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INTEGRATED PRODUCT TEAM WEST
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IN REPLY REFER TO

Ser 05/035
October 13, 2004

Mr. Phillip A. Ramsey
U.S. Environmental Protection Agency
Region IX
75 Hawthorne Street
San Francisco, CA 94105

Re: FINAL MONITORING PLAN FOR THE LITIGATION AREA, NAVAL WEAPONS STATION SEAL BEACH, DETACHMENT CONCORD, CONCORD, CALIFORNIA

Dear Mr. Ramsey,

In accordance with Sections 10.2 (b) and 10.7 (e) of the Federal Facility Agreement (FFA), enclosed please find for your information the "Final Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach, Detachment Concord." The comments received by the Navy on the draft version of this Secondary document (dated April 30, 2004) are included in Appendix B along with the Navy's responses.

2. If there are any questions regarding the enclosed plan, please contact me at telephone No. 650-746-7451 or Internet e-mail: stephen.f.tyahla@navy.mil.

Sincerely,

Stephen F. Tyahla, P.E., CHMM
Lead Remedial Project Manager

Enclosure
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U.S. Fish and Wildlife Services (Attn: Beckeye Stanton)
National Oceanic and Atmospheric Administration (Attn: Denise Klimas)
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California Department of Toxic Substances Control Region 1 (Attn: Jim Pinasco)
California Regional Water Quality Control Board, SFBAY (Attn: Laurent Meillier)
California Department of Fish and Game (Attn: Frank Gray)

Re: FINAL MONITORING PLAN FOR THE LITIGATION AREA, NAVAL WEAPONS STATION SEAL BEACH, DETACHMENT CONCORD, CONCORD, CALIFORNIA

Copy to (continued):
Restoration Advisory Board (RAB) Co-Chair (Attn: Ms. Mary Lou Williams)
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Contra Costa Mosquito & Vector Control District (Attn: Karl Malamud-Roam)

GENERAL SERVICES ADMINISTRATION
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Monitoring Plan for the Litigation Area

Naval Weapons Station Seal Beach Detachment Concord
Concord, California

GSA.105.00023

FINAL

October 13, 2004

Engineering Field Activity West
Naval Facilities Engineering Command
San Bruno, California

TETRA TECH, INC.

GENERAL SERVICES ADMINISTRATION
Contract No. 10F-0076K
Order No. N62474-03-F-4023
GSA.105.00023

Final

MONITORING PLAN FOR THE LITIGATION AREA

Naval Weapons Station Seal Beach Detachment Concord
Concord, California

October 13, 2004

Prepared for

DEPARTMENT OF THE NAVY
Engineering Field Activity West
Daly City, California

Prepared by

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ACRONYMS AND ABBREVIATIONS

µg/L	Microgram per liter
^{210}Pb	Lead-210
AWQC	Ambient water quality criteria
BERA	Baseline ecological risk assessment
bgs	Below ground surface
CCC	Criterion continuous concentration
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	Chemical of concern
COE	U.S. Army Corps of Engineers
CPC	Chemical Pigment Company
DDT	Dichlorodiphenyltrichloroethane
DQO	Data quality objectives
EPA	U.S. Environmental Protection Agency
EPC	Exposure Point Concentration
ER-L	Effects-range low
ER-M	Effects-range median
ES	Environmental Solutions, Inc.
FS	Feasibility study
FWS	U.S. Department of the Interior Fish and Wildlife Service
GCC	General Chemical Corporation
gpd	Gallon per day
GSA	General Services Administration
HQ	Hazard quotient
Honeywell	Honeywell International Incorporation
ICP/MS	Inductively coupled plasma and mass spectrometry
INRP	Integrated Natural Resources Management Plan
IT	International Technology Corporation
L/min	Liter per minute
LOE	Line of evidence
mg/L	Milligram per liter
mm/yr	Millimeter per year

msl	Mean sea level
Navy	U.S. Department of the Navy
NEDD	Navy Electronic Data Deliverable
NOAA	National Oceanic and Atmospheric Administration
NWS SBD	Naval Weapons Station Seal Beach Detachment
PCB	Polychlorinated biphenyl
PRC	PRC Environmental Management, Inc.
QEA	Qualitative ecological assessment
QAPP	Quality assurance project plan
RASS	Remedial action subsite
RI	Remedial investigation
ROD	Record of decision
RWQCB	San Francisco Bay Regional Water Quality Control Board
SAMTRAK	Tetra Tech's Sample tracking database
SARA	Superfund Amendments and Reauthorization Act
SVOC	Semivolatile organic compound
Tetra Tech	Tetra Tech EM Inc.
TDS	Total dissolved solids
TOC	Total organic carbon
TRV	Toxicity reference value
UCL	Upper confidence limit
USACE	U.S. Army Corps of Engineers
VOC	Volatile organic compound
WES	Waterways Experiment Station
WOE	Weight-of-evidence
XRF	X-ray fluorescence

1.0 INTRODUCTION

The U.S. Department of the Navy (Navy), Naval Facilities Engineering Command, Engineering Field Activity West, tasked Tetra Tech EM Inc. (Tetra Tech) to develop a revised long-term monitoring plan for Litigation Area sites at the Naval Weapons Station Seal Beach Detachment (NWS SBD) Concord, Concord, California. The purpose of the revised long-term monitoring plan is to develop a focused monitoring program using the data quality objectives (DQO) process, as recommended in the 5-year periodic review assessment report (Tetra Tech 2003). This is a revision of the original monitoring plan developed by the U.S. Army Corps of Engineers (USACE) in 1989 (Lee and others 1989).

The long-term monitoring plan is a requirement under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA), in cases where (1) contaminants are left in place and (2) the record of decision (ROD) was signed after October 1986. The revised long-term monitoring plan was prepared using the DQO process (EPA 2000a) and follows the U.S. Environmental Protection Agency's (EPA's) framework approach for developing monitoring plans at hazardous waste sites (EPA 2004). The objectives of the revised monitoring plan can be grouped into four categories: (1) demonstrate compliance with regulatory requirements, (2) assess effectiveness of prior remedial activities, and (3) identify changes in site conditions, and (4) assess ongoing risk to ecological receptors.

The revised monitoring plan is organized as follows: Section 1.0 provides an overview of the document, Section 2.0 discusses development of the monitoring objectives, Section 3.0 provides details of the individual monitoring components, Section 4.0 presents the data management plan, and Section 5.0 lists the references used in preparing this plan. Applicable figures and tables are provided at the end of each respective section. Information on key statistical concepts as well as an overview of selected methods that will be used to analyze monitoring data for the Litigation Area, are provided in Appendix A. Responses to agency comments are provided in Appendix B, and the Sampling and Analysis Plan (Field Sampling Plan/Quality Assurance Project Plan) [FSP/QAPP]) is Appendix C.

1.1 SITE BACKGROUND

NWS SBD Concord is in north-central Contra Costa County, approximately 30 miles northeast of San Francisco, California (Figure 1-1). The Navy facility includes an ocean-shipping terminal to transfer ordnance from trucks or railcars to ships that, since 1999, has been used by the U.S. Army. The facility is bounded on the north by Suisun Bay, on the south and west by the city of Concord (population 121,000), and on the east by private land and the city of Pittsburg. It encompasses nearly 13,000 acres in two holdings known as the Inland Area and Tidal Area (Figure 1-1).

The Tidal Area is composed of property on the mainland (6,077 acres) and islands (1,571 acres). Piers and most other facilities in the Tidal Area are part of the original property of the Naval Magazine, Port Chicago. In the late 1960s and early 1970s, the Navy purchased several parcels

of land to create a buffer zone around the Tidal Area. Eight of those parcels, which cover a total of 307 acres, were later found to be contaminated. Subsequent litigation with the prior owners resulted in settlements, and the parcels became known as the Litigation Area. During the remedial investigation (RI) and feasibility study (FS) conducted by the U.S. Army Corps of Engineers (USACE) Waterways Experiment Station (WES) for the Navy, the parcels were grouped into the following four remedial action subsites (RASS) (Figure 1-2).

- RASS 1 is a 210-acre site adjacent to Suisun Bay that is composed of tidally influenced brackish wetland with minimal upland and associated transitional zone habitat.
- RASS 2 consists of 13 acres of upland, wetland, and transitional habitat and lies directly south of RASS 1.
- RASS 3 consists of 71 acres of primarily upland and lies south of RASSs 1 and 2. RASS 3 also contains a small emergent tidal marsh and an ephemeral stream, Nichols Creek.
- RASS 4 consists of 13 acres of upland and nontidal wetland areas 1.5 miles east of RASSs 1, 2, and 3.

The RI for the Litigation Area was completed by WES in 1988 and identified six metals (arsenic, cadmium, copper, lead, selenium, and zinc) as chemicals of concern (COC) (Lee and others 1986, 1988). The final FS, submitted in September 1988, recommended remedial alternatives and cleanup criteria for soil at each RASS (Cullinane and others 1988). On April 6, 1989, the Navy issued a final remedial action plan (Navy 1989a) and signed a ROD (Navy 1989b) for remediation of Litigation Area sites contaminated with metals.

The remedy required that some contaminated soil be left in place to avoid destroying sensitive wetland habitat for several threatened and endangered species. Each RASS was divided into three areas on the basis of the proposed action: active remediation, passive remediation, and monitoring (Navy 1989a, 1989b). Contaminated soil was excavated and removed in active remediation areas. Contaminated soil was left in place in passive remediation areas, and intensive monitoring was implemented. Monitoring areas consisted of portions of each RASS and required less intensive monitoring than the passive remediation areas.

Between 1992 and 1995, the Navy completed four remedial actions to remove contaminated soil at the Litigation Area, and revegetation was completed by 1996. The Navy implemented a monitoring plan as part of its remedial design to assess the effects and potential migration of contaminated soil left in place. After 5 years of post-remediation monitoring, the Navy completed a review assessment as required under CERCLA and amended by SARA in cases where (1) contaminants are left in place, and (2) the ROD was signed after October 1986. The main purpose of this 5-year review was to evaluate the implementation and effectiveness of the selected remedy and to assess whether any additional actions were necessary. The 5-year review identified deficiencies in the remedy and data gaps. Based on these findings, the 5-year review presented the following recommendations: (1) collect additional data in focused studies to address data gaps, (2) conduct a follow-on supplemental FS to address portions of the site that were not protected,

and (3) implement a focused monitoring program based on the DQO process. This revised monitoring plan is based upon the recommendations of the 5-year review report (Tetra Tech 2003), which included the following specific proposals for ongoing monitoring of the site:

- **Conduct Periodic Monitoring:** The Navy plans to collect samples to monitor conditions at the site in the future. In developing the monitoring plan using the DQO process, the Navy will meet with the regulatory agencies to assess monitoring requirements and will include the revised monitoring plan in the next annual amendment of the site management plan.
- **Implement the DQO Process:** The DQO process should be used to focus future monitoring objectives.
- **Focused Monitoring Efforts on Areas of Concern:** To make best use of limited resources, future monitoring should be focused on smaller portions of the site where unacceptable risk or continued contaminant migration is suspected.
- **Clearly Identify Temporal Scope:** Any future monitoring should include more specific temporal boundaries to (1) optimize and focus the scope and duration of monitoring efforts, (2) provide specific trigger levels for additional action, and (3) establish exit criteria for cessation of monitoring.
- **Link Monitoring to Risk-based Questions:** Any future monitoring should provide data needed to answer questions about risk and contaminant migration.
- **Consider Spatial Variability of Chemical Concentrations in Design:** Any future monitoring should take into account the observed variability in lateral and vertical distribution of contaminants in the design of the sampling program.
- **Clearly Identify Trigger Levels:** Any future monitoring should be closely tied to specific trigger levels for any contingency actions such as additional remediation or revision of the frequency of monitoring.

1.2 HISTORY OF MONITORING AT THE LITIGATION AREA

The "Monitoring Plan for Contamination Remediation at Naval Weapons Station, Concord, California" was prepared for the Navy by WES as part of the remedy (Lee and others 1989); the Navy's contractors carried out monitoring. The long-term monitoring plan established a program to monitor potential migration and ecological effects of contaminants left in place. The monitoring program set forth only general objectives and was significantly revised during its implementation. The following sections describe historical monitoring at the Litigation Area.

1.2.1 Preremediation Monitoring

The preremediation monitoring program included both chemical and ecological monitoring. Based on the RI conducted at the site (Lee and others 1986), the chemical monitoring program initially addressed six metals of concern: arsenic, cadmium, copper, lead, selenium, and zinc.

The Litigation Area and the two reference areas were overlaid with a 100-foot grid system to facilitate consistent location of the samples. Most sampling locations (approximately 75 percent) were concentrated along the boundaries between the active remediation areas, passive remediation areas, and monitoring areas (Figure 1-3). Approximately 25 percent of the sampling locations were randomly placed throughout the active, passive, and monitoring areas.

Samples for chemical analysis were collected for surface soil, sediment, and surface water. Surface soil samples were collected from 0 to 0.5 foot below ground surface (bgs). Several subsurface soil samples were collected from 0.5 to 1.0 and 1.0 to 1.5 feet bgs from areas where additional subsurface characterization was needed; however, these samples were not part of the regular monitoring program. Sediment samples were collected from 0 to 0.5 foot below the sediment surface in the bottom of the creek, ditches, sloughs, and ponds. Surface water samples were collected from overlying water at each sediment sampling location. Three replicate samples were collected at the same time at each soil and sediment sampling location to evaluate variability. Three rounds of surface water samples were collected at each location, with approximately 16 days between the rounds.

Preremediation ecological monitoring included vegetation, small mammal, and rail surveys. Vegetation surveys included vegetation characterization, plant community mapping, and a special status plant survey. The plant community mapping and special status plant survey were conducted throughout the Litigation Area. Vegetation characterization and small mammal surveys were conducted at 85 soil sampling locations. These locations are circled in red on Figure 1-3. For the small mammal surveys, several individual trapping sites were randomly located within a 100-foot by 100-foot grid at each location. The surveys of the California rail focused on documenting the presence of special status bird species (California clapper rail and California Black Rail) along four transects in the over 220 acre tidal marsh in RASS 1 and RASS 2.

1.2.2 Post-remediation Monitoring

Analysis of data collected before and during remediation required refinement of some aspects of the design of the post-remediation monitoring program. The Navy met with EPA and other agencies to discuss concerns about the monitoring design and to develop a revised monitoring program. Concerns included (1) bias in the sampling design, (2) the lack of samples in sloughs or ditches and other portions of the site, (3) the high variability of existing chemistry data and the feasibility of assessing changes using the original design, and (4) the artificial distinction between the monitoring and passive areas, since both were contaminated. The Navy and regulatory agencies agreed to redesign the monitoring program and to slightly alter the monitoring objectives. The revised objectives included the following (PRC Environmental Management, Inc. [PRC] 1997a):

- Objective 1: Collect data that will assist in evaluating long-term changes in site conditions.
- Objective 2: Evaluate potential contaminant migration to Suisun Bay (groundwater, surface water, and sediment).

- Objective 3: Assess whether the active remediation areas become recontaminated; if so, assess the extent of recontamination and potential sources.
- Objective 4: Evaluate contaminant migration in the unremediated areas.
- Objective 5: Monitor the overall habitat quality of the site, including the success of restoration and use of the site by special status plants and animals.
- Objective 6: Assess whether groundwater is contaminated.

The Navy agreed to add sampling locations across the site, including in the sloughs and ditches where few samples had been collected previously. The design was also changed to include randomly selected sampling locations and single, rather than triplicate, samples at each location. The Navy and the regulatory agencies agreed that this approach would allow for better characterization of contaminant levels on a broader spatial scale across the site.

For this approach, each RASS was divided into spatial units based on habitat type and topography for sampling under the monitoring program (Figures 1-2 and 1-4). These spatial units are described as follows:

- **Marsh Surface Reference Area (Unit 1):** For comparison, the northwestern corner of the marsh was proposed as the marsh reference area in 1995. The unit is relatively far from the source of contamination and probably represents regional ambient conditions related to deposition of chemicals from Suisun Bay or other sources.
- **Northern Marsh Surface (Unit 2):** The northern marsh surface unit is bordered on the north by Suisun Bay, on the west and south by Lost Slough, and on the east by Honeywell International Incorporation (Honeywell) property; the unit is tidally inundated.
- **Northern Ditches (Unit 3):** The northern marsh is bisected by a series of manmade mosquito ditches, where sediment and surface water have been sampled.
- **Southwestern Marsh Surface (Unit 4):** The area lies on the southwestern side of RASS 1 and is bordered by the northern and central reaches of Lost Slough on the north and east, Stevens Road on the west, and the railroad track berm on the south; the unit is tidally inundated.
- **Southwestern Ditches (Unit 5):** The southwestern marsh is bisected by a series of manmade mosquito ditches that are tidally inundated.
- **Central Marsh Surface (Unit 6):** The central marsh is just west of the RASS 1 remediated area (Unit 8), bordered by the transitional upland area of Unit 12 to the south, Lost Slough to the west, and to the north is separated from the northern marsh (Units 2 and 3) by a small slough.
- **Central Ditches (Unit 7):** The central marsh is bisected by a series of manmade mosquito ditches that are tidally inundated.

- **RASS 1 Remediated Area (Unit 8):** The marsh surface to the east of the central marsh and west of Honeywell property; this area was remediated to remove metals-contaminated soils.
- **Northern Lost Slough (Unit 9):** A natural tidal channel meandering through the Litigation Area marsh. The northern reach is closest to Suisun Bay and includes the mouth of the slough where it meets the bay.
- **Central Lost Slough (Unit 10):** The central reach of Lost Slough lies in a north-south orientation between the central and southeastern marsh; the portion of the slough is tidally connected to the RASS 3 pond through a small mosquito ditch.
- **Southwestern Reach of Lost Slough (Unit 11):** The smaller southwestern reach of Lost Slough runs westerly across Unit 4 and is a blind slough that narrows near its end on the western side of RASS 1.
- **RASS 2 Transitional Uplands (Unit 12):** This area consists of wetland and transitional upland between RASS 1 and the railroad berm; part of this unit includes the remediated area of RASS 2.
- **Nichols Creek and Pond (Unit 13):** Nichols Creek is a seasonal stream in RASS 3 that drains from the nearby hills and flows through the grassland habitat of Unit 13 into the pond at RASS 3 and eventually into Lost Slough. This area includes the remediated portion of RASS 3. Elevations range from approximately 27 feet above mean sea level (msl) in the southeastern area to approximately 7 feet above msl on the edge of the pond in the northwestern area.
- **RASS 4 Upland (Unit 14):** RASS 4 is approximately 0.5 mile east of the other RASSs and consists of upland habitat; part of Unit 14 includes the remediated area in RASS 4.
- **RASS 4 Wetland (Unit 15):** The emergent nontidal wetland in the eastern part of RASS 4 receives water from a drainage ditch from the surrounding upland habitat and housing development in the eastern part of RASS 4.
- **Upland Reference Area (Unit 16):** The upland reference area is bounded on the north by Port Chicago Highway and on the south by the Contra Costa Canal. This area is relatively far from and upgradient of the source of contamination and therefore probably represents regional ambient conditions related to deposition of chemicals from upland or other sources.

After remediation, the Navy annually conducted monitoring and prepared after-remediation remedial action monitoring reports for 5 years (PRC 1996, 1997a; Tetra Tech 1998, 1999, 2000). Figure 1-4 shows the locations sampled during the post-remediation monitoring events. Field monitoring activities included the following:

- Chemical analysis of soil, sediment, and surface water samples
- Ecological characterizations of avian, small mammal, and plant receptors
- Monitoring of revegetation success in remediated areas
- Toxicity tests (bioassays)
- Special studies to address contaminant migration concerns
- The dates and post-remediation monitoring activities during years 1 through 5 at the Litigation Area are listed as follows.

Activity	Year 1	Year 2	Year 3	Year 4	Year 5
Soil, sediment, and surface water sampling	August to September 1995	December 1996 to March 1997	May to June 1997	June to July 1998	May to June 1999
Vegetation surveys and revegetation monitoring	July 1995 to January 1996	June to October 1996	July to September 1997	August to November 1998	August to October 1999
Small mammal surveys	June to September 1995	July to November 1996	September to October 1997	September to October 1998	September to October 1999
Avian and Black Rail surveys	June to August 1995 and December 1995 to February 1996	April to July 1996	June 1997	May to June 1998	April to May 1999
Aerial photographs	June 1995	August 1996	July 1997	September 1998	September 1999
Storm event surface water sampling	--	--	--	--	January to April 1999
Characterization of flow and migration through Nichols Creek	--	--	--	March 1998	--
Toxicity tests	--	--	June 1997 (urchin porewater test)	June to November 1998 (topsmelt sediment-water interface test)	--

Note:

-- Activity was not conducted during that monitoring event.

Statistical methods were used to designate the number of soil, sediment, and surface water samples necessary to answer specific monitoring questions. On the basis of evaluation of data from year 1 monitoring, the Litigation Area was divided into the 16 spatial units previously described (Figure 1-4). Priorities were established for sampling of the spatial units based on the level of concern about concentrations of contaminants; the appropriate number of samples to be collected from each unit was identified using statistical power analysis. To allow comparison of data, sampling locations from the year 1 monitoring event and qualitative

ecological assessment (QEA) (PRC 1997b) sampling activities were repeated during year 2. If the number of existing sampling locations within each spatial unit was less than the number of samples required to detect significant changes, as identified by the power analysis, sampling locations were added for the year 2 and subsequent sampling. A stratified random approach was used to select the additional sampling locations within each spatial unit. For that reason, sample size and some sampling locations for year 1 differ from years 2, 3, 4, and 5. Sample sizes were increased after year 1.

Although the number of samples was identified by priority and statistics, a random grid system was used to select actual sampling locations. As originally devised in the WES monitoring plan (Lee and others 1989), the spatial units are overlain with a grid system that divides the site into 100-foot by 100-foot grids. The grid system facilitates consistent sampling over time and allows analysis of data by a geographic information system. Each 100-foot by 100-foot grid in a spatial unit was assigned a number. New sample grids were selected randomly in areas where additional samples were needed. The selected grids were designated as the sampling locations for the spatial unit. The sampling location grids established for year 1 and added for year 2 remained consistent for all subsequent monitoring years. A different random quadrant within the 100-foot by 100-foot was sampled each year for soil locations to characterize contamination on the scale of the grid. A permanent station was established for sediment and surface water locations in a ditch or slough closest to the selected point stake, and the same location was sampled each year.

