach required open and ongoing communication between the field technical team and agency partners during critical phases of data acquisition and interpretation. As described above, the field team posted available data and daily summary reports on the FTP site at the end of each field day for agency reference. Daily summary reports included a description of work conducted, data collected, and field decisions with supporting rationale. The objective of this Triad project was to be transparent and interactive in the acquisition and interpretation of site data and in forging collaborative decisions.

RESULTS

Review of historic land use, facility operations, and chemical use yielded two areas of interest. No history of industrial operations or development southwest of Stuart Mesa Road was found. One area of interest was a tank maintenance facility near push location 14 northeast of Stewart Mesa Road. Military tanks were reportedly serviced in this area from the mid-1950s through the 1990s. Chemicals were reportedly used in the cleaning and servicing operations, however facility personnel did not recall the cleaning agents used.

A second area of interest was identified north of the Former Waste Stabilization Pond. This area was rumored to have been used for equipment disassembly. Specifically, fuel tanks from a hovercraft were reportedly dismantled in this area. Such equipment parts were not identified in site walks of this area, and no supporting facility with mechanical tools and equipment has been identified in this area.

Consistent with the boring log from well 9W-07A, CPT logs from this investigation indicate a lithology characterized by interbedded layers of silt, sandy silt, clay, and sand.

Groundwater analytical results from the twelve temporary direct push wells installed during the Phase II Lithologic and Groundwater Investigation are summarized in Exhibit 2. Target VOCs were not detected in ten of the temporary wells including 2, 5, 6, 7, 8, 9, 10, 11A, 11B, and 12.

Target VOCs were identified in groundwater samples at location 13, adjacent to monitoring well 9W-07A. Groundwater samples collected from temporary direct push well 13A contained TCE and PCE in reported concentrations of 4.6 and 54 μg/L, respectively. Groundwater samples collected from temporary direct push well 13B contained PCE in a reported concentration of 17 μg/L. The results of this Lithologic and Groundwater Investigation did not support a source area in the developed area upgradient of the site. Although the team had prepared for a Phase III Focused Source Area Investigation in the developed area by pre-clearing many potential locations for underground utilities, the project team with regulatory concurrence decided to modify the field program and move the Focused Source Area Investigation to the undeveloped areas closer to well 9W-07A.

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During the Phase III investigation, over 690 linear feet were assessed for VOCs by MIP/DSITMS. PCE was identified at location 11, in three continuous measurement intervals. The greatest PCE concentration, 1,000 ppb, was identified in location 11 between 42.5 to 44.4 feet bgs. PCE concentrations attenuated sharply with depth, with a concentration of 500 ppb measured in the 44.4 to 45.5 foot interval, and an estimated concentration of 100 ppb in the 45.5 to 46.4 foot interval. The 100 ppb value was reported even though this concentration was outside the calibration range, and is equivalent to a fixed laboratory "J" flagged value. Target VOCs were not detected at any other MIP location. The lateral and vertical extent of PCE measured in location 11 is bracketed by locations 10, 17, 16, 12, and 13, representing up-, down- and cross-gradient samples. With these data, PCE in location 11 is bounded laterally within approximately 200 feet, and vertically within 10 feet.

Several MIP borings were added to address specific agency partner concerns. Location 15 was added to address a potential data gap associated with the IR Site 9 Former Grease Pit (Exhibit 1). Location 16 was added to increase data density and CSM resolution between location 11 where PCE was identified, and location 8 where PCE was not detected. Location 17 was added at the request of the RWQCB, to increase data density and assess the impact of surface drainage in that area.

Following standard operating procedures (SOPs), a calibration check was run prior to and following each MIP push. Following the initial push with the new probe at location 5, the MIP detection limit was consistently in the 250 ppb range with two exceptions. At location 10, MIP detection limits were qualified as estimated due to the post push calibration check being outside the acceptance criteria. The system was recalibrated prior to the next push. Review of groundwater results at this location by the project team led to a decision to accept MIP data from location 10 as non-critical in the context of project objectives. The decision allowed additional data to be collected from other locations, given the schedule constraints. At location 17, at a depth of 42.5 feet, a pressure loss occurred in the MIP system, and a small tear was observed in the membrane during post-push tests at the surface. The post-push calibration check yielded a 50 percent response, resulting in an adjusted MIP detection limit of 500 ppb at location 17 between 42.5 feet and the total depth at 50 feet bgs.