Based on the previous years' monitoring results and discussions with the regulatory agencies, additional sampling or special studies were conducted to address concerns about the site, as follows:

- **Year 2:** Sampling locations were added in areas of concern, such as the slough, that had been inadequately represented in the original monitoring design. Analysis of mercury in surface water, soil, and sediment samples collected in RASS 4 was added because the qualitative ecological assessment (QEA) (PRC 1997b) identified mercury as a COC in RASS 4. Analysis of total organic carbon (TOC) in soil and sediment samples was added to evaluate the mobility of metals in soil.
- **Year 3:** Turbidity and salinity were measured in surface water samples in addition to pH, conductivity, temperature, and dissolved oxygen.
- **Year 4:** Additional studies were implemented, including profiles of the mosquito abatement ditches and winter surface water sampling in Nichols Creek. Filtered (dissolved) surface water chemistry samples were added at a subset of the surface water sampling locations.
- **Year 5:** Additional surface water studies included (1) sampling during a winter storm event of both filtered and unfiltered surface water, (2) installation of a sensor to measure turbidity and other parameters, and (3) analysis of hardness. A pollen and lead study was conducted using lead-210 (^{210}Pb) and palynological techniques to assess sediment accretion rates on the marsh surface.

Ecological characterization and toxicity assessment underwent the following changes or additions:

- **Year 2:** Characterization of benthic invertebrates was discontinued after year 1. The endpoint was not considered a reliable indicator of contaminant effects because of natural variability in the composition of the benthic community. New trapping grids were added to the small mammal characterization in year 2 to assess recolonization of remediated areas by small mammals.
- **Year 3:** Sea urchin development tests were conducted on pore water from nine locations in Lost Slough and in the RASS 3 pond area.
- **Year 4:** Special status plant species were mapped using a global positioning system. Sediment-water interface toxicity tests using topsmelt (*Atherinops affinis*) embryos were conducted on 10 sediment samples from Lost Slough.

In 1995, the Navy finalized the plan for monitoring the success of the revegetation and restoration of the actively remediated areas (H.T. Harvey and Associates, Inc. 1995). This plan established success criteria for the various revegetation efforts in the active remediation areas of each RASS. The success of revegetation was monitored annually.

1.3 MONITORING DESIGN FRAMEWORK AND THE DATA QUALITY OBJECTIVES PROCESS

In developing this revised monitoring plan, the Navy reviewed a number of technical resources on monitoring design (see Appendix A) as well as EPA Directive Number 9355.4-28 on the development of monitoring plans for hazardous waste sites (EPA 2004). The technical guidance and EPA's directive emphasize development of focused monitoring objectives and clearly-defined criteria for evaluating program performance. The Navy adopted the general framework approach as well as many of the recommendations from EPA (2004) in developing the revised monitoring plan for the Litigation Area.

EPA's directive for the development of monitoring plans for hazardous waste sites follows a six step process, as described below:

Step 1. **Identify Monitoring Objectives:** Identify the general type of monitoring being conducted based, in part, on an examination of one or more site activities, and clearly specify the objectives of the monitoring program.

Step 2. **Develop Monitoring Plan Hypotheses:** Develop hypothesis statements or questions about the relationship between the site activity (or activities) and the potential outcomes for the activity.

Step 3. **Formulate Monitoring Decision Rules:** Develop decision rules that relate the site activity and the monitoring hypotheses and questions with the monitoring results. In this guidance, decision rules specified in Step 3 are considered preliminary and are finalized in Step 4.

Step 4. **Design the Monitoring Plan:** Identify the data needs, data collection and analysis methods, quality assurance/quality control requirements, and finalize the preliminary decision rules from Step 3.

Step 5. **Conduct Monitoring Analysis and Characterize Results:** Implement the monitoring plan, including data collection and analysis.

Step 6. **Management Decisions:** Evaluate the monitoring results with respect to the decision rules and make management decisions for the site based on how well the site activity has met its stated objectives.

The Navy's monitoring plan for the Litigation Area generally follows the first four steps described above, except that the decision rules specified in Step 3 did not require revision in Step 4, so the decision rules are treated as final after Step 3 was complete.

As recommended in the 5-year review (Tetra Tech 2003) and in EPA (2004), the Navy also used the DQO process to develop the revised monitoring plan. The DQO process is a systematic planning process for identifying the type, quality, and quantity of data needed to make defensible decisions (EPA 2000). The seven steps of the DQO process are described below:

Step 1. **State the problem:** Describe the contamination problem requiring new environmental data, and identify the resources available to resolve the problem.

Step 2. **Identify the decision:** Define the decision statement by combining the principal question attempting to be resolved with the alternative actions that may be taken.

Step 3. **Identify inputs into the decision:** Ascertain the information needed to resolve the decision statement.

Step 4. **Define the study boundaries:** Specify the spatial and temporal boundaries that the data must characterize to support the decision.

Step 5. **Develop the decision rule:** Establish a logical "if…then" statement that that specifies the conditions that will cause a choice to be made between alternative actions.

Step 6. **Specify limits on decision errors:** Evaluate the probability limits on potential errors for the decision rule, which are used to establish performance goals.

Step 7. **Optimize the design for obtaining data:** Develop a resource-effective sampling and analysis design for generating data that will satisfy the DQOs.

The EPA directive relies heavily on the use of the DQO process, and many of the steps in the two frameworks overlap (EPA 2004). EPA (2004) discusses the relationship between the steps of both processes. The DQO process was chosen as the primary planning approach for the revised monitoring plan at the Litigation Area because it is a well-tested and reliable method for identifying the type, quantity and quality of data needed to make decisions in a resource-efficient manner. Details of the seven DQO steps are provided in the sampling and analysis plan in Appendix C, as well as in the discussion of Steps 1 through 4 from EPA (2004) in Section 3.0.

2.0 SELECTION OF MONITORING OBJECTIVES

This section describes the iterative process that was followed in selecting the final set of objectives that were incorporated in the revised monitoring plan for the Litigation Area.

An initial set of monitoring objectives was identified based on results and recommendations from the 5-year review report (Tetra Tech 2003), as well as on input received from the regulatory agencies during a meeting held on October 20, 2003. The Navy used the DQO process to identify objectives judged to have the greatest potential for yielding information that would aid the Navy in making management decisions at the Litigation Area. The screening process applied a set of evaluation criteria, and imposed the requirement that each objective must address one or more focused questions that are relevant to long-term management of the site. The evaluation criteria included asking whether additional data collection could be justified based on the overall quality of information provided. For example, it was asked whether any additional data collected could be subject to clear and unambiguous interpretation. It was also of interest to know the ability to measure a specific component of monitoring with precision and accuracy, and whether sampling error (that is, natural variability in the parameter being measured) would significantly impede the Navy's ability to detect any spatial and temporal trends at the site. It was also of interest to know the relative magnitude of change that could be reliably detected because monitoring is typically focused on detecting change. Many of these questions were posed to assist the Navy in developing performance criteria that could be used to gauge the effectiveness of the monitoring program over time.

Based on this initial screening process, some objectives were eliminated, and others were modified. On December 18, 2003, the Navy distributed a draft template summarizing the proposed monitoring plan for the Litigation Area and requested written comments on (1) the basic monitoring components selected, and (2) the proposed monitoring frequency for each component. The Navy also requested a brief technical rationale for any recommended modifications or additions to the monitoring plan. Comments were received from the San Francisco Bay Regional Water Quality Control Board (RWQCB) on December 24, 2003; the U.S. Department of the Interior Fish and Wildlife Service (FWS) on January 6, 2004; and the California Department of Fish and Game on January 7, 2004. On January 27, 2004, the Navy responded to this set of agency comments. Additional comments were then received from FWS on January 27, 2004, and from RWQCB on January 30, 2004.

The Navy released a draft of the monitoring plan on April 30, 2004. Comments on the draft plan were received from the Clearwater Revival Company on June 3, 2004; the FWS on June 8, 2004; the RWQCB on June 18, 2004; and the EPA on June 29, 2004. Responses to comments received on the draft plan are provided as Appendix B to the final plan.

After comments on the draft plan had been reviewed, the Navy again evaluated the agency recommendations using the DQO process and the screening criteria discussed previously. The Navy sent a letter to EPA and other stakeholders on July 22, 2004, outlining proposed modifications for the final plan. The proposed changes included using EPA (2004) as the basic framework for developing the plan, as well as increases in the frequency and intensity of monitoring for several existing components, and the addition of two new monitoring components.

Because a number of agency comments concerned the exclusion of plant and wildlife sampling from the monitoring program, these components were further considered in developing the final plan. The Navy has raised the following issues with respect to plant and wildlife monitoring:

- Populations of plant and animal species at the Litigation Area are expected to fluctuate for reasons unrelated to environmental contamination; therefore, causal factors for any observed changes in counts or estimated densities cannot be identified with any degree of certainty, and may not have any relationship to the levels of CERCLA chemicals measured at the site.
- Population sizes across the Litigation Area have not been accurately estimated and are not easily measurable using the standard sampling protocols currently available. Instead, these protocols are best for confirming the presence of species. Selection of sampling locations is typically based on best professional judgment and knowledge of habitat requirements for different species, and inferences drawn from the data are strictly applicable only to those subareas studied. Therefore, comparisons of year-to-year trends in counts or estimated densities cannot be used for making reliable inferences concerning site-wide changes at the population level.
- Given the reasons stated in the two bullets above, it is not possible to derive meaningful decision rules and evaluate decision errors within the DQO process, which suggests that any additional monitoring data for these components will have limited utility for making management decisions at this site in relation to CERLCA contamination.

The Navy has decided to eliminate routine monitoring of special status plant and wildlife species from the Installation Restoration program. Instead the Navy will continue to evaluate the status of plants and wildlife as part of its Integrated Natural Resources Management Plan (INRMP). The Navy will consult with FWS and the other regulatory agencies on future monitoring of plants and wildlife through the INRMP program. This decision was based on the Navy's evaluation of the type and relative quality of data that have been collected as part of the pre- and post-remediation monitoring program at Litigation Area and the relevancy of this information to managing site activities associated with CERCLA contamination.

The following four categories of objectives were adopted for the final monitoring plan:

1. Assess compliance with regulatory standards
2. Assess effectiveness of prior remedial activities
3. Identify changes in site conditions
4. Assess risk to ecological receptors

Section 3.0 discusses how these objectives will be addressed by the individual monitoring components.

The Navy considered several key factors in selecting the monitoring components and elements of the final sampling design. Most important, was that concentrations of several COCs occur at levels in surface water, groundwater, soil, and sediment that pose an unacceptable risk to ecological receptors. The Navy is currently evaluating remedial alternatives for managing CERCLA contamination in sediment and surface water in the mosquito ditches (Units 5 and 7), the western arm of Lost Slough (Unit 11), and in Nichols Creek (Unit 13) through the FS process. As a result, the revised monitoring plan is restricted in scope. It includes only portions of the site where unacceptable risk remains that are not being evaluated as part of the ongoing FS. Once the FS is completed and a remedy is selected, the Navy will reevaluate its overall strategy for monitoring at the Litigation Area. This strategy may include preparing a separate plan to monitor activities that arise from recommendations made in the FS, development of a single site-wide plan, or other action. Even if two separate monitoring plans are needed in the near term, the Navy envisions that both would be merged at some future date.

In the interim, the Navy's current plan is focused on monitoring surface water in the main reach of Lost Slough, groundwater at all site locations, and soil on the marsh surface. Five years of post-remediation monitoring and focused investigations conducted as part of a baseline ecological risk assessment (BERA) show concentrations of chemicals have changed little over time in portions of the site that were not treated as part of the original remedial action. The BERA concluded that unacceptable risk remains at selected locations across the site. Still, at least in the case of soil on the marsh surface, the threat does not warrant damaging sensitive habitat through additional excavation of soil. Therefore, the fundamental question addressed by the revised monitoring plan is whether there is any increase in estimates of ecological risk that would prompt the Navy to reevaluate its decision not to subject the marsh surface to further removal actions.

Consequently, detection of landscape-scale changes in site conditions was included as an additional component of monitoring in the final plan. The Navy believes that developing a cost-effective means of tracking major changes in vegetation and other surface features at the site will provide early warning of potentially significant new threats to ecological receptors. The detection of large increases in the threat to ecological receptors was also emphasized in developing decision rules and trigger levels for each of the components of the monitoring. Revisions to the final plan include using simple, non-statistical triggers, such as any regulatory criteria or other action levels that are exceeded, to prompt closer scrutiny of the results. A weight-of-evidence (WOE) process will ultimately be used to evaluate multiple lines of evidence (LOE) in selecting one or more alternative actions identified for each monitoring component if a trigger level is exceeded.

The Navy has also specified exit criteria for each component of monitoring as part of the final plan. However, given the nature of the contamination at the Litigation Area, the Navy believes it is unlikely that monitoring will be suspended for any of the components in this plan at any time in the near future. The Navy will continue to work with the regulatory agencies in evaluating the monitoring results after each new sampling event; the Navy further feels it is appropriate to periodically reassess the overall goals and performance of the program, and make any adjustments that may be indicated.

3.0 COMPONENTS OF MONITORING

The revised monitoring plan consists of the following five components:

1. Monitoring of Concentrations of Metals in Surface Water in the Main Reach of Lost Slough (Units 9 and 10)
2. Monitoring of Concentrations of Metals in Groundwater
3. Monitoring of Concentrations of Metals in Soil on the Marsh Surface (RASS 1 and 2)
4. Supplemental Evaluation of Risk to the California Black Rail
5. Monitoring of Landscape-Scale Changes in Site Conditions

The following sections describe each component of monitoring in detail.

3.1 MONITORING OF CONCENTRATIONS OF METALS IN SURFACE WATER IN THE MAIN REACH OF LOST SLOUGH (UNITS 9 AND 10)

Post-remediation monitoring and focused studies conducted as part of a BERA prepared for the first 5-year assessment at the Litigation Area have shown that concentrations of metals in surface water continue to exceed the ambient water quality criteria (AWQC). The Navy will continue routine monitoring of surface water in the main reach of Lost Slough (Units 9 and 10) to assess compliance with regulatory requirements, evaluate ongoing risk to ecological receptors, and address concerns that contaminant loads are being transported off site into Suisun Bay. The following sections provide additional background on prior studies conducted in Lost Slough and details of the monitoring plan for assessing concentrations of metals in surface water.

3.1.1 Background

Surface water bodies in the tidal marsh at the Litigation Area (RASS 1) consist of the natural slough (referred to as Lost Slough), tributaries that meander throughout the marsh, and the network of manmade mosquito abatement ditches. Semidiurnal tides in Suisun Bay flood and drain the slough and mosquito abatement ditches in the Litigation Area twice daily. The ditches and slough are normally partially filled with water.

Surface water samples were collected at 30 locations during the preremediation monitoring described in the baseline conditions report (PRC 1994), and 29 of these locations were included in the post-remediation monitoring program. During preremediation monitoring, samples were collected at 30 locations and analyzed for total metals (unfiltered samples) and dissolved metals (filtered samples). Most samples were unfiltered during post-remediation monitoring; however, a subset of filtered samples was collected for special studies during year 4 and year 5 post-remediation monitoring. During year 1, post-remediation monitoring surface water samples were collected at 26 locations. Monitoring was expanded to 134 locations during years 2, 3, and 4 (Figure 1-4). For year 5, the number of surface water sampling locations was reduced from 134 to 88 to allow for additional filtered samples and other special studies.

Chemical concentrations in surface water samples were compared with chronic and acute AWQC. Although neither saltwater nor freshwater AWQCs were entirely appropriate because the majority of the Litigation Area surface water is brackish (a mixture of both fresh water and salt water), the lower of freshwater or saltwater AWQCs was selected as the most conservative criteria. Freshwater AWQCs used for comparison were adjusted for a site-specific water hardness of 400 milligrams per liter (mg/L) calcium carbonate.

Beginning in 1997, the Navy began conducting focused studies to further define the dynamics of surface drainage and potential contaminant migration in the marsh. The studies also were intended to assess whether Lost Slough acts as a conduit for contaminant migration in surface water from the marsh in the Litigation Area to Suisun Bay (Tetra Tech 2003). These studies included (1) a tidal influence study (Tetra Tech 1997), (2) surface water monitoring during a winter storm (Tetra Tech 2000), (3) tidal water quality sampling in winter of 1999 (Tetra Tech 2000), and (4) tidal water quality sampling in fall of 2000 (Tetra Tech 2003). In addition, RWQCB sampled tidal water quality in fall 2000.

A tidal influence study was conducted from September 27 to October 2, 1997, to evaluate the effects of tidal variations on groundwater and surface water in the marsh at the Litigation Area. The study was conducted by monitoring surface water elevation, electrical conductivity, and temperature at nine locations: five groundwater monitoring wells; the RASS 3 pond; and three locations in Lost Slough, including the mouth of the slough and two locations in the upper slough (Tetra Tech 1997). Temperature and electrical conductivity of groundwater and surface water were continuously monitored for 10 tidal cycles, and salinity was calculated from these data using the practical salinity scale of 1978 (Lewis 1980).

In the second focused study, the Navy conducted storm surface water monitoring during the wet season for the winter of 1999 to assess whether significant sediment was mobilized during winter storms. Concentrations of total metals collected during winter storms were compared with the annual post-remediation monitoring data collected at the same locations during the annual monitoring in the dry season. The Navy collected surface water samples from 12 locations in the marsh at the Litigation Area during three separate winter storms for this investigation. Analytical results for surface water samples from the marsh were also compared with AWQC. This focused sampling event is fully described in the year 5 remedial action monitoring report (Tetra Tech 2000).

The field team attempted to collect samples when the potential for mobilization was highest (when winter storms coincided with unusually high outgoing tides). Unfortunately, significant rain events (defined as greater than 0.2 inch in the previous 24 hours) did not coincide with unusually high outgoing tides (defined as more than 3 feet above msl) during the early part of the 1999 rainy season. Accordingly, samples were collected during storm events that coincided with moderately high outgoing tides. Both filtered and unfiltered samples were collected during or shortly after each storm.

In the third focused study, the Navy evaluated the potential impact of contamination in the marsh on surface water quality in Suisun Bay. Tidal flooding typically inundates the Litigation Area marsh twice daily, and an elevated lip along the shoreline of Suisun Bay directs essentially all of the surface water that enters and exits the marsh through the mouth of Lost Slough. The Navy

sampled tidal water quality at the mouth of Lost Slough during the winter of 1999 to assess the quality of water entering and exiting the marsh. Surface water entering and exiting the slough during the wet season was characterized by collecting samples at the mouth of the slough at 2-week intervals on five separate dates. Tidal water quality sampling conducted in 1999 is described in detail in the year 5 monitoring report (Tetra Tech 2000).

Depth-discrete surface water samples were collected at the bridge near the mouth of Lost Slough from about 3 feet above the bottom of the slough (Figure 1-4). Samples were analyzed for total and dissolved metals, total dissolved solids (TDS), total suspended solids, and hardness. Separate aliquots of water were collected from the slough for the filtered and unfiltered metals samples. Samples were collected during both incoming and outgoing tides to allow direct comparison of ambient water quality entering the slough from Suisun Bay with water quality as it exits the slough.

In the fourth focused study, tidal water quality sampling was repeated in October 2000 to characterize water quality entering and exiting the marsh at the end of the dry season. Samples were collected for analysis of tidal water quality in October 2000 using techniques identical to those used to collect the samples in 1999 to maintain comparability between the two data sets, with three exceptions. First, water samples from outgoing tides were collected about 1 hour before low tide rather than midway through the outgoing tide to characterize the least diluted water exiting the slough from the farthest reaches of the slough and ditches. Second, samples were collected on discontinuous dates (October 5, 6, 20, 23, and 24) rather than at 2-week intervals because of logistical considerations. Third, in 1999, samples were collected in two aliquots, and one filtered in the field and the other unfiltered. In 2000, the two aliquots were collected and placed (composited) in a jug for transfer to the field trailer, where it was mixed thoroughly, then pumped from the jug directly into a preserved sample bottle (for the unfiltered sample) and through a 0.45 micron in-line filter into a preserved sample bottle (for the filtered metals sample).

On October 6 and 20, 2000, RWQCB also collected surface water samples from incoming and outgoing tides at a location about 50 yards south of the bridge location where the Navy samples were collected. RWQCB's samples were collected at approximately the same time and place as two of the Navy samples. However, water quality in the two sets of samples is expected to differ because RWQCB collected the samples using ultra-clean field sampling techniques and analyzed the samples using EPA Method 1638 (inductively coupled plasma and mass spectrometer [ICP/MS]) analytical techniques (Tetra Tech 2003). RWQCB and Navy results were discussed in the 5-year review report (Tetra Tech 2003).

RWQCB also collected samples on October 20 at a nearby location in Lost Slough (Figure 1-4). Location R01SH221 is about 500 feet from the bridge and 150 feet from the junction of Lost Slough and the north-south cut that leads up to the bridge. RWQCB collected and analyzed the samples of incoming and outgoing tides at R01SH221 using ultra-clean sampling techniques and ICP/MS analytical techniques. The conclusions of the surface water monitoring and special studies conducted at the Litigation Area are summarized in the following text.

All of the post-remediation average concentrations of total metals were lower than preremediation concentrations in surface water in both the northern and central marsh ditch units (Unit 3 and 7). Total concentrations of arsenic, copper, lead, and zinc were higher during post-remediation monitoring in the central reach of Lost Slough (Unit 10). A similar result occurred for Nichols Creek and pond (Unit 13), where copper, lead, and zinc were higher during post-remediation monitoring. In the RASS 4 wetland (Unit 15), all of the post-remediation total metals concentrations were lower, although not as dramatically as in the ditch units. A pattern of higher average post-remediation total metals concentrations in the Unit 10 slough and Nichols Creek and pond (Unit 13) suggests that on- or off-site sources of metals to surface water pathways may be continuing.

Average concentrations of dissolved metals were significantly lower than average total concentrations, indicating that large proportion of metal concentrations in surface water are a result of suspended solids in the water. The pattern for preremediation versus post-remediation concentrations of dissolved metals was similar to the concentrations of total metals, indicating a general decrease after remediation, particularly in Units 3, 7, and 15. In Units 10 and 13, however, the higher post-remediation total concentrations for arsenic, copper, lead, and zinc are not typically reflected in the dissolved concentrations, suggesting that any migration of metals in these units is likely in the form of suspended sediments.

Evaluation of post-remediation results suggests that concentrations of metals in surface water from the mosquito ditches are generally higher than concentrations in water from Lost Slough. Concentrations of all six metals in surface water samples from the ditches in the southern portion of RASS 1 (Units 5 and 7) exceeded AWQC; however, arsenic, copper, and zinc were detected at concentrations that exceed AWQC more frequently than were cadmium, lead, or selenium. Concentrations in surface water samples from Units 10 and 11 also were greater than AWQC for copper and zinc; concentrations were much lower in Unit 9 near Suisun Bay, and a few concentrations were detected that exceeded AWQC. Nichols Creek and the wetland in RASS 3 exhibited variable water sampling results. Concentrations of copper and zinc exceeded benchmarks at numerous locations. Detection limits above AWQC, particularly for copper, limit the interpretation of nondetect data.

Water draining from Lost Slough also undergoes significant dilution before it discharges to Suisun Bay (Tetra Tech 1997). Sediments and associated metals do not appear to be mobilized to a significant extent during winter storms, and AWQC were consistently exceeded only for copper (Tetra Tech 2000). Tidal water quality samples collected at the mouth of Lost Slough during the winter of 1998 to 1999 and the fall of 2000 (location R01SH666, Figure 3-1) showed the same general features; the quality of water entering and exiting the Litigation Area marsh during both sampling events was generally comparable. Almost 70 percent of the analytical results for the winter of 1998 to 1999 were either below detection limits or were qualified as nondetected during data validation. Detection limits and detected concentrations were lower than AWQC for all metals, except copper, indicating that contaminant concentrations in water entering and exiting the Litigation Area marsh does not exceed applicable water quality criteria. Almost 95 percent of the analytical results from the fall of 2000 were below detection limits, and detection limits were lower than AWQC for all metals except copper. Copper was detected in both incoming and outgoing tides in a set of samples from a single tidal cycle on March 5, 1999. Concentrations of copper in the incoming and

outgoing tides in this sample set were comparable, indicating that the Litigation Area marsh does not export copper to Suisun Bay. Incoming and outgoing tides exceeded AWQC for copper in both sets of tidal water quality samples.

Analytical results for copper were compromised to some extent by an analytical detection limit that was high in comparison with the marine criterion continuous concentration (CCC) of 3.1 micrograms per liter (µg/L). The Navy used different laboratories to analyze samples collected in the winter of 1998 to 1999 and the fall of 2000. Although the new laboratory was able to achieve a lower detection limit for copper than the previous laboratory, the detection limit still exceeded the marine CCC for copper. Analytical results for copper were also affected by an unexplained artifact that caused filtered concentrations to exceed unfiltered concentrations.

RWQCB collected samples at two nearby locations during tidal water quality sampling in the fall of 2000 but used a different analytical technique that consistently achieved lower detection limits. RWQCB's samples also showed that no concentrations of dissolved metals exceeded AWQC and that concentrations of metals in incoming tides were comparable with concentrations in outgoing tides. There was no significant difference between RWQCB samples collected at the junction of Lost Slough, at the north-south cut that leads to the bridge sampling location, and at a different location farther up Lost Slough.

Analytical results for samples collected to date strongly suggest that the Litigation Area marsh does not export significant concentrations of metals to Suisun Bay through Lost Slough. Detection limits and detected concentrations for all metals (except copper) were below AWQC. Detected concentrations in samples collected during incoming tides were generally comparable with outgoing tides. The analytical laboratory used by the Navy was unable to achieve a low detection limit for copper; therefore, the conclusion that concentrations of copper in incoming tides are comparable with those in outgoing tides is based on a limited number of samples. This conclusion is supported by three sets of samples collected and analyzed by RWQCB that show that copper concentrations in incoming and outgoing tides were essentially identical, and below the marine CCC.

3.1.2 Step 1: Monitoring Objectives

The objectives of the surface water monitoring component are as follows:

1. Assess compliance with regulatory standards
2. Detect a significant increase in estimated risk to ecological receptors from exposure to surface water
3. Evaluate the potential for off-site transport of elevated concentrations of COCs to Suisun Bay

Compliance with regulatory standards will entail comparing concentrations of COCs in surface water with the AWQC (EPA 2002, Part III 40 Code of Federal Regulations [CFR] Part 131). Existing data from the site and the BERA conducted as part of the first 5-year review have documented that concentrations of COCs in surface water at selected locations pose an unacceptable risk to aquatic ecological receptors and plants and wildlife. The Navy is currently addressing issues of sediment contamination in Lost Slough and the mosquito ditches as part of an FS. The second objective of this monitoring component is to be able to detect any changes in the estimated risk to ecological receptors that would represent a significant increase over current conditions. For the third objective, measurement of concentrations of metals in excess of the AWQC near the mouth of Lost Slough will be interpreted as evidence that off-site transport of elevated concentrations metals is occurring.

3.1.3 Step 2: Monitoring Hypotheses

The null hypotheses addressed in the surface water monitoring component are:

1. One or more COCs exceed the AWQC
2. There has been a significant increase in risk to aquatic ecological receptors or plants and wildlife exposed to COCs in surface water
3. Elevated concentrations of one or more COCs are being transported offsite to Suisun Bay

All of the monitoring hypotheses for this component are based on the more protective baseline condition that threshold criteria have been exceeded. They require the Navy to provide incontrovertible evidence that COCs are at levels that do not exceed regulatory standards or pose an unacceptable risk to ecological receptors to be rejected.

3.1.4 Step 3: Monitoring Decision Rules

This section presents details of the decision, decision rules, alternative actions, and exit criteria associated with the monitoring objectives and hypotheses identified for the surface water component.

Decision: Determine if total or dissolved concentrations of one or more COCs in surface water exceed the AWQC at selected locations in the main reach of Lost Slough, whether there is evidence that risk to ecological receptors is increasing, and whether elevated levels of COCs are being transported off site to Suisun Bay.

The decision rules for this decision are as follows:

If one or more COCs in surface water exceeds the chronic AWQC at any sampling location, then the Navy will use a WOE process to select one of the following alternative actions:

- Evaluate remedial alternatives through the FS process. This evaluation will be based, in part, on information provided by the FS that is currently reviewing alternatives for remediating contaminated sediment in Lost Slough and the mosquito ditches
- Continue monitoring, with or without modifications to the sampling design, and
- No further action (terminate monitoring)

This set of decision rules is based on the most protective trigger level, so that additional evaluation is required in cases where even a single COC exceeds the AWQC at a point location during any sampling event. The final selection of an alternative action will use a WOE process to evaluate the following LOEs:

- Number of COCs that exceed the AWQC
- Number of locations where one or more COCs exceed the AWQC
- Frequency (number of sampling events) that AWQC are exceeded
- Relative magnitude they are exceeded
- Temporal and spatial trends in concentrations of COCs
- Estimation of risk to aquatic ecological receptors and plants and wildlife that consume or come into contact with surface water

Assessment of risk to ecological receptors will include the calculation of exposure point concentrations (EPC) of COCs in surface water. Following EPA guidance (EPA 1992, 2002, 2004a), EPCs will be based on calculating a one-sided upper confidence limit (UCL) of average chemical concentrations. If the magnitude of risk to ecological receptors is found to be increasing substantially over conditions observed during the previous 5 years of monitoring, the Navy will select evaluation of remedial alternatives through the FS process as the preferred alternative action. If surface water conditions are trending toward success (that is, concentrations of COCs and estimated risk are decreasing), then the Navy will continue monitoring and will evaluate options to decrease the monitoring frequency or number of sampling locations. If concentrations in surface water are not changing substantially, then the Navy will continue monitoring with no changes to the sampling design.

The Navy will conclude that elevated concentrations of COCs are being transported off site to Suisun Bay if concentrations of any COCs in samples collected near the mouth of Lost Slough exceed the AWQC.

Exit Criteria: If concentrations of all COCs are below the AWQC at all locations for six consecutive sampling events, then routine surface water monitoring will be discontinued. If this condition is met, the Navy will consult with the regulatory agencies on the need for spot monitoring of surface water on a less frequent basis.

3.1.5 Step 4: Monitoring Design

DQOs for the surface water monitoring component are presented in the QAPP in Appendix C.

Surface water grab samples will be collected from three locations in both Units 9 and 10 during three sampling events (approximately 1 to 2 weeks between each event) during the wet and dry seasons (that is, nine samples per season per unit for a total of 18 samples per unit per year or 36 samples per year from both units). Samples will be collected at random locations from three regions in each of the two reaches. The regions are defined as the bottom, middle, and top one-third of each reach. Samples will be collected during an outgoing tide and will be analyzed for dissolved and total metals, temperature, pH, conductivity, and total suspended solids. A map showing the sampling locations is presented on Figure C-3 in the QAPP.

3.1.6 Data Analysis and Presentation of Monitoring Results

Results for metals in surface water will be presented in summary tables and figures after each full round (all six sampling events during the wet and dry seasons) of sampling. Tables and figures will be used to compare concentrations of individual metals measured at each location during each sampling event with the AWQC, as well as to summarize statistical information such as average concentrations and measures of variability. EPCs will also be calculated for individual reaches of the slough. Appendix A provides additional discussion of the options that will be evaluated for the statistical treatment of surface water data.

Examples of figures for comparing temporal trends at single and multiple sampling locations are provided in Figures 3-2, 3-3, and 3-4. Figure 3-2 is an example of how data can be graphically summarized to show differences in concentrations of metals between or among sampling locations and events. Figure 3-3 shows how this same type of information can be presented for an individual sampling location. Figure 3-4 provides an example of the statistical output for parametric (ANOVA) and nonparametric Kruskall-Wallis (Zar 1996; Gilbert 1987) tests used to compare concentrations over three or more sampling events. Other types of plots may be prepared in cases where the data analysis suggests additional questions of interest and where other graphical displays of the data may prove useful. The location names on Figures 3-2 and 3-3 would be changed to reflect the three locations established in each reach of the main slough to present monitoring results for surface water.

3.2 MONITORING OF CONCENTRATIONS OF METALS IN GROUNDWATER

The Navy recognizes the potential for groundwater to act as a migration pathway for transporting contaminants from the Litigation Area marsh to Suisun Bay or to nearby drinking water. As a result, the Navy has addressed this potential by conducting groundwater monitoring and a tidal influence study (Tetra Tech 1997, 2003). Although concentrations of contaminants have declined substantially after removal actions for soil, and interaction between groundwater and surface water appears to be minimal, some concentrations of metals continue to exceed AWQC in selected wells. The Navy will continue to assess the concentrations of total metals in groundwater wells at the Litigation Area. The following sections provide background information on groundwater issues at the site and outline the approach for continued long-term groundwater monitoring.

3.2.1 Background

The Navy has conducted groundwater monitoring and a tidal influence study to evaluate the degree of interaction between groundwater and surface water for the Litigation Area. The groundwater work conducted to date included sampling before, during, and after remediation; surveying water levels; and reviewing relevant investigations on neighboring properties.

Twenty-three monitoring wells have been installed to date in the Litigation Area. Wells 2MG20, 2MG21, and 2MG22 were installed in 1987 as a part of the RI conducted by the USACE WES (Lee and others 1988). These three wells were installed within a 100-foot radius of a rubble pile at the kiln site in RASS 2, a known source of contamination in soil, to assess whether groundwater was affected by the contamination. A fourth well (3MG19) was installed about 1,500 feet south of the kiln site as a background well.

After the board had reviewed the RI, RWQCB issued a tentative administrative order to the Navy, requesting a more detailed analysis of site groundwater. In response to this tentative order, WES identified 18 additional locations for monitoring wells in the Litigation Area. The additional wells were installed by International Technology Corporation (IT) in 1988.

One additional well was installed by Tetra Tech in 2004 on the border of Chemical Pigment Company (CPC) to evaluate groundwater-surface water interactions and the potential for migration of contaminants into Nichols Creek, as recommended in the final 5-year periodic review report (Tetra Tech 2003). Locations of all monitoring wells in the Litigation Area are illustrated on Figure C-3 in the QAPP.

The monitoring wells have been sampled in five separate episodes since they were installed, as summarized below. With the exception of the fifth sampling event (data for groundwater collected in fall 2003), historical analytical results for each monitoring well were presented in Attachment E3 of the final 5-year review report (Tetra Tech 2003). The first sampling episode occurred in May and August 1987. The four wells WES installed were sampled for analysis of six metals (arsenic, cadmium, copper, lead, selenium, and zinc) as a part of the RI (Lee and others 1988). Elevated concentrations of lead and zinc were detected in samples from several wells. Both filtered and unfiltered samples were collected for analysis of metals. Only filtered metals concentrations were reported in Attachment E3 because unfiltered metals samples are influenced by turbidity levels (Tetra Tech 2003).

The second sampling episode was conducted by IT. Beginning in February 1989, all 22 wells in the Litigation Area were sampled quarterly for four quarters (IT 1993). For the first two quarters of sampling (February and May 1989), the wells were sampled for metals, volatile organic compounds (VOC), semivolatile organic compounds (SVOC), TOC, TDS, and major anions. Samples were not analyzed for VOCs and SVOCs in subsequent quarters because the results from the first two quarters of sampling showed that VOCs and SVOCs were only rarely present in groundwater.

The third sampling episode was conducted by Environmental Solutions, Inc (ES). Beginning in March 1991, ES sampled all of the wells quarterly for metals for a period of eight quarters, ending in December 1992 (IT 1993). Following the quarterly sampling, ES sampled the wells on

four other occasions (March 1993, June 1993, March 1994, and July 1994) to evaluate concentrations of metals in groundwater during and after soil remediation.

The fourth sampling episode occurred in October 1996 to assess post-remediation concentrations in groundwater. The wells were sampled using low-flow rate sampling techniques, where possible. Wells that could not sustain pumping rates of 0.1 liter per minute (L/min) were purged dry, allowed to recharge overnight, and sampled the following day. Unfiltered groundwater samples were collected from both sets of wells. The October 1996 groundwater sampling event is described in detail in the tidal influence study and post-remediation groundwater monitoring technical memorandum (Tetra Tech 1997).

The fifth sampling episode occurred in October 2003 to assess post-remediation groundwater concentrations in groundwater. The wells were sampled using low-flow rate sampling techniques, where possible. Wells that could not sustain pumping rates of 0.1 L/min were purged dry, allowed to recharge overnight, and sampled the following day. Unfiltered groundwater samples were collected from both sets of wells. The results of the October 2003 groundwater sampling event are summarized in the Litigation Area data gaps technical memorandum, which was released on June 28, 2004 (Tetra Tech 2004).

The conclusions that can be drawn for groundwater based on studies conducted to date at the Litigation Area are summarized in the following paragraphs.

Groundwater in the marsh at the Litigation Area generally flows to the north or northwest toward the tidal wetlands. An elongated groundwater mound roughly coincides with Nichols Creek, which directs groundwater flow toward the southwest in the southwestern corner of the site. The exact position of this groundwater high is difficult to assess with the data, and the position of the high appears to shift slightly over time.

A maximum seepage velocity of 0.7 meter per year (2.3 feet per year) is estimated for the silty clay that underlies the marsh. The wells are 2,000 feet from the shoreline of Suisun Bay and 150 feet from the nearest ditch; therefore, any contamination detected in the monitoring wells would take a minimum of 870 years to reach the shoreline of Suisun Bay or a minimum of 65 years to reach the nearest mosquito ditch.

Monitoring in the Litigation Area demonstrates that groundwater has historically been contaminated with metals and that concentrations of metals declined substantially after metals-contaminated soils had been removed. Concentrations of selected metals in groundwater exceed AWQC in some wells in the marsh at the Litigation Area. Concentrations of metals in groundwater that exceed AWQC have not been considered a major issue at the site because groundwater flow velocities are slow. Furthermore, groundwater discharge to the sloughs, mosquito ditches, and subtidal discharge along the shoreline is likely to be small when compared with the volume of flowing surface water.

Motor oil-range hydrocarbons were detected in almost all of the wells sampled. Chromatograms of these hydrocarbons do not match the expected chromatograms for petroleum fuels; therefore, these hydrocarbons appear to be naturally occurring and do not appear to be related to petroleum hydrocarbon contamination. Hydrocarbons detected in selected wells may be related to

petroleum products, but concentrations are typically low (less than 0.5 mg/L). No other organic compounds were detected in groundwater.

CPC is southeast of the Litigation Area marsh and upgradient from Nichols Creek. Recent data from CPC shows that groundwater is contaminated with high concentrations of the same metals that affect groundwater in the Litigation Area. For example, zinc was detected at a concentration of 2,900,000 µg/L (0.29 percent) in a sample from well V-4R in 1993 and at concentrations that exceeded 50,000 µg/L in wells along the western fence line of CPC, within 50 feet of Nichols Creek (Cooper, White, and Cooper, LLP 1999).

GCC is located southeast of RASS 1, separated from NWS SBD Concord by Honeywell property. RASS 1 has no common borders with GCC. High concentrations of aluminum (2,400,000 µg/L), arsenic (400,000 µg/L), copper (810 µg/L), mercury (2.5 µg/L), nickel (1,200 µg/L), selenium (140 µg/L), and zinc (4,700 µg/L) were detected in groundwater at GCC. In addition, chlorinated solvents and total petroleum hydrocarbons were detected at concentrations up to 310 µg/L (IT 1999).

Although decisive information is lacking, the balance of evidence strongly suggests that the interaction between groundwater and surface water in the marsh at the Litigation Area is limited. Groundwater and surface water in Nichols Creek and the RASS 3 pond appear to be interconnected in upland areas, however.

Groundwater in the Litigation Area has not been formally classified, but would likely be considered nonpotable because most wells do not meet the criteria for protection as a potential drinking water source under Federal or State guidance for groundwater classification. Specifically, most wells in the Litigation Area marsh exhibit concentrations of TDS greater than 3,000 to 10,000 mg/L, and are screened in a silty clay formation that cannot sustain a yield of 150 gallons per day (gpd). However, some wells screened in a silty sand lens have concentrations of TDS below 3,000 mg/L and may be able to yield 150 gpd of groundwater. The sand lens has limited areal extent, however, and prolonged pumping of wells screened in this lens would dewater the lens. Wells screened in the sand lens are not expected to be capable of sustaining pumping rates of 150 gpd in the long term.

Statistical comparisons of spatial and temporal trends were performed using the data collected in October 2003 and previous data from 1996 (Tetra Tech 2004). The results showed that the concentrations of arsenic and copper were higher in samples collected in 2003. However, results for lead and selenium were mixed, and data for zinc were not significantly different in 2003 than in 1996. The concentration of cadmium was reported to be significantly higher in 2003, but the difference is likely an artifact of statistical analysis of nondetected results. The higher concentration in 2003 may be as result of increased suspended solids in the 2003 samples, as evidenced by higher concentrations of aluminum.

3.2.2 Step 1: Monitoring Objectives

The objectives of the groundwater monitoring component are as follows:

1. Assess compliance with regulatory standards

2. Detect a significant increase in estimated risk to ecological receptors from exposure to COCs from groundwater sources

3. Detect transport of COCs onto Navy property from offsite sources on the eastern border of the Litigation Area

Compliance with regulatory standards will be assessed by comparing concentrations of metals in groundwater with the AWQC (EPA 2002, Part III 40 CFR Part 131). Existing data from the site and the BERA conducted as part of the first 5-year review have documented that concentrations of some COCs in wells at selected locations are at levels that could pose an unacceptable risk to aquatic ecological receptors and plants and wildlife. This unacceptable risk would occur in cases where an exposure pathway is present. The second objective of this monitoring component is be able to detect any changes in the estimated risk to ecological receptors from exposure to sources in groundwater that would represent a significant increase over current conditions. The third objective is to detect ongoing or new releases of COCs from neighboring properties along the eastern border of the Litigation Area that are transported onto Navy property via the groundwater pathway.

3.2.3 Step 2: Monitoring Hypotheses

The null hypotheses addressed in the groundwater monitoring component are as follows:

1. One or more COCs exceed the AWQC in at least one well
2. There has been a significant increase in risk to aquatic ecological receptors or plants and wildlife exposed to COCs via the groundwater pathway
3. COCs are being transported onto Navy property via groundwater from off site sources located along the eastern border separating the Litigation Area and neighboring properties

All of the monitoring hypotheses for this component are based on the more protective baseline condition that threshold criteria have been exceeded. They therefore require the Navy to provide incontrovertible evidence that COCs are at levels that do not exceed regulatory standards or pose an unacceptable risk to ecological receptors to be rejected.

3.2.4 Step 3: Monitoring Decision Rules

This section presents details of the decisions, decision rules, alternative actions, and exit criteria associated with the monitoring objectives and hypotheses identified for the groundwater component.

Decision 1: Determine if total concentrations of one or more COCs exceed the AWQC in groundwater monitoring wells and whether there is evidence that any of the AWQC exceeded poses a significant increase in risk to ecological receptors.

The decision rule for this decision is as follows:

If one or more COCs exceed the chronic AWQC in any groundwater monitoring well, then the Navy will use a WOE process to select one of the following alternative actions:

- Evaluate remedial alternatives through the FS process. This evaluation will be based, in part, on information provided by the FS that is currently reviewing alternatives for remediating contaminated sediment in Lost Slough and the mosquito ditches. (Also see the discussion under Decision 2 for cases where there is evidence of ongoing or new releases of COCs from off-site sources.)
- Continue monitoring, with or without modifications to the sampling design, and
- No further action (terminate monitoring)

This decision rule is based on the most protective trigger level, so that additional evaluation is required in cases where even a single COC exceeds the AWQC in a sample from an individual well during any sampling event. The final selection of an alternative action will be use a WOE process to evaluate the following LOEs:

- Number of COCs that exceed the AWQC
- Number of wells where one or more COCs exceed the AWQC
- Frequency (number of sampling events) that AWQC are exceeded
- Relative magnitude they are exceeded
- Temporal and spatial trends in concentrations of COCs
- Estimation of risk to aquatic ecological receptors or plants and wildlife that are exposed to COCs in the groundwater pathway

As discussed for the surface water component, assessment of risk to ecological receptors will include the calculation of EPCs of COCs in groundwater. If the magnitude of risk to ecological receptors is found to have increased substantially over conditions observed during the previous 5 years of monitoring, the Navy will select evaluation of remedial alternatives through the FS process as the preferred alternative action. This alternative action may also be combined with a decision to pursue appropriate action against one or more responsible parties if there is evidence of ongoing or new releases of COCs from offsite sources (see Decision 2).