Data Quality Assessment

Overall data quality was determined based on the evaluation of both sampling and analytical variability. The elements affecting sampling variability such as matrix type, sample collection, handling, and overall adherence to SOPs were assessed qualitatively as part of the QA oversight for this project. Analytical uncertainty was evaluated based on the type of analytical tool used (MIP/DSITMS or GC/MS) and the review of associated QC parameters including system calibration. Potential data usability issues were evaluated in relation to the CSM to ensure that the data would support field decisions. Data quality assessment results were documented in daily summary reports and posted to the project FTP site.

- **EPA 8260B:** All quality control parameters reviewed in association with EPA Method 8260B were within the established limits for analytical precision and bias. No problems resulting from the evaluation of sampling uncertainty were identified that would limit the usability of these data for its intended purpose.

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- **MIP/DSITMS:** Following the SOP, QC measures for the MIP/DSITMS interface included daily calibration and continuing calibration checks prior to and following each push. QC measures consisted of verification check standards ranging from 250 to 2,000 ppb as well as system blanks to monitor instrument stability and reproducibility over time. With the exception of two MIP locations (MIP 10 and MIP 17), calibration checks were generally well within the established acceptance criteria. The post-push calibration checks at these two locations yielded a response below the acceptance criteria, resulting in adjusted detection limits. Groundwater sample results at these same locations provided a collaborative data set, which supported project conclusions and recommendations.

SUMMARY AND CONCLUSIONS

The integrated results of this investigation provided a robust CSM, identified IR Site 1114 lithologic conditions, preferential pathways, and a limited VOC presence. Over 690 feet of continuous VOC data were collected using SCAPS-MIP/DSITMS, in addition to detailed lithologic data from CPT logs and groundwater quality data from temporary direct push wells.

The greatest VOC concentration was 1,000 ppb PCE identified by the MIP/DSITMS at location 11 within a 2-foot interval at the water table. PCE concentrations attenuate sharply with depth, decreasing an order of magnitude within two feet of the highest measured concentration. Target VOCs were not detected below 46.5 feet bgs. The vertical distribution of VOCs was further supported by the temporary direct push groundwater data set.

The PCE identified in location 11 is bounded laterally within approximately 200 feet, and vertically within 10 feet. PCE is vertically stratified, with greatest concentrations measured at, or near, the water table. PCE concentrations indicate a dilute source. Dense non-aqueous phase liquid conditions and product-level concentrations were not encountered.

There are no complete pathways linking the PCE identified at IR Site 1114 to receptors. The depth of contamination is over 40 feet bgs, and the site is overlain by protected endangered species habitat, and is therefore not subject to development. Finally, the site is located approximately ½ mile upgradient from the non-beneficial use boundary.

In consideration of these findings, a recommendation of no further action was made. Regulatory agency partners have tentatively concurred, and site closure is currently in progress. Implementation of the Triad approach using the SCAPS-MIP/DSITMS coupled with expedited turnaround groundwater data generated from traditional EPA Method 8260B provided a high-density data set, identification of preferential pathways for contaminant migration, and a refined CSM which resulted in expedited site closure with agency concurrence. Cost savings estimated at $2.5 M were realized, and the site characterization and cleanup schedule was reduced by approximately 3 years.

REFERENCES

Crumbling, D.M., J. Griffith, & D.M. Powell. (2003). Improving Decision Quality: Making the Case for Adopting Next Generation Site Characterization Practices. Remediation 13: 2, 91-111. Available: http://cluin.org/download/char/spring2003v13n2p91.pdf

This is a preprint of an article published in the Winter 2004 issue of *Remediation: The Journal of Environmental Cleanup Costs, Technologies & Techniques, Vol. 15,* No. 1, pp. 57-68. The published reprint is available through http://www.interscience.Wiley.com/

Innis-Tennebaum Architects, Inc. (1990). Marine Corps Base Camp Pendleton, California Masterplan Volumes I and II, Draft. Prepared for Southwest Division Naval Facilities Engineering Command. August.

Public Works Center San Diego (2003). Preliminary Final Technical Memorandum, Summary of Soil and Monitoring Well Sampling, IR Site 9, 41 Area Stabilization Pond, Marine Corps Base Camp Pendleton, California, July.

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