If groundwater conditions are trending toward success (that is, COC concentrations and estimated risk are decreasing), then the Navy will continue monitoring and will evaluate options to decrease the monitoring frequency or the number of wells to be sampled. If concentrations in groundwater are not changing substantially, then the Navy will continue monitoring with no changes to the sampling design.

Exit Criteria: If all COCs are below the chronic AWQC for three consecutive events in any well, then the Navy will consider terminating monitoring for that well. The exception to this rule will be “upgradient” wells located on the eastern border of the Navy’s property, which are part of the

subset of sentinel wells being used to detect ongoing as well as any new releases from off-site sources.

Decision 2: Determine if there is evidence of migration of COCs via groundwater from off-site sources onto Navy property.

The decision rules for this decision are as follows:

If there is evidence that COCs from off-site sources are being transported onto Navy property in groundwater, then the Navy will select one of the following alternative actions:

- Pursue appropriate action against one or more potentially responsible parties
- Continue monitoring, with or without modifications to the sampling design, and
- No further action (terminate monitoring)

This set of decision rules is based on the most protective trigger level, so that additional evaluation is required in cases where even a single COC exceeds the AWQC in a sample from an individual well during any sampling event. The final selection of an alternative action will be based on a WOE process and will evaluate the same LOEs described under Decision 1. However, selection will emphasize examining spatial trends in wells along a gradient that extends from the border of the property toward the interior of the Litigation Area.

Exit Criteria: The Navy believes that migration of COCs from off-site sources poses an ongoing threat to ecological receptors at the Litigation Area and will continue to monitor wells along the border of the property until there is compelling evidence that offsite sources of contamination have been contained or eliminated. Therefore, the Navy is not proposing exit criteria for sentinel wells located on the border of the property at the present time, but will periodically reevaluate this decision as part of the normal review process for the monitoring program.

3.2.5 Step 4: Monitoring Design

DQOs for the groundwater monitoring component are presented in the QAPP in Appendix C.

A single sample will be collected from each of the existing 23 groundwater monitoring wells, plus three new wells that will be installed before the next round of sampling, during a single sampling event in the wet season every 3 years (Figure C-3). The three additional groundwater monitoring wells will extend into the deep aquifer. Two of these wells will be located in RASS 1 along the berm that separates the Navy and Honeywell to the east, and one well will be located southwest of the berm in RASS 2, near existing well R02AG009. The three new wells will be designated as R01DG024, R01DG025, and R02DG026. Lithology in the Litigation Area marsh at depths more than about 15 feet bgs has not been defined by the existing wells. As a result, drilling and continuous lithologic logging will extend to a depth of 60 feet for the new wells. The new deep wells will be screened in a deep aquifer (if present).

A subset of wells, including the three new wells, will be identified as "sentinel" wells and will be sampled once per year during the wet season. The sentinel wells will be located near the border of the property (that is, wells that have the potential to measure ongoing migration from off-site sources). In addition, they will include any wells that show an increasing trend in concentrations based on the previous two rounds of sampling (that is, data collected in 2003 and during the next round of sampling) or wells where concentrations of metals are reported that are consistently in excess of the AWQC. The full set of sentinel wells will be identified following the next round of sampling, and annual sampling of this subset of wells will begin the following year (that is, the year after the next round of sampling).

All wells will be sampled for analysis of total metals, total dissolved solids and total suspended solids using low-flow rate sampling techniques. The wells will also be sampled for temperature, pH, and electrical conductivity using field measurements. In the first year only, the three new wells will also be sampled for analysis of VOCs, SVOCs, total petroleum hydrocarbons (extractable and purgeable), and pesticides and herbicides.

The existing and three proposed new groundwater monitoring wells at the Litigation Area are listed in the following table and presented on Figure C-3 in the QAPP.

Existing Groundwater Monitoring Wells at the Litigation Area			
R01AG002	R02AG008	R03AG010	R04MG015
R01AG003	R02AG009	R03MG006	R04MG016
R01AG004	R02MG007	R03MG011	R04MG017
R01MG001	R02MG020	R03MG012	
R01PG005	R02MG021	R03MG013	
R01PG018	R02MG022	R03MG014	
R01DG024	R02DG026	R03MG019	
R01DG025		R03MG023	

3.2.6 Data Analysis and Presentation of Monitoring Results

Appendix A provides additional discussion of the options that will be evaluated for the statistical treatment of groundwater data. Results for metals in groundwater will also be presented in summary tables and figures after each sampling event. Examples of figures for comparing temporal trends at single and multiple sampling locations are provided in Figures 3-2, 3-3, and 3-4. The location names on Figures 3-2 and 3-3 would be changed to reflect the location identifiers for individual wells to present results for groundwater monitoring.

3.3 MONITORING OF CONCENTRATIONS OF METALS IN SOIL ON THE MARSH SURFACE IN RASS 1 AND 2

Chemical spills from adjacent facilities in the 1950s, 1960s, and 1970s released metals onto the surface of the Litigation Area marsh, especially in the southeastern portion of the marsh. Although the remedial action conducted in 1993 and 1994 removed soils from the most contaminated areas, some of the contaminated soils outside of the remediated areas remained (Figure 1-4). The Navy conducted postremediation monitoring and several focused studies to assess whether the remaining metals-contaminated soils were (1) a potential risk to ecological receptors at the site, (2) mobile, and (3) affecting water and sediment quality in uncontaminated portions of the marsh and in Suisun Bay. Elevated concentrations of metals were detected in soil at selected locations in the unremediated areas of RASS 1 and 2. The following sections provide background information on soil at the site and outline the approach for continued long-term soil monitoring.

3.3.1 Background

The geology at the Litigation Area is dominated by Pleistocene and Holocene geomorphology. The subsurface zone consists of interfingering alluvial and estuarine depositional environments. Footslopes, flood plains, and marsh or wetland areas of Quaternary age characterize the Litigation Area. Terraced Pleistocene alluvial fans and flood plain deposits form the footslopes. Pleistocene deposits are overlain by Holocene flood plain deposits that consist of unconsolidated sands, silts, gravels, and clays. In the wetland areas adjacent to Suisun Bay, Holocene alluvial material has been overlain by fine-grained silt and clay, mixed with organic material that comprises Bay Mud.

Geotechnical investigations conducted during remedial design suggested that the upper 1.5 feet of surface soil in RASS 1 typically consists of Bay Mud. Surficial clayey silt is soft to very soft and moist and contains small roots of living marsh plants. A very compressible, saturated porous peat or silty peat (a buried layer of water-saturated, spongy dead marsh vegetation) is found directly beneath the surface soil and extends to a depth of at least 3 feet (Tetra Tech 2003).

As described in Section 1.2.2, soil samples were collected during each of the five annual monitoring events after remediation. The number of soil samples collected during the annual monitoring events was designated by priority and statistics using a random grid system to select actual sampling locations.

The Navy conducted long-term turbidity monitoring, a soil accretion study, and marsh surface metals profiling using X-ray fluorescence (XRF) in an effort to obtain more detailed information about potential mobilization of contaminated soils from the marsh surface. These investigations are described in detail in the following paragraphs.

In 1999, the Navy conducted long-term turbidity monitoring to assess the net direction of sediment transport as suspended solids in the Litigation Area marsh. Turbidity is defined as the ability of a translucent material to scatter or absorb light rather than transmit it (American Public Health Association 1989) and is considered an indirect measure of suspended particles in water. The goal of the long-term turbidity monitoring was to assess sediment transport by recording

changes in turbidity at the mouth of Lost Slough over many tidal cycles and winter rainfall events. Transport of sediments into the marsh would be expressed as turbidity asymmetry, where incoming tides have higher turbidity than outgoing tides. Turbidity at the mouth of Lost Slough was recorded with a submerged water quality sonde at 15-minute intervals from January 18 to April 20, 1999, for a total of approximately 8,000 separate turbidity measurements during 140 complete tidal cycles. The instrument was calibrated at the beginning of monitoring and at 2-week intervals during the monitoring period.

As an additional effort to assess mobilization of contaminated soils from the marsh surface, the Navy measured soil accretion rates in 1999 at three locations in the southeastern corner of RASS 1, where high concentrations of metals are present at the marsh surface. The age of marker horizons within the soil cores were identified using ^{210}Pb dating and palynological techniques. In addition, the net accretion rates were estimated by dividing the amount of soil accumulated above the soil horizon by the time elapsed since the horizon was deposited. These isotopic and palynological techniques are described in detail in the year 5 monitoring report (Tetra Tech 2000).

In October 2000, the Navy created profiles of the vertical distribution of metals by collecting 10-inch-long soil cores from 13 locations across the marsh surface and vertically profiling these soil cores using energy dispersive XRF spectrometry. The purpose of creating profiles to illustrate the vertical distribution of metals was to establish whether (1) ongoing accretion of cleaner soils on the marsh surface is gradually burying the contaminated soil and (2) metals are migrating vertically from the marsh surface. The 13 surface soil core locations in the marsh were selected to represent the most contaminated areas for a variety of metals based on existing monitoring data and to achieve lateral coverage of the entire marsh (Figure 3-1). The conclusions drawn from monitoring and focused studies are summarized in the following paragraphs.

Concentrations of metals in soil and sediment on the scale of the spatial unit have undergone little change over the 5 years of post-remediation monitoring. Spatial units with significant metals contamination have remained contaminated; remediated areas, reference areas, and areas farther from the historical spills consistently show low concentrations of metals. Considerable variability in lateral and vertical distributions of metals was evident on the scale of the sampling grid.

Both reference areas (Units 1 and 16) and the northern marsh (Units 2 and 3) remain relatively uncontaminated. The effects-range median (ER-M) was exceeded in only 35 instances (7 percent of sample results) in 500 individual metal sample results for arsenic, cadmium, copper, lead, and zinc collected from Units 2 and 3 over a 5-year period. In Units 2 and 3, mean concentrations of metals in soil have also remained similar over 5 years of monitoring, and the number of results exceeding benchmarks for soils in each unit have remained relatively consistent.

The central marsh (Units 6 and 7), west of the RASS 1 remediated area, still exhibits some of the highest concentrations of metals in the Litigation Area because of its proximity to a former contamination source in the GCC waste ponds. Mean concentrations of metals and the number of results that exceeded benchmarks in Units 6 and 7 have been relatively consistent over 5 years of monitoring; these results suggest no significant migration of metals into or out of these units.

Although ongoing post-remediation monitoring has established that soils in some parts of the Litigation Area marsh are contaminated with high concentrations of metals, evidence suggests that the most contaminated horizons on the marsh surface are being gradually buried by cleaner soils brought into the marsh as suspended solids in Lost Slough. Three lines of evidence support this hypothesis:

- Continuous turbidity monitoring for 140 tidal cycles during the 1998 to 1999 rainy season showed that water entering the marsh through Lost Slough is more turbid than water exiting the marsh. Statistical analysis of the turbidity data showed significantly higher turbidity in incoming tides than in outgoing tides. This finding suggests that Lost Slough imports soils into the Litigation Area marsh and that these soils are sequestered in the marsh.
- A soil accretion study in 1999 demonstrated that the marsh is accreting soils at a rate of approximately 2.5 millimeters per year (mm/yr). The study examined three soil cores from the most contaminated portion of the marsh and used palynological and lead isotope dating techniques to establish the age of several horizons within the soil columns. These two dating techniques established independently that the marsh has been accreting soils in these three locations for the past 200 years at an average rate of approximately 2.5 mm/yr.
- Profiles for metals from 13 locations across the marsh surface demonstrate that the most contaminated horizon of marsh soils occurs at a depth of 3 to 5 inches below the surface and that metals concentrations of metals in soils decline both above and below that horizon. This decline in concentrations in soil toward the surface is consistent with progressive burial by clean sediments brought into the marsh through Lost Slough. The 13 profiles demonstrate that a horizon of cleaner soils is present at location across the entire marsh surface.

3.3.2 Step 1: Monitoring Objectives

The objectives of the marsh surface soil monitoring component are:

1. Compare COC concentrations in marsh surface soil with ecological benchmarks
2. Detect a significant increase in estimated risk to ecological receptors from exposure to marsh surface soil

Previous monitoring of the marsh surface and the BERA conducted as part of the first 5-year review at the Litigation Area have used the National Oceanic and Atmospheric Administration (NOAA) effects-range low (ER-L) and ER-M ecological benchmarks to assess potential risk to ecological receptors from exposure to sediment as well as soil on the marsh surface (Long and Morgan 1991). The effects ranges were derived using empirical toxicity data for marine and estuarine sediments and were originally proposed as informal guidelines for evaluating data for sediment collected through NOAA's National Status and Trends Program. The effects ranges have since been widely used in environmental assessment studies, including screening level ERAs, throughout North America (Long and others 1995, Long and McDonald 1998). The Navy has some concerns regarding the applicability of the NOAA benchmarks for assessing the

potential biological effects of metals in this medium because surface soil in the marsh at the Litigation Area cannot strictly be classified as marine or estuarine sediment. Therefore, the Navy will conduct a survey of the ecotoxicity literature and will reevaluate the data for soil and results of food chain modeling from the Litigation Area to develop site-specific ecological benchmark values for the site. The Navy will document this evaluation and its recommendation for soil benchmark values in a technical memorandum that will be provided to the regulatory agencies for review.

Existing monitoring data and focused investigations conducted for the BERA have documented that concentrations in soil of some COCs at selected locations pose an unacceptable risk to ecological receptors on the marsh surface. The second objective of this monitoring component is be able to detect any changes in the estimated risk to ecological receptors from exposure to marsh surface soil that would represent a significant increase over current conditions.

3.3.3 Step 2: Monitoring Hypotheses

The null hypotheses addressed for the marsh surface soil monitoring component are as follows:

1. One or more COCs in marsh surface soil exceed ecological benchmarks at one or more locations
2. There has been a significant increase in risk to ecological receptors from exposure to COCs in soil on the marsh surface

All of the monitoring hypotheses for this component are based on the more protective baseline condition that threshold criteria have been exceeded. In addition, they require the Navy to provide incontrovertible evidence that COCs are at levels that do not exceed ecological benchmarks or pose an unacceptable risk to ecological receptors to be rejected.

3.3.4 Step 3: Monitoring Decision Rules

This section presents details of the decision, decision rules, alternative actions, and exit criteria associated with the monitoring objectives and hypotheses identified for the marsh surface soil component.

Decision: Determine if concentrations of one or more COCs in marsh surface soil exceed ecological benchmarks and whether there is evidence that any of the ecological benchmarks that were exceeded pose a significant increase in risk to ecological receptors.

The decision rules for this decision are as follows:

If concentrations of one or more COCs in marsh surface soil exceed ecological benchmarks at any sampling location, then the Navy will use a WOE process to select one of the following alternative actions:

- Evaluate remedial alternatives through the FS process
- Continue monitoring, with or without modifications to the sampling design, and
- No further action (terminate monitoring)

This set of decision rules is based on the most protective trigger level, so that additional evaluation is required in cases where even a single COC exceeds established ecological benchmarks at any location on the marsh surface during any sampling event. The final selection of an alternative action will be use a WOE process to evaluate the following LOEs:

- Number of COCs that exceed ecological benchmarks
- Number of locations where one or more COCs exceed ecological benchmarks
- Frequency (number of sampling events) that ecological benchmarks are exceeded
- Relative magnitude that the ecological benchmarks are exceeded
- Temporal and spatial trends in concentrations of COCs
- Estimation of risk to aquatic ecological receptors or plants and wildlife that consume or come into contact with marsh surface soil

As discussed for the surface water and groundwater components, assessment of risk to ecological receptors from exposure to soil on the marsh surface will include calculation of EPCs for all COCs. If the magnitude of risk to ecological receptors is found to have increased substantially over conditions observed during the previous 5 years of monitoring, the Navy will select evaluation of remedial alternatives through the FS process as the preferred alternative action. If conditions on the marsh surface are trending toward success (that is, COC concentrations and estimated risk are decreasing), then the Navy will continue monitoring and will evaluate options to decrease the monitoring frequency or number of sampling locations. If concentrations of COCs on the marsh surface are not changing substantially, then the Navy will continue monitoring with no changes to the sampling design.

Exit Criteria: If all COCs in marsh surface soil are below the ecological benchmarks at all sampling locations for two successive sampling events, then monitoring of marsh surface soil will be discontinued. If all COCs are below the ecological benchmarks for only a subset of sampling locations for two successive sampling events, then the Navy will evaluate discontinuation of monitoring for the subset of locations only.

3.3.5 Step 4: Monitoring Design

DQOs for the marsh surface soil monitoring component are presented in the QAPP in Appendix C.

Samples of marsh surface soil will be collected every 5 years and will use the existing network of locations (that is, each location is defined by a 100- by 100-foot grid) established as part of the existing post-remediation monitoring design. Sampling locations were selected if they met either of two criteria applied to the existing 5 years of post-remediation monitoring data:

- A single measurement from any monitoring event with an ER-M for arsenic greater than 1.0 (unitless), and
- A single sample from any monitoring event with a mean ER-M quotient greater than 1.5 (unitless) for all COCs

A total of 32 marsh surface sampling locations met at least one of the selection criteria. Two grid locations, R02SS269 and R01SS138, were considered redundant, so R02SS269 was eliminated and samples will be collected only from R01SS138. One new 100-by 100-foot grid was established east of location R01SS078 (the new location identifier is R01SS308) to fill a spatial data gap identified by the FWS in its comments on the draft monitoring plan. The final set of 32 locations is shown on Figure C-3 in the QAPP and in the table below.

Sampling Locations in RASS 1 and RASS 2		
RASS 1		RASS 2
R01SS062	R01SS119	R02SS137
R01SS076	R01SS125	R02SS141
R01SS078	R01SS128	R02SS142
R01SS083	R01SS135	R02SS146
R01SS084	R01SS138	R02SS147
R01SS088	R01SS143	R02SS150
R01SS089	R01SS253	R02SS151
R01SS091	R01SS258	R02SS207
R01SS106	R01SS264	R02SS267
R01SS107	R01SS308	R02SS268
R01SS108		R02SS272

A single random sample will be collected at a depth of 0 to 0.5 feet below ground surface from each of the four quadrants at each sampling location. Therefore, a total of 128 surface soil samples (32 locations times 4 samples per location) will be collected every 5 years. Samples will be analyzed for total metals (the full suite of contract laboratory program metals), pH, and total organic carbon.

3.3.6 Data Analysis and Presentation of Monitoring Results

Monitoring data will be analyzed using both quantitative and qualitative methods. Appendix A provides additional discussion of the options that will be evaluated for the statistical treatment of data for surface soil in the marsh. Tabular summaries of descriptive statistics will be prepared after each additional sampling event, and overall summaries will be prepared by combining data across sampling events. The types and formats of the summary tables will be similar each of the annual monitoring reports and in the 5-year review report (Three examples are provided on Figures 3-2, 3-3, and 3-4). Graphical presentations of the data, including box-plot figures and

maps, will accompany each of the tables. Other types of plots may be prepared in cases where the data analysis suggests additional questions of interest and where other graphical displays of the data may prove useful.

3.4 SUPPLEMENTAL EVALUATION OF RISK TO THE CALIFORNIA BLACK RAIL

A supplemental evaluation of risk to the California Black Rail is included in the final monitoring plan as a one-time sampling event to address a data gap identified in the BERA.

3.4.1 Background

Black Rails have been monitored annually as part of the post-remediation monitoring at the site, and the estimated density of rails has increased over this 5-year period. Black Rail densities are estimated to have increased by as much as ten-fold since an initial survey conducted in 1991, before the site was remediated. However, Black Rails are secretive and are seldom observed in the wild, so population estimates are based on extrapolating responses to recorded calls. The habits and feeding preferences of the Black Rail are poorly known, although literature sources report that Black Rails are opportunistic feeders, and consume a variety of invertebrates (mollusks, amphipods, insects, and spiders) as well as the seeds of some plants. In the San Francisco Bay Area, fragmentation and loss of habitat are believed to be important threats to populations of the Black Rail. The Black Rail also has a number of natural predators, including the Great Blue Heron and Northern Harrier, which are found at the Litigation Area.

The BERA conducted as part of the 5-year assessment review assessed risk to the California Black Rail from exposure to chemicals in the mosquito ditches (organic chemicals) and Lost Slough (inorganic chemicals). Risk was considered below a level of concern for exposure to dichlordiphenyltrichlorethane (DDT) (all hazard quotients [HQ] below 1.0 using the high toxicity reference value [TRV]), while some unacceptable risk was shown for exposure to total PCBs and Arocolor based on an assumed diet of amphipods (risk was acceptable for a diet composed of clams). An HQ of 1.19 to 2.38 (range calculated based on using the full detection limit or one-half the detection limit for non-detects) was obtained for total PCBs using the high TRV and literature-derived bioaccumulation factors for calculating concentrations of PCBs in amphipods. Unacceptable risk was shown for exposure to arsenic, cadmium, lead, and zinc based on HQs calculated using the high TRV and area-wide doses for sediment and a diet consisting of amphipods. HQs were below 2.0, except for zinc where the HQ was 12.69. Maximum tissue and sediment concentrations were used in all calculations because the Black Rail is a threatened species.

Risk was not assessed for exposure of Black Rails to the marsh surface because no data were available for concentrations of chemicals in prey or other dietary components from this portion of the Litigation Area. This lack has been identified as a data gap because Black Rails are thought to use the marsh surface for both cover and forage. Concentrations of metals in soil have been well characterized across the marsh, so the unknown factor for assessing risk in this portion of the site is estimating the dose that could be ingested by birds that feed on the marsh surface. This supplemental evaluation of risk to the Black Rail is proposed as a one-time sampling event, and will measure metal concentrations in typical prey items for the Black Rail from areas of the marsh surface where the highest concentrations of COCs have been measured in soil.

3.4.2 Step 1: Monitoring Objectives

The objective of this monitoring component is as follows:

1. Evaluate risk to the California Black Rail from ingestion of COCs in soil and prey on the marsh surface

Existing monitoring data and focused investigations conducted for the BERA have documented unacceptable risk to the California Black Rail from ingestion of several COCs in the mosquito ditches and Lost Slough. The BERA and comments received from the FWS have identified the lack of an assessment of risk to the Black Rail from ingestion of surface soil in the marsh as a data gap for the Litigation Area. This monitoring component provides for a focused investigation to fill this data gap and supplement existing risk estimates for the Black Rail.

3.4.3 Step 2: Monitoring Hypotheses

The null hypothesis addressed in this monitoring component is as follows:

1. Ingestion of COCs in soil and/or prey on the marsh surface poses an unacceptable risk to the California Black Rail

This monitoring hypothesis is based on the more protective baseline condition that unacceptable risk exists. In addition, it requires the Navy to provide incontrovertible evidence that COCs in marsh surface soil or prey of the rail are at protective levels to be rejected.

3.4.4 Step 3: Monitoring Decision Rules

This section presents details of the decision, decision rules, alternative actions, and exit criteria associated with the monitoring objective and hypothesis identified for the supplemental evaluation of risk to the California Black Rail.

Decision: Determine if concentrations of COCs in marsh surface soil or prey of the California Black Rail are at sufficient levels to pose an unacceptable risk to this species.

The decision rules for this decision are as follows:

If concentrations of one or more COCs in marsh surface soil or prey of the California Black Rail are at sufficient levels to pose an unacceptable risk to this species, then the Navy will select one of the following alternative actions:

- Evaluate remedial alternatives through the FS process
- Continue monitoring, with or without modifications to the sampling design, and
- No further action (terminate monitoring)

The final selection of an alternative action will be use a WOE process to evaluate the following LOEs:

- Relative contribution of individual COCs that drive risk
- Magnitude of the HQs for individual COCs
- Number of locations where risk is determined to be unacceptable
- Temporal and spatial trends in the distribution of risk

If the magnitude of risk to the California Black Rail from ingestion of COCs in soil or prey on the marsh surface is found to be substantially greater than the risk predicted in the BERA for ingestion of COCs in sediment, then the Navy will reevaluate site-wide risk to the Black Rail and determine whether an evaluation of remedial alternatives through the FS process is warranted. If risk from ingestion of contaminants in soil or prey on the marsh surface is no greater than is predicted for exposure to sediment, then the Navy will continue to measure concentrations of COC in marsh surface soil to monitor exposure conditions for the Black Rail.

Exit Criteria: If all concentrations of COCs in marsh surface soil and prey are below levels that pose an unacceptable risk to the California Black Rail, then the Navy will not propose additional focused monitoring for this species. Exposure conditions for the Black Rail will continue to be assessed through monitoring component for surface soil at the marsh. Decisions to discontinue monitoring of marsh surface soil will be based on ecological benchmarks for soil that have been exceeded.

3.4.5 Step 4: Monitoring Design

DQOs for the supplemental evaluation of risk to the California Black Rail are presented in the QAPP in Appendix C.

Samples to measure whole-body concentrations of COCs in prey items of the California Black Rail and concentrations in collocated soil samples will be collected within three areas on the marsh surface during the next round of sampling. This sampling event will be one time, but may need to be conducted over a period of several months to account for the temporal variability of target prey items. Sampling will focus on areas of the site where the highest concentrations of arsenic and other COCs have been measured during the first 5 years of post-remediation monitoring.

As previously mentioned, Black Rails are known to be opportunistic feeders and consume a variety of invertebrates and seeds (including cattails and bulrush). Since neither the diet of Black Rails on the marsh surface nor the seasonal availability of potential prey items are known, it is not possible to identify all of the parameters of the sampling design before the field work is conducted.

The design will be based on collecting a minimum of three samples for at least two food categories: terrestrial invertebrates and seeds. Each sample will consist of a composite of individual terrestrial invertebrates or seeds collected within an existing 100- by 100-square-foot grid from representative rail habitats on the marsh surface. The three sampling locations are

shown on Figure C-3 in the QAPP. It may be necessary to pool more than one invertebrate species or the seeds from more than one plant species to collect a sufficient sample for chemical analysis. Different species of terrestrial invertebrates and types of seeds will be maintained in separate sample containers during the field collection, and a decision on the need for pooling will be made after sampling is completed and an assessment is made on the relative mass of each food type collected within each of the sampling grids. If sufficient biomass is collected for multiple invertebrate species and seeds of multiple plant species, selection will be based on the prey or food items that have the greatest potential for bioaccumulation of arsenic and other COCs. (Selection also will be subject to the availability of information on bioaccumulation in the technical literature for the prey or food items collected.)

3.5 MONITORING OF LANDSCAPE-SCALE CHANGES IN SITE CONDITION

The Navy recognized during Step 1 (problem formulation) in development of the DQOs for the final plan that the existing monitoring design for the Litigation Area does not provide a way to detect landscape-scale changes in conditions that could provide early warning of potential degradation in habitat quality or other negative impacts to plants and wildlife. This section presents the details of a new component the Navy is adding to the long-term monitoring program to efficiently track landscape-scale changes in site conditions.

3.5.1 Background

The Navy reviewed the existing monitoring program for the Litigation Area and comments received from the regulatory agencies on the draft plan as part of the process for developing the objectives for the revised plan (see Section 2.0). As part of this review, the Navy also considered findings from the BERA, which concluded that unacceptable risk to ecological receptors from exposure to surface water, groundwater, soil, and sediment, remains at selected locations throughout the site. The finding of unacceptable risk is likely to be a persistent feature for areas of the site, such as the marsh surface, where remediation is not currently being proposed based on concerns over the potential for destroying sensitive habitat. As a result, the Navy recognized that an important goal of any future monitoring should be to detect changes in exposure or other factors that could lead to a significant increase in risk. That is, the threat to plants and wildlife from exposure to elevated concentrations of metals on the marsh surface is not considered high enough to risk damaging this sensitive habitat through additional soil removal actions. However, evidence of a significant increase in risk would be cause to reconsider remedial options for the marsh surface. Therefore, the Navy has incorporated detection of a significant increase in risk as a primary goal for all of the components in the long-term monitoring plan.

The Navy believes the monitoring currently proposed for surface water, groundwater, and marsh surface soil is sufficient to satisfy the goal of detecting a significant increase in risk to plants and wildlife from exposure to COCs in these media. However, the Navy recognizes that the current monitoring design for the Litigation Area does not provide a means of detecting important site-wide changes in vegetation communities or other surface features that might signal degradation in habitat quality or other deleterious impacts to special status plants and wildlife. For this reason, the Navy wishes to develop an efficient means of tracking landscape-scale changes in site conditions, and is proposing to include this new capability as a permanent feature of the long-term monitoring program.

3.5.2 Step 1: Monitoring Objectives

The objective of this monitoring component is as follows:

1. Establish a means for assessing landscape-scale changes in site conditions that could signal the potential for habitat degradation or other negative impacts to plants and wildlife

The Navy requires an efficient means of monitoring for coarse- or landscape-scale changes in site conditions that could result in negative impacts to plant and animal communities. An approach is needed to track site-wide changes in dominant vegetation communities, especially in habitats used by special status species such as the California Black Rail and saltmarsh harvest mouse.

3.5.3 Step 2: Monitoring Hypotheses

The null hypothesis addressed in this monitoring component is as follows:

1. Landscape-scale changes in site conditions are occurring that could result in negative impacts to plants and wildlife

This monitoring hypothesis is based on the more protective baseline condition that deleterious changes in site conditions are occurring. In addition, it requires the Navy to provide incontrovertible evidence that site conditions are not changing in such a way as to pose increased risk to ecological receptors to be rejected.

3.5.4 Step 3: Monitoring Decision Rules

This section presents details of the decision, decision rules, alternative actions, and exit criteria associated with the monitoring objective and hypothesis identified for assessing landscape-scale changes in site conditions.

Decision: Determine whether significant landscape-scale changes in vegetation or other site factors are occurring that could signal the potential for negative impacts to plants and wildlife.

The decision rules for this decision are as follows:

If monitoring results indicate that landscape-scale changes in site conditions are occurring that could signal the potential for negative impacts to plants and wildlife, then the Navy will further evaluate the extent of any potential impacts and prepare technical recommendations for any proposed actions. Alternative actions, therefore, will depend on the specific nature of the changes. The proposed actions could include modifying the monitoring plan to include a focused investigation of the causal factors underlying any observed changes in site conditions, or an evaluation of remedial alternatives through the FS process.

Exit Criteria: Because this monitoring component is designed to provide early warning of a significant change in site conditions that could signal the potential for significant degradation of habitat for plants and wildlife, the Navy is not proposing any exit criteria for suspending monitoring at this time.

3.5.5 Step 4: Monitoring Design

DQOs for the detection of landscape-scale changes in site conditions monitoring component are presented in the QAPP in Appendix C.

A pilot study will be conducted to evaluate alternative designs and data collection methods for assessing landscape-scale changes in site conditions. The pilot study will be conducted as part of the next sampling event and will be used to establish the design parameters for subsequent monitoring events.

The Navy will evaluate the feasibility of using aerial photographs as a means to provide coarse or landscape-scale resolution of dominant vegetation types across the site (as well as changes in other surface features). Ground surveys will be used to evaluate the accuracy in identifying selected vegetation types based on features identified in the photographs. If deemed technically feasible and cost effective, this approach will create a permanent record of the relative cover of different vegetation communities (and other surface features at the site) and will allow the Navy to assess whether significant changes are occurring over time.

The Navy will also evaluate the utility of establishing a network of permanent photo points in selected areas of the site to provide better resolution of changes in vegetation and other surface features at a finer spatial scale. Existing vegetation maps, analysis of aerial photographs, and results of previous wildlife studies will be used to define candidate areas for establishing permanent photo points.

Landscape-scale changes in site conditions will be assessed every 3 years.

4.0 INFORMATION MANAGEMENT PLAN

An information management system is necessary to ensure efficient access so that decisions based on the data can be made in a timely manner. Field and analytical data collected from this site and off-base adjacent sites are critical to site characterization efforts, development of the comprehensive conceptual site model, risk assessments, and selection of remedial actions to protect human health and the environment.

4.1 DATA VALIDATION AND USABILITY

Validation and verification of the data generated during field and laboratory activities are essential to obtaining data of defensible and acceptable quality. Verification and validation methods will be provided for field and laboratory activities. All field personnel will be responsible for following the sampling and documentation procedures described in the sampling and analysis plan so that defensible and justifiable data are obtained. Laboratory personnel will verify analytical data at the time of analysis and reporting and through subsequent reviews of the raw data for any nonconformances to the requirements of the analytical method.

An independent third-party contractor will validate all laboratory data in accordance with current EPA national functional guidelines (EPA 1994, 1999). The data validation strategy will be consistent with Navy guidelines. For this project, 80 percent of the data will undergo cursory validation, and 20 percent of the data will undergo full validation. Cursory validation will be completed on 80 percent of the summary data packages for analysis of sediment and groundwater samples, and full validation will be completed on 20 percent of the data.

4.2 DATA MANAGEMENT

After the field and laboratory data reports are reviewed and validated, the data will be entered into Tetra Tech's database for NWS SBD Concord. Data generated from field activities conducted on adjacent properties by the California Department of Toxic Substances Control or GCC represent a fourth primary pathway for the Litigation Area specifically, which will also be entered into the database, if applicable. These data are critical for developing the conceptual model for the site. Data pathways must be established and well documented to evaluate whether the data have been accurately loaded into the database in a timely manner.

4.2.1 Data-Tracking Procedures

All data generated in support of this project are tracked through a Tetra Tech database, which is in Oracle. Information related to the receipt and delivery of samples, project order fulfillment, and invoicing for laboratory and validation tasks is stored in the Tetra Tech sample tracking database (SAMTRAK). All data are filed according to the project number.

4.2.2 Data Pathways

Data are generated from three primary pathways at NWS SBD Concord: field activities, laboratory analytical data, and validated data. Data from all three pathways must be entered into the NWS SBD Concord database. For the Litigation Area specifically, data generated from field activities conducted on adjacent properties by the California Department of Toxic Substances Control or GCC represent a fourth primary pathway, which will also be entered into the database, if applicable. These data are critical for developing the conceptual model for the site. To evaluate whether the data have been accurately loaded into the database in a timely manner, data pathways must be established and well documented.

Data generated during field activities are recorded using field forms. These forms are reviewed for completeness and accuracy by the analytical coordinator or field team leader. Data from the field forms, including the chain-of-custody form, are entered into SAMTRAK according to the project number.

Data generated during laboratory analysis are recorded in hardcopy and in NEDDs after the samples have been analyzed. The laboratory will send the hardcopy and NEDDs records to the analytical coordinator. The analytical coordinator reviews the data deliverable for completeness, accuracy, and format. After the format has been approved, the electronic data are manipulated and downloaded into the database. Tetra Tech data entry personnel will then update SAMTRAK with the total number of samples received and number of days required to receive the data.

After validation is complete, the analytical coordinator reviews the data for accuracy. Tetra Tech will then update the database with the appropriate data qualifiers. SAMTRAK is also updated to record associated laboratory and data validation costs.

4.2.3 Data Management Strategy

The data will be loaded into the Tetra Tech database for storage, further manipulation, and retrieval after the off-site laboratory and field reports are reviewed and validated. The database will be used to provide data for chemical and geologic analysis and for preparing reports and graphic representations of the data. Additional data acquired from field activities are recorded on field forms that are reviewed for completeness and accuracy by the analytical coordinator or field team leader. Hard copies of forms, data, and chain-of-custody forms are filed in a secure storage area according to project and sample identification numbers.

4.3 DATA ANALYSIS AND REPORTING

Monitoring data for soil will be analyzed using both quantitative and qualitative methods. Tabular summaries of descriptive statistics will be prepared for each additional round of data collected, and overall summaries will be prepared by combining data across sampling rounds. The types and formats of the summary tables will be similar to each of the annual monitoring reports and in the 5-year review report (Tetra Tech 2003). Graphical presentations of the data, including box-plot figures and maps, will accompany each of the tables. Other types of plots may be prepared in cases where the data analysis suggests additional questions of interest and where other graphical displays of the data may prove useful.

Results for surface water will be presented in summary tables and figures after each full round (wet plus dry season) of sampling. Temporal trends at single and multiple sampling locations will be compared for this monitoring component.

Results for metals in groundwater will be presented in summary tables and figures after each round of sampling. Temporal trends at single and multiple sampling locations will be compared.

5.0 REFERENCES

American Public Health Association. 1989. *Standard Methods for the Examination of Water and Wastewater.* 17th Ed.

Cooper, White, and Cooper, LLP. 1999. Letter Regarding Groundwater Monitoring Results from Chemical and Pigment Company Facility. From Keith Howard, Cooper, White and Cooper, LLP. To Ralph Lee, Naval Weapons Station, Seal Beach Detachment (NWS SBD) Concord. May 10.

Cullinane, M.J., C.R. Lee, and L.J. O'Neill. 1988. "Feasibility Study of Contamination Remediation at Naval Weapons Station, Concord, California Volume I." Miscellaneous Paper EL-86-3. U.S. Department of the Army, Waterways Experiment Station, Corps of Engineers. September.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. John Wiley & Sons, Inc. New York, New York.

H.T. Harvey and Associates, Inc. 1995. "RASSs 1 to 4 Final Revegetation Monitoring Plan, Naval Weapons Station, Concord, California." April 3.

International Technology Corporation (IT). 1993. "Final Technical Memorandum: Results of Field Investigation Activities, Litigation Area Sites, NWS Concord, California." September 22.

IT. 1999. "RCRA Corrective Measures Study, Task 1 Activities Report, General Chemical Corporation, Bay Point Works Facility." March.

Lee, C.R., and others. 1986. "Final Report of Remedial Investigation of Contaminant Mobility at Naval Weapons Station, Concord, California." Miscellaneous Paper EL-86-2. U.S. Department of the Army, Waterways Experiment Station, Corps of Engineers. January.

Lee, C. R., and others. 1988. "Remedial Investigation of Contaminant Mobility at Naval Weapons Station, Concord, California; Subtitle Appendix 2.5 - 1986/87 Data." Miscellaneous Paper EL-86-2. U.S. Army Corps of Engineers, Waterways Experiment Station. Vicksburg, Mississippi.

Lee, C.R. M.J. Cullinane, L.J. O'Neill, and D.L Brandon. 1989. "Monitoring Plan for Contamination Remediation at Naval Weapons Station, Concord, California." U.S. Department of the Army, Waterways Experiment Station, Corps of Engineers. April.

Lewis, E.L. 1980. "The Practical Salinity Scale 1978 and Its Antecedents." *IEEE Journal of Oceanographic Engineering.* Volume OE-5. No. 1. Pages. 3 through 8. January.

Long, E.R. and L.G. Morgan. 1991. "The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program." National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 52, Seattle, Washington. August.

Long, E.R., MacDonald, D.D., Smith, S.L., and F.D. Calder. 1995. "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." *Environmental Management.* 19(1): 81-97.

Long, E.R. and D.D. MacDonald. 1998. "Recommended Use of Empirically Derived Sediment Quality Guidelines for Marine and Estuarine Ecosystems." *Human and Ecological Risk Assessment*. 4(5): 1019-1039.

PRC Environmental Management (PRC). 1994. "Hydrogeological and Analytical Data Compilation and Interpretation, Litigation Area Sites, NWS Concord, California." September 20.

PRC. 1996. "After Remediation (Year 1) Draft Remedial Action Monitoring Report, Litigation Area, Naval Weapons Station, Concord, California." May 31

PRC. 1997a. "After Remediation (Year 2) Draft Remedial Action Monitoring Report, Litigation Area, Naval Weapons Station Concord, California." July 2.

PRC. 1997b. "Qualitative Ecological Assessment, Litigation Area, Naval Weapons Station, Concord, California." September 2.

Tetra Tech EM Inc. (Tetra Tech). 1997. "Technical Memorandum: Tidal Influence Study and Postremediation Groundwater Monitoring, NWS Concord, California." July 22.

Tetra Tech. 1998. "After Remediation (Year 3) Draft Remedial Action Monitoring Report, Litigation Area, Naval Weapons Station, Concord, California." January 5.

Tetra Tech. 1999. "After Remediation (Year 4) Draft Remedial Action Monitoring Report, Litigation Area, Naval Weapons Station, Concord, California." January 13

Tetra Tech. 2000. "After Remediation (Year 5) Remedial Action Monitoring Report, Litigation Area, NWS SBD Concord, California." January 6.

Tetra Tech. 2003. "Final Five-Year Periodic Review Assessment Litigation Area, Naval Weapons Station, Seal Beach Detachment Concord." June 30.

Tetra Tech. 2004. "Data Gaps Technical Evaluation Report for the Litigation Area, NWS SBD Concord, California." Draft Report. June.

U.S. Department of the Navy (Navy). 1989a. "Final Remedial Action Plan for the Release, and the Threatened Release, of Hazardous Substances on Parcels 572, 573, 574, 575, 576, 579D, and 581 on the Naval Weapons Station, Concord, California." April 6.

Navy. 1989b. "Record of Decision of Selection of Final Remedial Action Plan for the Release, and the Threatened Release, of Hazardous Substances on Parcels 572, 573, 574, 575, 576, 579D, and 581 on the Naval Weapons Station, Concord, California." April 6.

U.S. Environmental Protection Agency (EPA). 1992. "Supplemental Guidance to RAGS: Calculating the Concentration Term." Publication 9285.7-081. Office of Solid Waste and Emergency Response, Washington, DC. May.

EPA. 1994. "National Functional Guidelines for Inorganic Data Review." Office of Emergency and Remedial Response. Washington, DC. EPA-540/R-94/013. February.

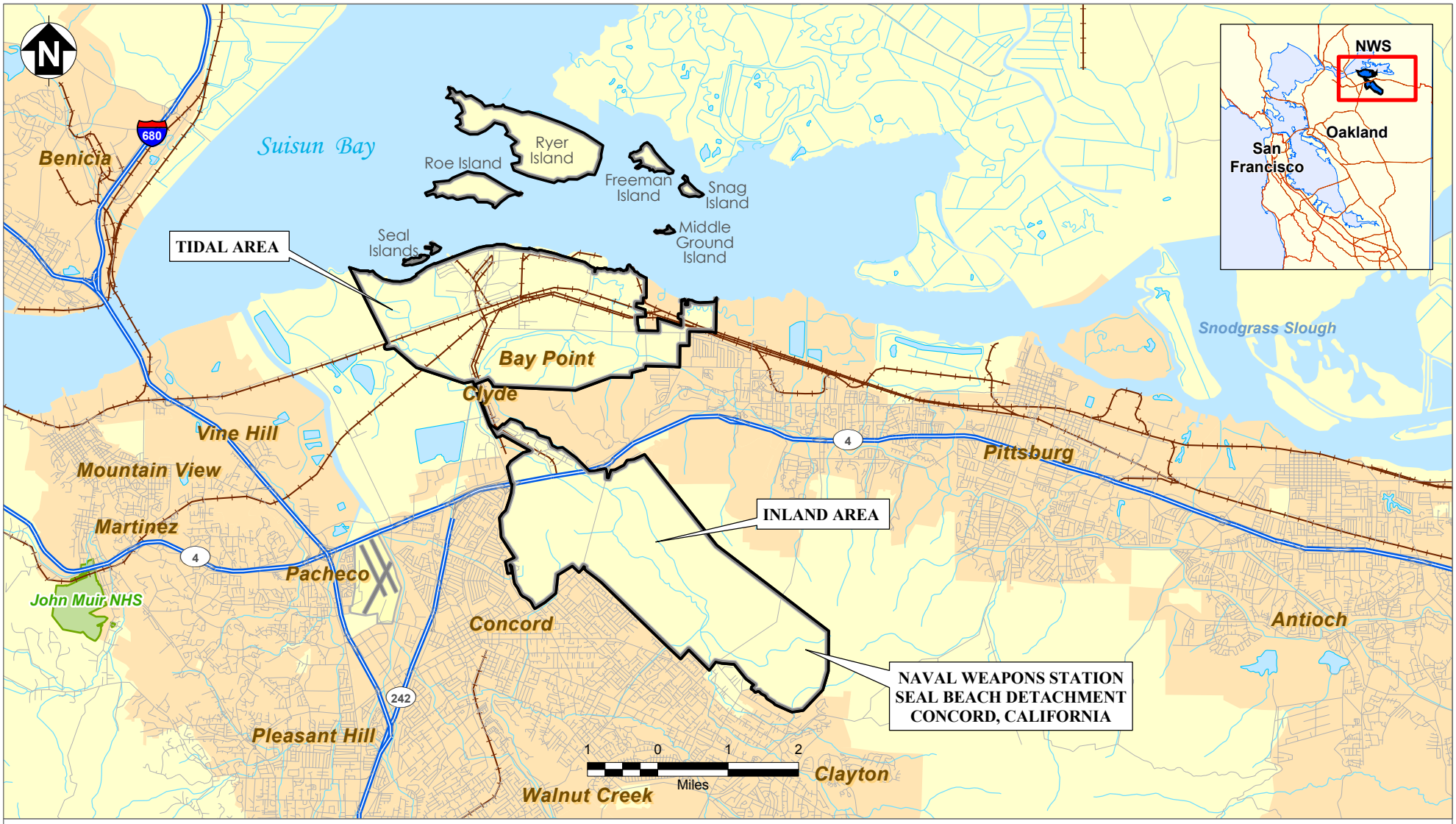
EPA. 1999. "National Functional Guidelines for Organic Data Review." Office of Emergency and Remedial Response. Washington, DC. EPA-540/R-99-008. October.

EPA. 2000. "Data Quality Objectives Process for Hazardous Waste Site Investigations." EPA QA/G-4HW. Final." Office of Environmental Information, Washington, D.C. EPA/600/R-00/007. January.

EPA. 2002. "National Recommended Water Quality Criteria: 2002." EPA-822-R-02-047. Office of Water, Washington, DC. November.

Zar, J.H. 1996. *Biostatistical Analysis*. Third Edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

FIGURES



NAVAL WEAPONS STATION
SEAL BEACH DETACHMENT
CONCORD, CALIFORNIA

Tetra Tech EM Inc.

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE 1-1
SITE VICINITY MAP

Monitoring Plan

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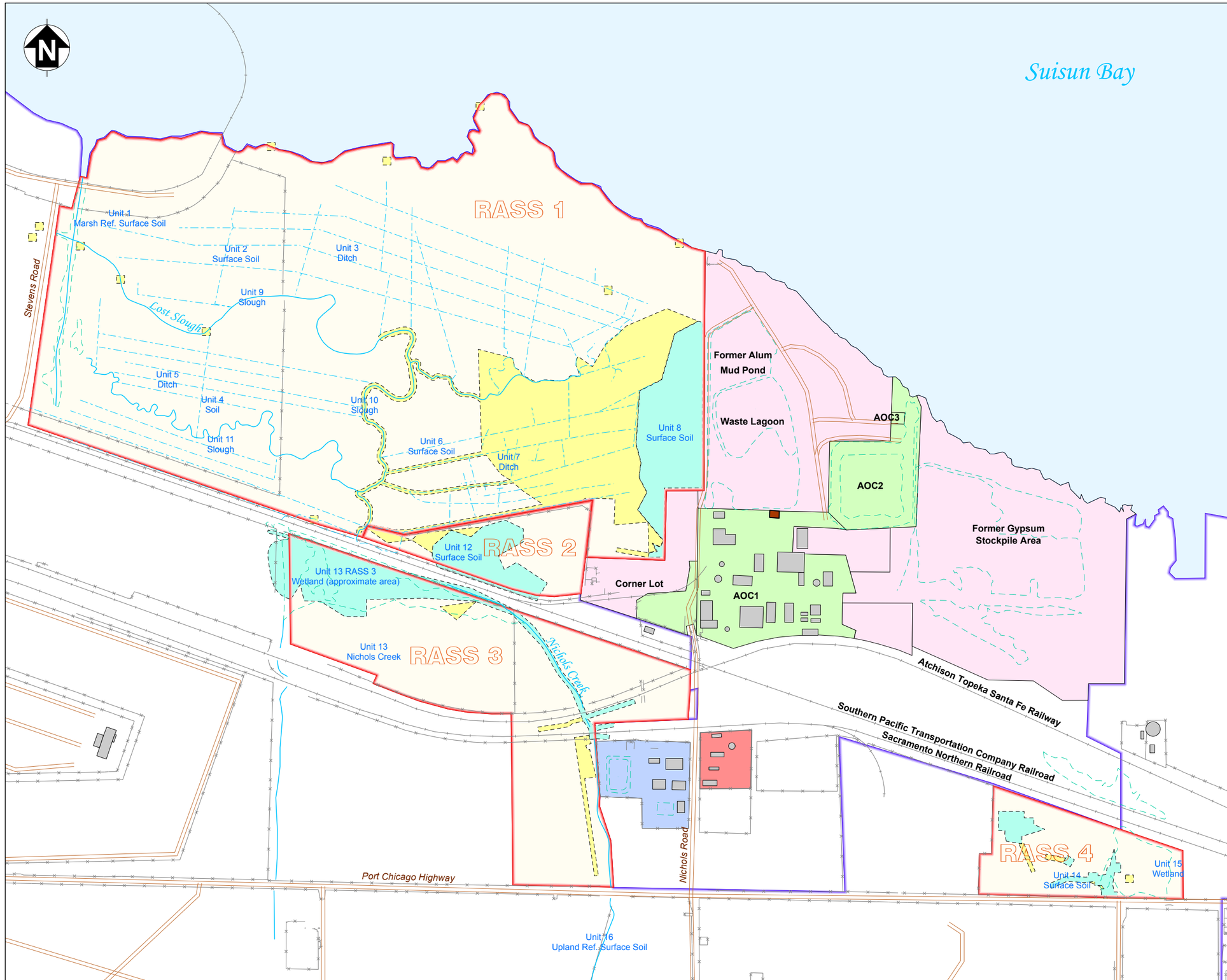

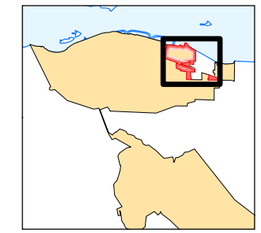

NWS SBD Boundary
RASS Boundary
Building
Fence
Road
Railroad
Creek
Mosquito Ditch
Active Remediation Area Boundary
Passive RAB

Neighboring Properties

Honeywell International Inc.
General Chemical Bay Point Works
Chemical and Pigment Company
G.W.F Power Systems
Polypure, Inc.

Notes:
1. NWS SBD - Naval Weapons Station Seal Beach Detachment.
2. RASS - Remedial Action Subsite.

600 0 600
Feet

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Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE 1-2
LITIGATION AREA
REMEDIAL ACTION SUBSITES
AND ADJACENT SITES

Monitoring Plan

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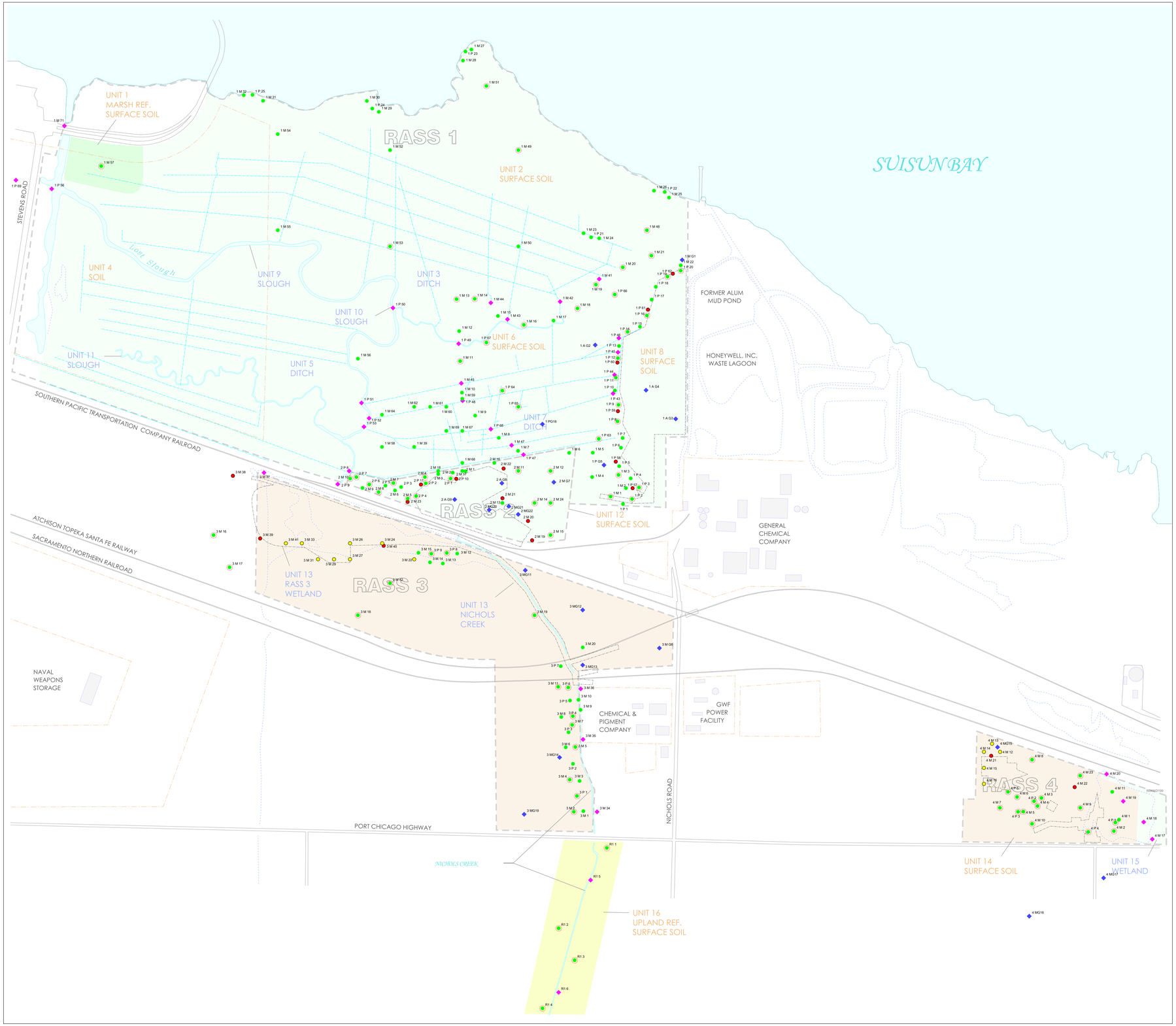
Replacement Page - 10/29/04



LEGEND:

- Vegetation & Small Mammal Characterization
- Fixed Photo
- Surface Soil
- Surface & Subsurface Soil
- Sediment & Surface Water
- Groundwater
- 1 P 63 / 2 M 12 SAMPLE LOCATION IDENTIFICATION; INDICATES PASSIVE REMEDIATION OR MONITORING LOCATION
- BUILDING
- ROAD
- RAILROAD TRACK
- ACTIVE REMEDIATION AREA BOUNDARY
- APPROXIMATE RASS BOUNDARY
- MOSQUITO DITCH
- FENCE
- OTHER SURFACE FEATURES

Tetra Tech EM Inc.

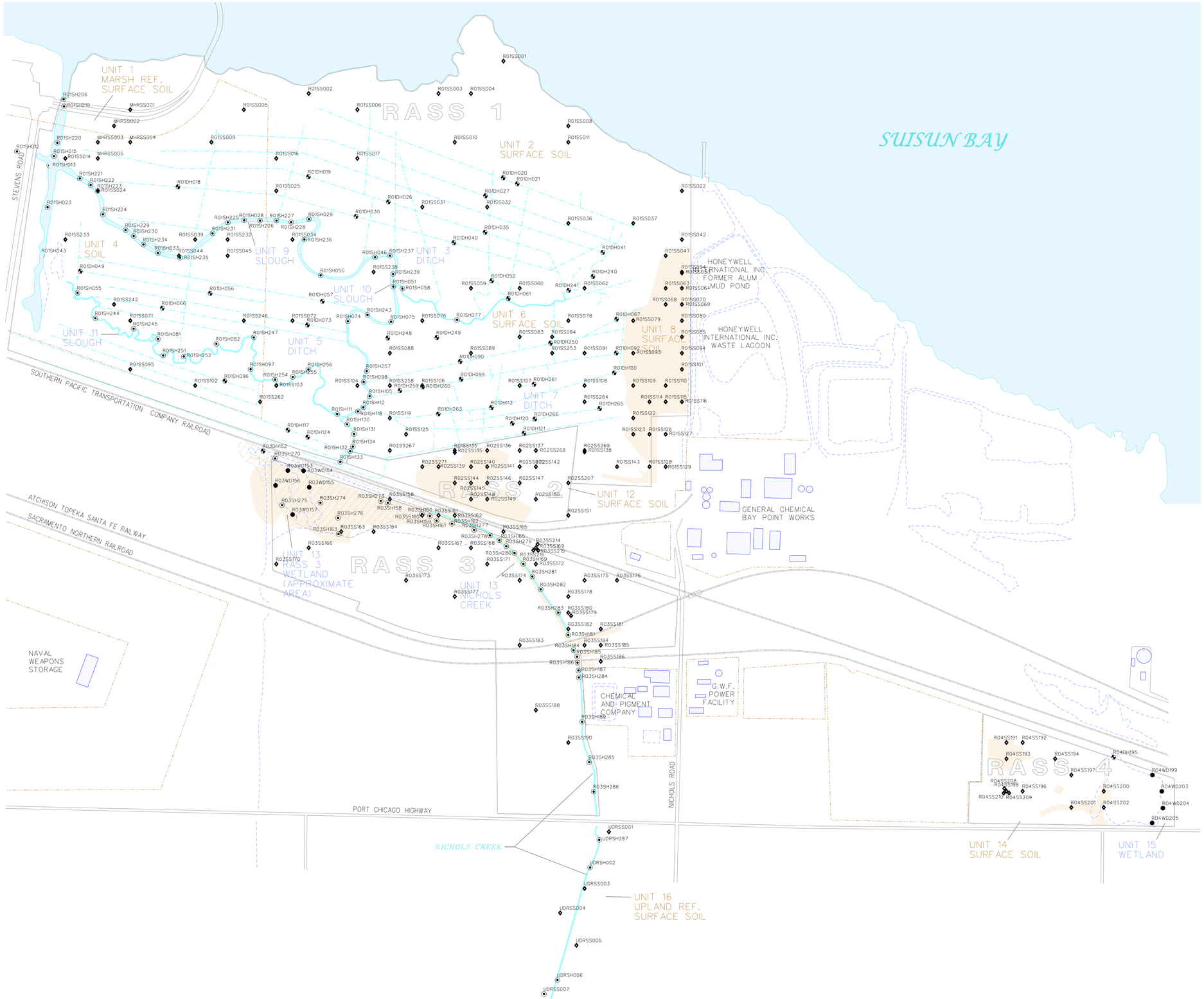
N

150 0 150 300 Feet

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE 1-3
PREREMEDIATION SAMPLE LOCATIONS
FROM BASELINE CONDITIONS REPORT
LITIGATION AREA

Monitoring Plan



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Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE 1-4
POSTREMEDIAL ACTION MONITORING
SAMPLE LOCATIONS
LITIGATION AREA

Monitoring Plan

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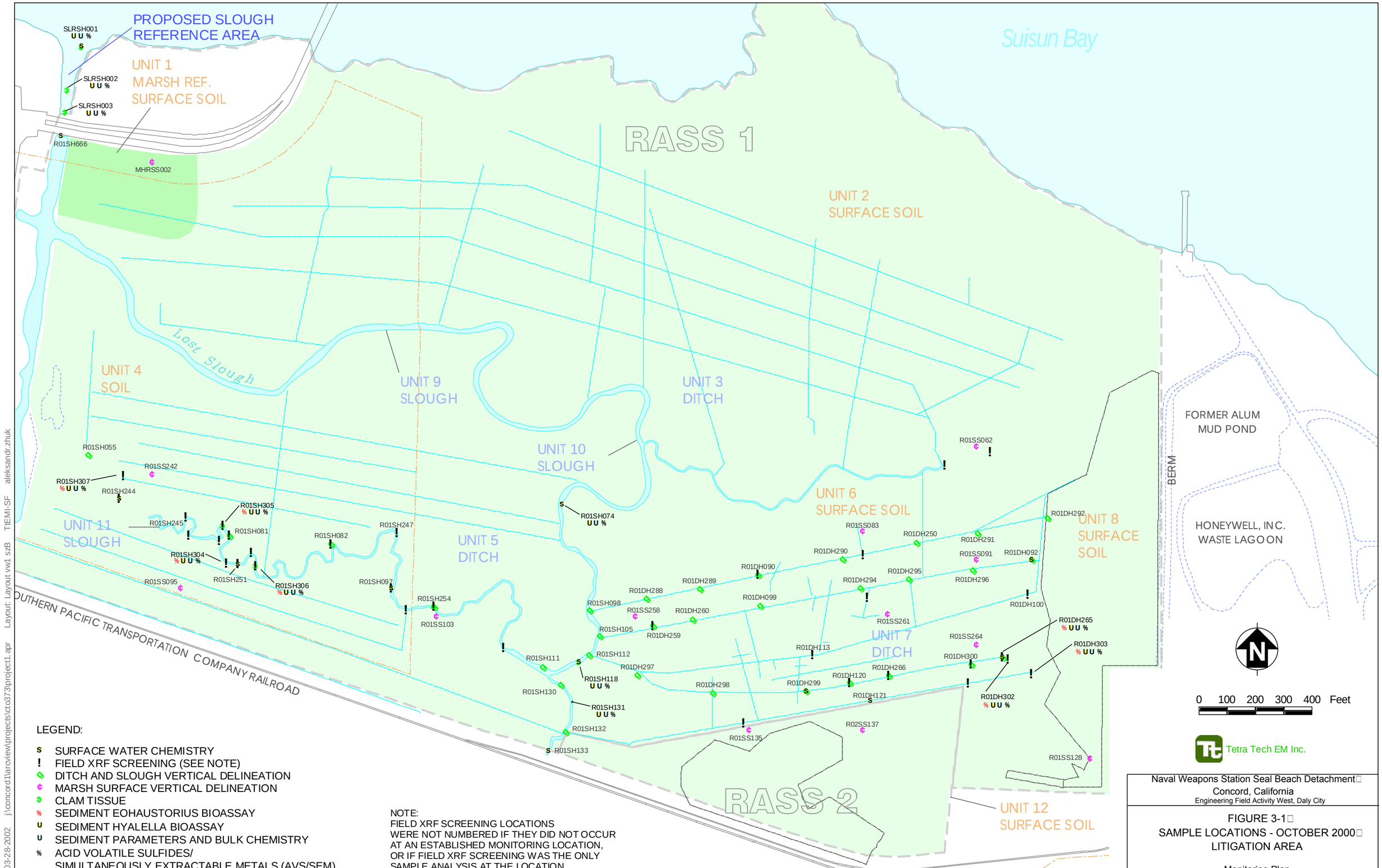

LEGEND:

- S SURFACE WATER CHEMISTRY
- ! FIELD XRF SCREENING (SEE NOTE)
- DITCH AND SLOUGH VERTICAL DELINEATION
- MARSH SURFACE VERTICAL DELINEATION
- CLAM TISSUE
- % SEDIMENT EOHAUSTORIUS BIOASSAY
- U SEDIMENT HYALELLA BIOASSAY
- U SEDIMENT PARAMETERS AND BULK CHEMISTRY
- % ACID VOLATILE SULFIDES/ SIMULTANEOUSLY EXTRACTABLE METALS (AVS/SEM)

NOTE:
FIELD XRF SCREENING LOCATIONS WERE NOT NUMBERED IF THEY DID NOT OCCUR AT AN ESTABLISHED MONITORING LOCATION, OR IF FIELD XRF SCREENING WAS THE ONLY SAMPLE ANALYSIS AT THE LOCATION

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE 3-1
SAMPLE LOCATIONS - OCTOBER 2000
LITIGATION AREA

Monitoring Plan

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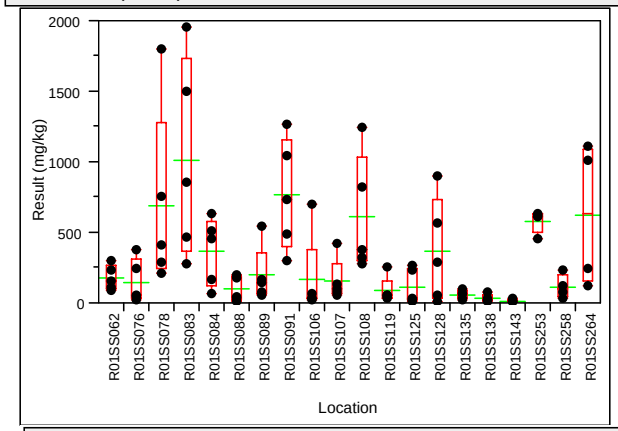
FIGURE 3-2

EXAMPLE OUTPUT FOR DATA SUMMARIZED BY INDIVIDUAL SAMPLING LOCATIONS AND ROUNDS (YEARS)

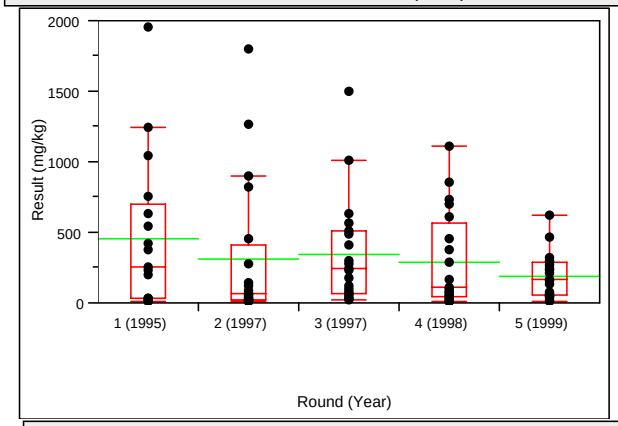
Spatial Unit=6, Metal=Arsenic

Outlier Box-Plots for Data Summarized by Sampling Location and Round (Year)

All Rounds (Years) Combined for Individual Locations



All Locations Combined Within Each Round (Year)



Quantiles for all Rounds (Years) Combined for Individual Locations

Level	Minimum	10%	25%	Median	75%	90%	Maximum
R01SS062	93.1	93.1	102.5	156.0	265.5	302.0	302.0
R01SS076	22.3	22.3	32.1	55.5	312.5	377.0	377.0
R01SS078	214.0	214.0	249.0	412.0	1279.5	1800.0	1800.0
R01SS083	273.0	273.0	371.5	861.0	1730.0	1960.0	1960.0
R01SS084	66.4	66.4	119.2	452.0	573.5	632.0	632.0
R01SS088	16.6	16.6	25.7	44.6	188.5	195.0	195.0
R01SS089	53.8	53.8	65.0	149.0	356.0	545.0	545.0
R01SS091	304.0	304.0	398.5	734.0	1160.0	1270.0	1270.0
R01SS106	25.3	25.3	28.5	36.7	383.1	705.0	705.0
R01SS107	55.9	55.9	65.2	95.1	274.5	418.0	418.0
R01SS108	274.0	274.0	299.0	380.0	1034.5	1250.0	1250.0
R01SS119	28.9	28.9	37.8	51.7	159.5	259.0	259.0
R01SS125	10.1	10.1	17.1	32.4	248.0	262.0	262.0
R01SS128	13.1	13.1	34.2	294.0	736.0	903.0	903.0
R01SS135	24.1	24.1	31.2	66.5	84.8	102.0	102.0
R01SS138	13.8	13.8	17.1	21.8	55.4	77.7	77.7
R01SS143	7.9	7.9	9.1	12.4	20.9	29.0	29.0
R01SS253	458.0	458.0	495.2	614.5	632.5	636.0	636.0
R01SS258	38.6	38.6	48.2	97.5	202.0	230.0	230.0
R01SS264	122.0	122.0	153.8	629.5	1085.0	1110.0	1110.0

Quantiles for all Locations Combined Within Each Round (Year)

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1 (1995)	10.2	12.5	32.0	259.0	695.5	1392.0	1960.0
2 (1997)	12.9	17.2	26.4	63.9	411.8	1233.3	1800.0
3 (1997)	20.5	29.8	69.0	241.0	509.5	972.6	1500.0
4 (1998)	7.9	10.5	40.0	107.0	568.2	848.3	1110.0
5 (1999)	12.4	27.0	55.3	164.0	286.0	455.4	622.0

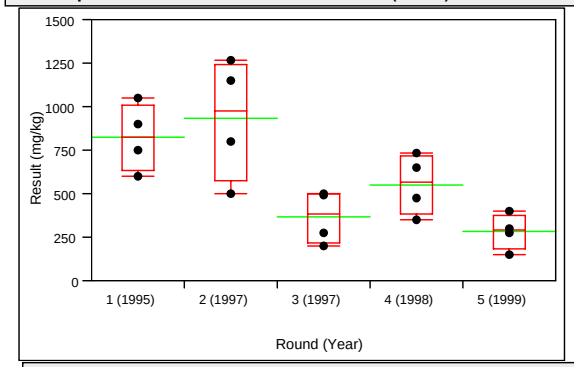
FIGURE 3-3

EXAMPLE SUMMARY FOR AN INDIVIDUAL SAMPLING LOCATION

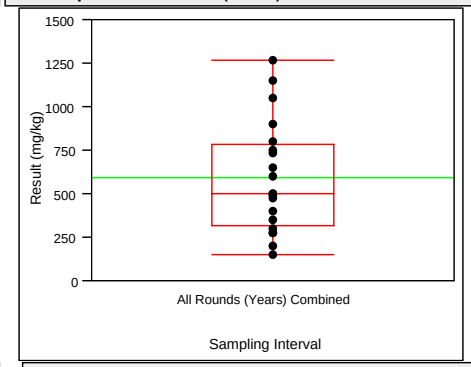
Spatial Unit=6, Metal=Arsenic, Location=R01SS091

Outlier Box-Plots for Data Summarized by Round (Year) and for all Rounds (Years) Combined

All Samples Combined for Individual Rounds (Years)



All Samples and Rounds (Years) Combined



Quantiles for Samples Collected Within Individual Rounds (Years)

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1 (1995)	600	600	637.5	825	1012.5	1050	1050
2 (1997)	500	500	575	975	1240	1270	1270
3 (1997)	200	200	218.75	384	498.25	500	500
4 (1998)	350	350	381.5	563	713	734	734
5 (1999)	150	150	181.25	289.5	376	400	400

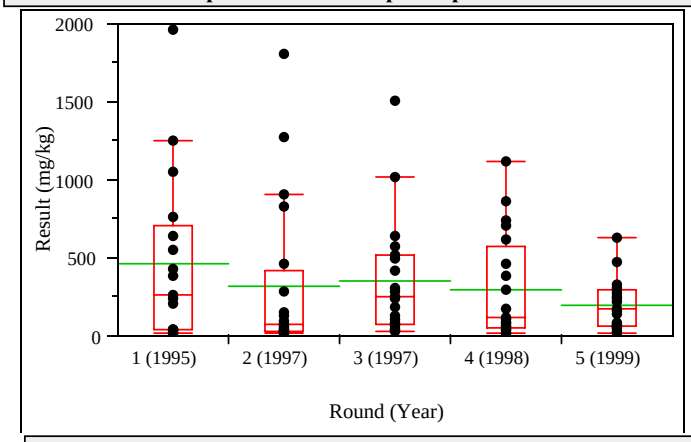
Quantiles for all Samples and Rounds (Years) Combined

Level	Minimum	10%	25%	Median	75%	90%	Maximum
All Rounds (Years) Combined	150	207.5	315.5	500	787.5	1140	1270

FIGURE 3-4

EXAMPLE OF PRESENTATION OF RESULTS FOR PARAMETRIC AND NONPARAMETRIC MULTIPLE-POPULATION TESTS

Parametric & Nonparametric Multiple-Population Tests



Quantiles

Level	Minimum	10%	25%	Median	75%	90%	Maximum
1 (1995)	10.2	12.52	32.05	259	695.5	1392	1960
2 (1997)	12.9	17.17	26.35	63.85	411.75	1233.3	1800
3 (1997)	20.5	29.77	68.95	241	509.5	972.6	1500
4 (1998)	7.9	10.47	39.95	107	568.25	848.3	1110
5 (1999)	12.4	26.96	55.35	164	286	455.4	622

Oneway Anova

Summary of Fit

Rsquare	0.045059
Adj Rsquare	0.00354
Root Mean Square Error	399.4789
Mean of Response	316.1093
Observations (or Sum Wgts)	97

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob > F
Round (Year)	4	692752	173188	1.0853	0.3685
Error	92	14681669	159583		
C. Total	96	15374421			

Means for Oneway Anova

Level	Number	Mean	Std Error	Lower 95%	Upper 95%
1 (1995)	17	460.088	96.888	267.66	652.52
2 (1997)	20	314.460	89.326	137.05	491.87
3 (1997)	20	343.440	89.326	166.03	520.85
4 (1998)	20	293.585	89.326	116.18	470.99
5 (1999)	20	190.570	89.326	13.16	367.98

Std Error uses a pooled estimate of error variance

Wilcoxon / Kruskal-Wallis Tests (Rank Sums)

Level	Count	Score Sum	Score Mean	(Mean-Mean0)/Std0
1 (1995)	17	912	53.6471	0.745
2 (1997)	20	852	42.6000	-1.137
3 (1997)	20	1100	55.0000	1.066
4 (1998)	20	953	47.6500	-0.236
5 (1999)	20	936	46.8000	-0.388

1-way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
2.5747	4	0.6313

TABLE

TABLE 3-1: SUMMARY OF MONITORING COMPONENTS FOR THE LITIGATION AREA

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Monitoring Component	Monitoring Plan Summary	
	Monitoring Frequency	**Main Elements of Sampling Design**
Monitoring of Surface Water Concentrations of Metals in the Main Channel of Lost Slough (Unit 9 and Unit 10)	Annual – three sampling events in the wet season and three events in the dry season	• Surface water grab samples will be collected from three locations within Unit 9 and three locations within Unit 10. Locations will be randomly selected from the bottom, middle, and top one-third of each Unit. • Three sampling events will be conducted in the wet season and three events in the dry season, with approximately 1 to 2 weeks between each event. • All samples will be collected during an outgoing tide. • Samples will be analyzed for total and dissolved metals (full suite), total suspended solids, temperature, pH, conductivity, dissolved oxygen. • A total of 36 samples will be collected each year: 2 Units times 3 locations times 3 events times 2 seasons
Monitoring of Groundwater Concentrations of Metals	Three year intervals for sitewide network of wells and annually for a subset of "sentinel" wells	• Three additional deep wells (down to 60 feet below ground surface) will be installed. Two of the new wells will be located in RASS 1 along the berm separating the Navy and offsite industrial properties to the east, and one well will be located southwest of the berm in RASS 2 near existing well R02AG009. • The three new wells plus the existing network of 23 wells will be sampled once every three years during the wet season. • A subset of wells, designated as "sentinel wells", will be sampled once per year during the wet season. The sentinel wells will be selected following the next sampling event, and will be comprised of wells located along the eastern border of the Navy's property (that is, wells that have the potential to measure ongoing migration from offsite sources), and any wells that show an increasing trend in metal concentrations based on the previous two sampling events (that is, October 2003 and the next sampling event) or wells where metal concentrations are reported that consistently exceed the AWQC. • All wells will be sampled using low-flow techniques and will be analyzed for total metals (full suite), temperature, pH, conductivity, total dissolved solids, and total suspended solids. For the first sampling event for the three new deep wells, analyses will also be conducted for VOCs, SVOCs, TPH (extractable and purgeable), and pesticides and herbicides.

TABLE 3-1: SUMMARY OF MONITORING COMPONENTS FOR THE LITIGATION AREA (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Monitoring Component	Monitoring Plan Summary	
	Monitoring Frequency	**Main Elements of Sampling Design**
Monitoring of Soil Concentrations of Metals on the Marsh Surface (RASS 1 and RASS 2)	Five year intervals	• A total of 31 existing marsh surface soil locations and one new location will be sampled every 5 years. The existing locations represent areas where elevated concentrations of arsenic and other chemicals of concern continue to be found. One new location (R01SS308) was added to the east of existing location R01SS078 to fill a spatial data gap. • Each location is defined by a 100 X 100 foot grid, and random samples will be collected from each of the four grid quadrats from a depth of 0 to 0.5 feet below ground surface. Therefore, a total of 128 samples will be collected during each sampling event. • Samples will be analyzed for total metals (full suite), pH, and organic carbon.
Supplemental Evaluation of Risk to the California Black Rail	One-time event during the next round of sampling	• Samples of two food items (insects and seeds) of the California Black Rail will be collected at three locations on the marsh surface where elevated concentrations of arsenic have consistently been measured. Each location is defined by a 100 X 100 foot grid. Co-located soil samples will also be collected at each of the three locations. • Depending on availability, it may be necessary to pool species of insects and the seeds of different plant to achieve sufficient biomass for each of the two groups. Individual species of insects and seeds will be maintained in separate containers during sampling, and a decision to pool samples will be made after sampling has been completed. It may be necessary to sample over a period of several months to account for temporal variability in the availability of the different food items. • Samples will be analyzed for total metals and the results will be used to support a limited reassessment of risk to the rail using a food-chain modeling approach.
Monitoring of Landscape-Scale Changes in Site Condition	Three year intervals	• A pilot study will be conducted during the next sampling event to evaluate the feasibility of using aerial photographs to measure coarse or landscape-scale changes in site conditions. Ground surveys will be used to evaluate the accuracy with which selected vegetation types can be determined based on features identified in the photographs. • The Navy will also evaluate the utility of establishing a network of permanent photo points in selected areas of the site to provide better resolution of changes in vegetation and other surface features at a finer spatial scale. Existing vegetation maps, analysis of aerial photographs, and results of previous wildlife studies will be used to define candidate areas for establishing permanent photo points. • If one or both of these elements are shown to provide information that will aid the Navy in making management decisions at the site, they will become a permanent part of the Navy's monitoring plan. Both monitoring elements will be repeated once every three years.

Notes:

AWQC Ambient water quality criteria
Navy U.S. Department of the Navy
RASS Remedial action subsite
SVOC Semivolatile organic compound
TPH Total petroleum hydrocarbons
VOC Volatile organic compound

APPENDIX A
STATISTICAL CONCEPTS AND OVERVIEW OF SELECTED METHODS

CONTENTS

ACRONYMS AND ABBREVIATIONS ..... A-iv

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2.0 STATISTICAL CONCEPTS AND TERMINOLOGY A-1

3.0 SELECTED STATISTICAL METHODS AND APPLICATION TO LITIGATION AREA DATA A-2

4.0 REFERENCES A-11

ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
AWQC	Ambient water quality criteria
COC	Chemical of concern
DQA	Data quality assessment
DQO	Data quality objectives
EPA	U.S. Environmental Protection Agency
H_A	Alternative hypothesis statement
H_0	Null hypothesis statement
LOE	Line of evidence
MDD	Minimum detectable difference
UCL	Upper confidence limit
WOE	Weight-of-evidence

1.0 INTRODUCTION

This appendix presents an overview of the statistical concepts considered and included in the monitoring plan.

Section 2.0 defines key statistical terms and concepts that pertain to the design of monitoring programs. Section 3.0 presents an overview of statistical methods for determining minimum sample sizes and calculating the power of selected tests, as well as details of the hypotheses addressed for specific tests that will be used to evaluate Litigation Area data for individual monitoring components.

2.0 STATISTICAL CONCEPTS AND TERMINOLOGY

The following terms are used in the data quality objectives (DQO) and data quality assessment (DQA) guidance (EPA 2000a, 2000b) and technical literature on monitoring designs, and represent key statistical concepts common to environmental sampling programs. Excellent sources for additional details on the application of statistical methods in the design of environmental monitoring programs include Gilbert (1987); Zar (1996); (Winer, Brown, and Michels 1991; EPA 2000b; Underwood 1993; McBean and Rovers 1998; Eberhardt and Thomas 1991; Andrew and Mapstone 1987; Mapstone 1995; Fairweather 1991; and Karr and Chu 1997).

Decision Errors. Refers to the probability of making an incorrect decision within the context of a hypothesis test. Two specific decision errors are recognized, Type I and Type II.

Minimum Detectable Difference (MDD). In the DQO literature the MDD is referred to as the size of the "gray region." The technical literature on power analysis also uses the term "effect size" although, depending on the source, the manner used to calculate the effect size can vary. Precise definition of the MDD depends on the analytical scenario, but in general terms this is the magnitude of difference or change one wishes to detect in a specific statistical test.

Null Hypothesis (H_0). The null hypothesis is often referred to as the baseline condition. In environmental scenarios, H_0 is typically chosen to define the true state of nature that is associated with the more serious decision error. For example, if H_0 is stated as "site concentrations exceed the action level", site managers must provide overwhelming evidence to reject H_0 and assure that concentrations are below a level of concern. This is sometimes referred to as the "guilty until proven innocent" option for structuring H_0. The alternative condition, that concentrations are below the action level, is referred to as the **alternative hypothesis (H_A)**.

Statistical Power. The probability of correctly rejecting H_0 when it is false. Power increases as a function of increasing sample size and the magnitude of change (that is, MDD or effect size) that can be detected with some pre-stated level of confidence. Power decreases with increasing variance, so as the amount of "noise" in the data increases, larger sample sizes are typically required to achieve acceptable power in tests.

Type I Error. The probability of incorrectly rejecting H_0 when it is true. Type I error is denoted by the symbol α and is sometimes referred to as the "false rejection" error. The α is sometimes referred to as the significance level for a test.

Type II Error. The probability of failing to reject H_0 when it is false. The Type II error is denoted by the symbol β. The power of a statistical test is $1-\beta$.

3.0 SELECTED STATISTICAL METHODS AND APPLICATION TO LITIGATION AREA DATA

A number of statistical approaches and tests are available for evaluating monitoring data collected at the Litigation Area. These tests generally fall into the following categories: (1) one population (or one-sample) tests, (2) two-population (or two-sample) tests, (3) multiple-population (or multiple-sample) tests, and (4) tests for trends. This section provides an overview of the underlying hypotheses and calculations for several of the more commonly employed tests, along with discussion of alternatives for applying these tests for specific monitoring components.

The decision rules used to evaluate individual monitoring components in this plan are conservative and rely on simple, non-statistical triggers. For example, simply exceeding any ambient water quality criteria (AWQC) for the surface and groundwater components or any ecological benchmark for the marsh surface soil component triggers additional evaluation of the data and selection of one or more alternative actions. Calculation of statistical parameters, such as the mean and upper confidence limit (UCL) of the mean, and tests of specific hypotheses are used in supplemental evaluations in an overall weight-of-evidence (WOE) process. For example, if one or more surface water measurements exceed the AWQC for a particular chemical of concern (COC), then the UCL of the average surface water concentration for that COC will be compared to the AWQC to assess exposure conditions for ecological receptors as an additional line of evidence (LOE) in the overall evaluation process.

Power and sample-size details for several of the more commonly employed statistical tests, as well as a discussion of specific applications of the tests for evaluating Litigation Area data, are provided below. Because the exact test or combination of tests used will be determined as part of an initial review of the data after each sampling event (that is, some exploratory data analysis will be conducted that may result in a recommendation for one or more *ad hoc* tests not initially envisioned), sample size and power calculations are not provided for specific analyses. Rather, general tables are provided for several common scenarios that cover a range of potential sample sizes based on pre-specified values for the power of the test as well as other input variables required in the different sample-size equations. Because statistical tests are being used as part of a supplemental evaluation (that is, as additional LOEs after a trigger condition is met), rather than as a primary means of making decisions for individual monitoring components, relatively less emphasis is placed on the importance of achieving high power or optimal test conditions. In cases where low power is achieved in a supplemental test, this will be considered as an additional factor in the WOE process.

ONE-POPULATION TESTS

One-population tests can be used to compare mean chemical concentrations to a fixed action level, such as the AWQC (for surface water and groundwater) or an ecological benchmark (for marsh surface soil). In cases where the more protective baseline condition is used (that is, the guilty until proven innocent H_0), a one-population test would address the following hypotheses:

H_0: The mean chemical concentration is greater than or equal to the action level

H_A: The mean chemical concentration is less than the action level

The minimum number of samples required to perform a one-population with fixed Type I and Type II errors can be estimated using the following equation from the Visual Sampling Plan software program (Hassig and others 2002):

Equation A-1

$$n = \frac{s^2\left(Z_{1-\alpha} + Z_{1-\beta}\right)^2}{\delta^2} + \frac{Z_{1-\alpha}^2}{2},$$

where:

n	=	the minimum number of samples required
s^2	=	estimate of the expected variance
$Z_{1-\alpha}$	=	quantile of the cumulative standard normal distribution equal to 1-α
$Z_{1-\beta}$	=	quantille of the cumulative standard normal distribution equal to 1-β
δ	=	MDD between the mean and its respective action level

The following equation from Zar (1996) can be used to calculate the MDD that can be detected between the mean concentration of a COC and its respective action level with fixed estimates for the Type I and Type II errors:

Equation A-2

$$\delta = \sqrt{\frac{s^2}{n}}\left(t_{\alpha(1),v} + t_{\beta(1),v}\right)$$

where:

δ	=	the MDD between the mean and a fixed action level
s^2	=	an estimate of the expected variance
n	=	the sample size
α(1)	=	alpha, the Type I error rate for a one-tailed test
β(1)	=	beta, the Type II error rate for a one-tailed test
v	=	the degrees of freedom for the test, calculated as n-1

The following table shows the minimum sample sizes that would be required to compare a mean concentration to an action level for different fixed values of the MDD and Type I and Type II decision errors.

Minimum Detectable Difference[1]	Type II Error (β)[2]	Type I Error (α)	Expected Variability[3]	Minimum Number of Samples Required
50%	20%	10%	50%	5
			100%	19
			200%	73
		5%	50%	8
			100%	26
			200%	100
40%	20%	10%	50%	8
			100%	29
			200%	114
		5%	50%	11
			100%	40
			200%	156
30%	20%	10%	50%	13
			100%	51
			200%	201
		5%	50%	19
			100%	70
			200%	276

Notes:

1 Expressed as a percentage of the fixed action level

2 1-ß is the power of the test

3 The estimated standard deviation expressed as a percentage of the fixed action level

TWO-POPULATION TESTS

Two-population tests can be used in cases where the means from two independent samples are compared. The following are common situations in monitoring studies where application of two-populations tests is appropriate:

- Comparison of mean chemical concentrations between two sampling events
- Comparison of mean chemical concentrations between two sampling locations
- Comparison of mean chemical concentrations (or other parameters) before and after a planned intervention
- Comparison of mean chemical concentrations (or other parameters) between assessment and reference areas

For the Litigation Area, two-population tests can be used to assess short-term temporal trends (that is, comparison of two successive sampling events) in concentrations of COCs in surface water, groundwater, or soil, as well as testing for differences between individual sampling locations or between two groups of sampling locations.

Either one- or two-sided hypothesis tests could be employed for scenarios in which two independent populations are compared, as shown in the examples below:

Two-sided test:

H_0: Mean chemical concentration between locations (or events) are equal

H_A: Mean chemical concentration between locations (or events) are not equal

One-sided test:

H_0: The mean chemical concentration at location X (or event X) is greater than location Y (or event Y)

H_A: The mean chemical concentration at location X (or event X) is less than or equal to location Y (or event Y)

In addition to the planned tests of temporal and spatial trends described above, *ad hoc* tests can be conducted to address a wide range of other focused questions. *Ad hoc* tests can be constructed to address specific questions that may arise during the data analysis, such as testing specific combinations of locations and/or sampling events. All of the tests previously described can be conducted by combining both temporal (events or years) and spatial (locations) data in a variety of ways. That is, tests can be constructed to compare means calculated for individual locations or groups of locations, and in each of these cases, the data can come from an individual sampling event or from combinations of sampling events. Several examples of *ad hoc* hypothesis tests are provided below:

H_1: The grand mean (all locations combined) concentration of arsenic measured in round 5 (1999) in the passive remediation area of RASS 1 (Unit 6) is greater than the action level.

H_{1A}: The grand mean concentration of arsenic measured in round 5 (1999) in the passive remediation area of RASS 1 (Unit 6) is less than or equal to the action level.

H_2: The mean concentration of arsenic measured at locations X and Y during years 4 and 5 in the passive remediation area of RASS 1 (Unit 6) is greater than the mean concentration measured at location Z

H_{2A}: The mean concentration of arsenic measured at locations X and Y during years 4 and 5 in the passive remediation area of RASS 1 (Unit 6) is less than or equal to the mean concentration measured at location Z

H_3: The mean concentrations of copper measured during the wet and dry seasons in the main reach of Lost Slough are equal

H_{3A}: The mean concentrations of copper measured during the wet and dry seasons in the main reach of Lost Slough are not equal

The minimum number of samples required to perform a two-population t-test with fixed Type I and Type II decision errors can be estimated using the following equation from the Zar (1996):

Equation A-3

$$n \geq \frac{2s_p^2}{\delta^2}\left(t_{\alpha,v} + t_{\beta(1),v}\right)^2,$$

where:

n	=	the minimum number of samples required
s_p^2	=	estimate of the pooled variance
$t_{\alpha,v}$	=	quantile of the t distribution at α (one or two-tailed) with v degrees of freedom
$t_{\beta!v}$	=	quantile of the t distribution at β with v degrees of freedom
δ	=	MDD between two population means (calculated as the absolute value of the difference)

The following equation from Zar (1996) can be used to calculate the MDD for two-population tests with fixed estimates for the Type I and Type II decision errors:

Equation A-4

$$\delta \geq \sqrt{\frac{2s_p^2}{n}}\left(t_{\alpha,v} + t_{\beta(1),v}\right)$$

where:

δ	=	the MDD between population means
s_p^2	=	estimate of the pooled variance
$t_{\alpha,v}$	=	quantile of the t distribution at α (one- or two-sided) with v degrees of freedom
$t_{\beta(1),v}$	=	quantile of the t distribution at β (one-sided) with v degrees of freedom
n	=	the sample size (assumed equal for both populations)

If the sample sizes for the two populations are unequal, then the harmonic mean can be used in place of *n* in the previous equation. The harmonic mean is calculated as follows:

$$n = \frac{2n_1n_2}{n_1 + n_2}$$

where:

n_1	=	sample size of the first population
n_2	=	sample size of the second population

The following table shows the minimum sample sizes required for comparing mean concentrations between two independent populations for different fixed values of the Type I and Type II decision errors. The relative magnitude of difference between the two means is expressed in terms of the effect size, calculated as δ divided by the common standard deviation for the two means. Values of 0.80, 0.50, and 0.20 for the effect size are commonly defined as "large", "medium", and "small" effects, respectively, in the technical literature on power analysis.

Form of Test	Type I Error (α)	Type II Error (β)	Effect Size	Minimum Number of Samples Required From Each Population
1-tail	5%	10%	0.80	28
			0.50	70
			0.20	429
		20%	0.80	21
			0.50	51
			0.20	310
	10%	10%	0.80	21
			0.50	53
			0.20	329
		20%	0.80	15
			0.50	37
			0.20	226
2-tail	5%	10%	0.80	34
			0.50	86
			0.20	527
		20%	0.80	26
			0.50	64
			0.20	394
	10%	10%	0.80	28
			0.50	70
			0.20	429
		20%	0.80	21
			0.50	51
			0.20	310

MULTIPLE-POPULATION TESTS

Multiple population tests can be used to compare the means for three or more independent samples. The following are common situations in monitoring studies where application of multiple-population tests is appropriate:

- Comparison of mean chemical concentrations (or other parameters) for a time series of three or more sampling events
- Comparison of mean chemical concentrations (or other parameters) among three or more sampling locations
- Comparison of multiple treatments in a controlled study

For the Litigation Area, two-population tests can be used to assess temporal trends in concentrations of COCs in surface water, groundwater, or soil across three or more sampling events, as well as testing for differences among three or more sampling locations or groups of sampling locations.

The following is an example of the hypotheses evaluated using a multiple population test:

H_0: The mean chemical concentrations for all populations are equal

H_A: The mean chemical concentrations for at least two populations are different

It should be noted that rejection of H_0 only results in the conclusion that at least two of the means are significantly different. In order to better determine the exact relationship among all or a selected number of population means, *post hoc* multiple-comparison tests are needed. Discussion of *post hoc* tests may be found in a variety of sources, including Zar (1996) and Day and Quinn (1989).

The minimum sample size for each population in a multiple-population comparison can be estimated by first specifying the desired power, MDD, estimate of the population variance common to all populations being compared, and the number of populations in the comparison. In this example, the MDD is the smallest difference between the two most extreme population means that one wishes to be able to detect. The following equation from Zar (1996) can then be used to calculate a value for the parameter phi:

Equation A-5

$$\phi = \sqrt{\frac{n\delta^2}{2ks^2}}$$

where:

ϕ	=	phi is related to the noncentrality parameter and is obtained from statistical tables (see Zar 1996 or Pearson and Hartley 1951 for the original tables)
δ	=	the MDD between the two most extreme population means
k	=	the number of populations being compared
s^2	=	estimate of the population variance common to all groups in the comparison
n	=	the number of measurements in each population

An initial guess is made for n, the number of measurements in each population, and lookup tables for phi are used as part of an iterative process to arrive at a value for n that achieves the desired power and MDD. The lookup tables require calculation of two values for the degrees of freedom, denoted as v_1 (degrees of freedom for the groups) and v_2 (error degrees of freedom). v_1 is calculated as k-1 and v_2 is calculated as k(n-1). This approach assumes that the data will be analyzed using a parametric analysis of variance (ANOVA). The nonparametric Kruskal-Wallis test could also be used to compare multiple populations, and may be more appropriate in cases where assumptions for applying ANOVA cannot be met (Zar 1996, Gilbert 1987). Sample size requirements for the nonparametric will generally be slightly higher than that indicated for ANOVA, although the difference can generally be ignored if interest is only in providing rough estimates in a "range-finding" exercise.

The following equation from Zar (1996) can be used in "range-finding" exercises for estimating the MDD in tests comparing the means for three or more populations:

Equation A-6

$$\delta = \sqrt{\frac{2ks^2\phi^2}{n}}$$

where:

n is the number of measurements in each population and all other parameters are as defined above in the equation for estimating the minimum sample size.

Because the number of options for specifying k, v_1, and v_2 is large and values for these parameters cannot be identified beforehand, example power and sample-size calculations are not provided for this category of tests.

TREND TESTS

Several trend tests are available to detect linear or simple monotonic (that is, trends are either increasing or decreasing) trends in temporal (time series) or spatial data. Linear regression analysis is a parametric trend test that can be used in circumstances where basic assumptions of the test are met. Details for using linear regression analysis, as well as discussion of the assumptions of the test, are provided in many standard statistics texts as well as specialized sources in the environmental literature (Zar 1996, Gilbert 1987, McBean and Rovers 1998). EPA (2000b) cautions that several of the underlying assumptions for using regression analysis may not be met for environmental data, and recommends nonparametric approaches such as the Mann-Kendall test for monotonic trends and calculation of Sen's slope estimator. Details of these tests are provided in EPA (2000b) and Gilbert (1987).

The following is an example of the hypotheses evaluated in tests for linear and monotonic trends:

Linear Test:

H_0: The slope of the regression line is zero

H_A: The slope of the regression line is significantly different than zero

Monotonic Test:

H_0: There is no trend in chemical concentrations

H_A: There is either an increasing or decreasing trend in chemical concentrations

It should be noted that in the case of linear trends, test results are evaluated by determining whether the slope of the regression line is significantly different from zero. The examples provided above are for two-sided hypothesis tests, although in both cases one-sided tests can be conducted. An example of H_0 for a one-sided test for monotonic trends would be "There is an increasing trend in chemical concentrations." In this example, the baseline condition is that the trend is increasing, so this is test is conservative and would be more protective in situations where an increasing trend corresponds to greater environmental impact.

One additional nonparametric test that can be used to test for trends is the Wald-Wolfowitz runs test (EPA 2000b, Zar 1996). The runs test is a test for serial correlation, and can be used in cases where a long sequence of measurements is recorded and interest is in knowing whether the measurements are random or correlated in some fashion. Details for applying the runs test are provided in EPA (2000b) and standard statistical texts such as Zar (1996).

4.0 REFERENCES

Andrew, N.L. and B.D. Mapstone. 1987. "Sampling and the Description of Spatial Pattern in Marine Ecology." *Oceanography and Marine Biology Annual Review*. 25: 39-90.

Day, R.W. and G.P. Quinn. 1998. "Comparison of Treatments after Analysis of Variance." *Ecological Monographs*. 59(4): 433-463.

Eberhardt, L.L. and J.M. Thomas. 1991. "Design of Environmental Field Studies." *Ecological Monographs*. 61(1): 53-73.

Fairweather, P.G. 1991. "Statistical Power and Design Requirements for Environmental Monitoring." *Australian Journal of Marine and Freshwater Research*. 42: 555-567.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. John Wiley & Sons, Inc. New York, New York.

Hassig, N.L., Wilson, J.E., Gilbert, R.O., Carlson, D.K., O'Brien, R.F., Pulsipher, B.A., McKinstry, C.A., and D.J. Bates. 2002. "Visual Sampling Plan Version 2.0 User's Guide." PNNL-14002. Pacific Northwest Laboratory, Richland, WA. September.

Karr, J.R. and E.W. Chu. 1997. "Biological Monitoring: Essential Foundation for Ecological Risk Assessment." *Human and Ecological Risk Assessment*. 3(6): 993-1004.

Mapstone, B.D. 1995. "Scalable Decision Rules for Environmental Impact Studies: Effect Size, Type I, and Type II Errors." *Ecological Applications*. 5(2): 401-410.

McBean, E.A. and F.A. Rovers. 1998. *Statistical Procedures for Analysis of Environmental Monitoring Data and Risk Assessment*. Prentice-Hall, Inc., Upper Saddle River, NJ.

Pearson, E.S. and H.O. Hartley. 1951. "Charts for the Power Function for Analysis of Variance Tests Derived from the Non-Central F Distribution." *Biometrika* 38: 112-130.

Underwood, A.J. 1993. "The Mechanics of Spatially Replicated Sampling Programmes to Detect Environmental Impacts in a Variable World." *Australian Journal of Ecology*. 18: 99-116.

U.S. Environmental Protection Agency (EPA). 2000a. "Data Quality Objectives Process for Hazardous Waste Site Investigations." EPA QA/G-4HW. Final." Office of Environmental Information, Washington, D.C. EPA/600/R-00/007. January.

EPA. 2000b. "Guidance for Data Quality Assessment. Practical Methods for Data Analysis." EPA QA/G-9. GA00 Update." Office of Environmental Information, Washington, D.C. EPA/600/R-96/084. July.

Winer, B.J., Brown, D.R., and K.M. Michels. 1991. *Statistical Principals in Experimental Design*. Third Edition. McGraw-Hill, Inc. New York, New York.

Zar, J.H. 1996. *Biostatistical Analysis*. Third Edition. Prentice-Hall, Inc. Upper Saddle River, New Jersey.

APPENDIX B
RESPONSES TO REGULATORY AGENCY COMMENTS ON DRAFT MONITORING PLAN

RESPONSES TO REGULATORY AGENCY COMMENTS ON DRAFT MONITORING PLAN, LITIGATION AREA CONCORD NAVAL WEAPONS STATION, CONCORD, CALIFORNIA

This document presents the U.S. Department of the Navy's (Navy) responses to comments from staff from the U.S. Environmental Protection Agency (EPA); U.S. Department of the Interior, Fish and Wildlife Service (FWS); the Clearwater Revival Company (CRC) (on behalf of the Concord Naval Weapons Station – Local Reuse Association); and the California Regional Water Quality Control Board – San Francisco Bay Region (Water Board) on the Draft Monitoring Plan, Litigation Area, Concord Naval Weapons Station, Concord, California, dated April 30, 2004. The comments addressed below were received from CRC on June 3, 2004; FWS on June 8, 2004; the Water Board on June 18, 2004; and EPA on June 29, 2004.

RESPONSES TO EPA COMMENTS

GENERAL COMMENTS

1. Comment: The monitoring objectives selected for the Litigation Area are not sufficient, particularly because U.S. EPA and other agencies specified monitoring requirements in their comments on the Five-Year Period Review Assessment (Five-Year Review) (TtEMI 2003) that are not included in the Draft Monitoring Plan. After completing five years of post-remedial action monitoring, it is unclear why a new monitoring program is proposed in place of a scaled-back version of the original post-remediation monitoring program, which would allow for continued monitoring of non-remediated areas and would yield results that are easily compared to the already existing body of data at this site. The regulatory agencies, have specifically asked that the following components be included in the monitoring program:

- **Monitoring of metals concentrations in sediment at ditches and sloughs, surface water, and groundwater until further remedial actions are implemented at Remedial Action Subsite (RASS) 1 and RASS 3;**
- **Inspection of the restored areas at RASSs 1, 2, and 3 to ensure the continued success of revegetation; to identify any additional areas of stressed vegetation; and to evaluate trends in the distribution of pickleweed and other sensitive and special-status marsh vegetation, as was done over the first five years of post-remediation monitoring;**
- **Monitoring of endangered species;**

- **Monitoring of metals concentrations in surface water since metals were detected at concentrations exceeding State of California promulgated Ambient Water Quality Criteria (AWQC) in every habitat and these concentrations pose potential risk to aquatic receptors onsite;**
- **Monitoring near actively remediated areas is warranted because contamination was left in place; and**
- **Collection of sediment cores to demonstrate the assumption that sediment is accreting on the marsh surface.**

While the Draft Monitoring Plan addresses some of these concerns, there are many that it does not. As there is no proposal to conduct additional remedial actions at RASSs 1 or 3, it is imperative that an assessment of each concern is included as an objective for the proposed monitoring program at the Litigation Area.

Response: Based on comments received from the EPA, FWS, RWQCB, and CRC, the Navy is proposing substantial changes for the final monitoring plan. The following address specific issues raised by EPA in this comment.

Expansion of areas covered in the monitoring plan. The Navy believes that a monitoring plan for the mosquito ditches (Unit 7), the western arm of Lost Slough (Unit 11), and Nichols Creek (Unit 13) cannot be prepared effectively until, at a minimum, the feasibility study (FS) and proposed remedial action plan have been completed, yielding a likely decision on remedial actions at these areas. That is, distinct monitoring objectives, decision rules, trigger levels, and decisions will reflect the remedial status of a specific area. The Navy envisions preparing a different type of monitoring plan in the event that remediation is planned for any of these areas. In these cases, additional monitoring objectives and decision rules would be needed to assess the impacts of the remedial activities themselves, as well as the rates of recovery for affected plant and wildlife communities. The full extent and types of remedial activities that could be recommended are unknown at this time; therefore, the Navy prefers to address these areas under a separate plan and move forward with a more focused monitoring plan at this time to address concerns in areas that are not currently considered for remediation. The Navy believes that monitoring plans should be subject to periodic review and revision; therefore, it is conceivable that both plans could be merged at some future date based on the outcome of the remedial decision process for the sites being examined in the FS.

Continuation of plant and wildlife surveys. The Navy has expressed reservations with about continuing the same types of plant and wildlife surveys that have been used during the first 5 years of post-remediation monitoring. In particular, the Navy has reservations about sampling to estimate population densities. The Navy has consistently expressed concerns about the relative costs and benefits of maintaining the current

level of plant and wildlife monitoring over an extended period. The Navy also questions whether the high cost of these programs can be justified in light of the considerable uncertainties connected with this type of sampling, and the accuracy of any resulting inferences on changes at the population level. In addition to the challenges posed by sampling, a host of factors confound interpretation of the data. Furthermore, there is no clear connection between estimates of population size and concentrations of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) chemicals. A case in point is the finding of a significant increasing trend for the California Black Rail over the 5 years of post-remediation monitoring. The subcontractor that designed the monitoring program and analyzed the data, H.T. Harvey & Associates, took great care in evaluating confounding factors to explain the observed trend. The subcontractor provided reasonable evidence that the observed trend was not the result of sampling error or other artifacts. However, H.T. Harvey also concluded that the apparent increase in population was most likely produced by changes in climate and vegetation that improved habitat quality. Namely, wetter conditions promoted the development of dense stands of *Typha* and *Scirpus*, which are favored by the rail. The Navy is concerned that this type of monitoring does not provide information that can be directly related to CERCLA contamination. For this reason, the Navy feels that certain measures of habitat quality or suitability, such as quality and type of vegetative cover, may be of greater overall utility in assessing site conditions.

In light of these concerns, the Navy has reevaluated its position on the issue of routine monitoring of plants and wildlife, and has decided to remove these components from the CERCLA Installation Restoration (IR) program. In the future, these components will be monitored as part of the Navy's Integrated Natural Resources Management Plan (INRMP). The Navy will consult with the FWS and other regulatory agencies on future monitoring through the INRMP program.

However, the Navy is adding two monitoring components to the plan that address several of EPA's comments concerning plant and wildlife monitoring. These are summarized below:

1) Vegetation monitoring. As mentioned above, the Navy feels that certain measures of habitat quality, such as plant cover and forage, may be key to explaining changes observed in the relative size of populations of the California Black Rail and salt marsh harvest mouse. The Navy proposes to monitor for landscape-scale changes in site conditions that could signal the potential for habitat degradation or other negative impacts to plants and wildlife. The Navy is proposing to use aerial photography to evaluate changes in vegetation communities and other surface features every 3 years. Additional details of this new component are provided in Section 3.5 of the final monitoring plan.

2) Fill data gaps for evaluating risk to the California Black Rail. The Navy proposes to analyze concentrations of metals in terrestrial invertebrates and seeds collected on the marsh surface to fill a data gap identified in baseline ecological risk assessment (BERA) on risk to the California Black Rail. Dose estimates for the California Black Rail presented in the BERA assumed that the rails were consuming clams collected at the site, because that was the only invertebrate tissue available for use in the food-chain model. In addition, previous attempts to collect adequate volumes of marsh surface invertebrate tissues were unsuccessful. Because California Black Rails are known to ingest terrestrial invertebrates, seeds, and other prey items, there is some uncertainty associated with the risk evaluation, which is driving risk management decisions at the site. The Navy will use these new data to support a limited reassessment of the food-chain modeling results presented in the BERA. Details of the sampling design for this new component are in Section 3.4 of the final monitoring plan.

Expanded surface water monitoring in Lost Slough. As indicated previously, surface water in the ditches, western arm of Lost Slough, and Nichols Creek, will be monitored under a separate monitoring plan. Annual sampling in Units 9 and 10 of the main slough during outgoing tides in both the wet and dry seasons is expected to provide information on concentrations of dissolved and total metals that are being exported to Suisun Bay. Samples from Units 9 and 10 effectively integrate site-wide and off-site contributions of metals because the main channel of Lost Slough includes water coming from the ditches, the western arm of the slough, and Nichols Creek, as well as some groundwater. The large volume of water flowing through the main channel is also reasonably well mixed, so that little advantage is gained from increasing the number of samples collected. However, the Navy is proposing to add a mid-reach sampling location to both Units 9 and 10, which brings the total number of locations from each reach to three. Three separate sampling events are still proposed each year in both the wet and dry season, which brings the total number of surface water samples analyzed annually to 36 (3 sample locations per reach times 2 reaches multiplied by 3 events for each season multiplied by 2 seasons).

Expanded monitoring of marsh surface soil. The Navy will increase the number of soil sampling locations to include remediated portions of the marsh surface where concentrations of chemicals of concern remain at elevated levels. Based on a comment from FWS, an additional location will sampled in the passive remediation area of remedial areas subsite (RASS) 1 to fill a spatial data gap near an area where elevated concentrations of metals have been measured.

Measuring rates of accretion on the marsh surface. The Navy has studied several options for measuring accretion rates on the marsh surface and has concluded that it is technically infeasible to measure accretion rates over the short term (that is, annually or over periods of several years);

therefore, monitoring accretion rates is not being proposed for inclusion in the Navy's monitoring program at the current time. The Navy acknowledges that the slow rates of accretion previously estimated are not likely to contribute to a measurable reduction in risk to ecological receptors exposed to surface soil in the marsh in the near term.

Please see the response to EPA specific comment 11 for details on the Navy's proposal to install three additional groundwater wells and to expand the scope of the groundwater monitoring component.

2. Comment: **U.S. EPA does not agree with the Navy proposal to produce two monitoring plans for the Litigation Area (the subject Draft Monitoring Plan for active/passive remediated areas; a second plan for areas addressed by a March 2004 Draft Feasibility Study). Soil and sediment at Units 7, 9, 10, and 11 pose unacceptable risk to fish, benthic invertebrates, black rails, and the Salt Marsh Harvest Mouse (SMHM), yet these sites are not proposed for monitoring. Surface water at Units 5, 7, 10, 11, and 13 contain concentrations of metals greater than AWQC, yet these sites are not proposed for monitoring. Under CERCLA, contamination that potentially poses unacceptable risk must be monitored if it remains in place. No remedial actions have occurred since the finalization of the Five-Year Review, thus it appears that the monitoring objectives used in the Five-Year Review still apply. The recommendations and follow-up actions in the Five-Year Review (Page 10-3) suggest that future monitoring should focus on areas of concern, such as areas where unacceptable risk or continued migration is expected. Please revise the Monitoring Plan to include monitoring for soil and sediment at Units 7, 9, 10, and 11, and surface water at Units 5, 7, 10, 11, and 13.**

Response: Please see the response to EPA general comment 1 for an explanation of the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and for areas that are not currently being considered for remediation.

3. Comment: **The objectives and decision criteria for monitoring at the Litigation Area are not adequately developed. The Draft Monitoring Plan fails to identify the decision and define the question that the data collected during the study will ultimately conclude. The monitoring plan also fails to define decision criteria for increasing or decreasing monitoring or conducting additional remediation. While the Draft Monitoring Plan indicates that U.S. EPA's Data Quality Objective (DQO) process was followed during the development of the monitoring plan, it appears that some of the critical components for the DQO process were not included in the monitoring design. This is specifically apparent in Section 3.0 where statistical methodology is heavily discussed, yet no decision or logic statement designating which conditions would cause a choice to be made between alternatives is**

provided. In other words, what questions is the study trying to answer and what decisions will be made with the data collected during the study? Please revise the Monitoring Plan to include a thorough discussion of DQO Steps 2 and 5 and provide a table documenting the DQO process for this monitoring plan. Please revise the document to more strictly adhere to EPA's DQO process (EPA 1994).

Response: The Navy will incorporate the following modifications in the Final Monitoring Plan:

Adherence to the January 2004 EPA Office of Solid Waste and Emergency Response (OSWER) Directive No. 9355.4-28 "Guidance for Monitoring at Hazardous Waste Sites." To the extent practicable, the following elements of this directive will be incorporated in the final plan:

- Include a sampling and analysis plan (field sampling plan/quality assurance project plan) (SAP [FSP/QAPP]) with the final monitoring plan
- Restate the monitoring objectives to be in alignment with the guidelines presented in the directive
- Provide modified decision rules and decisions. Three decisions are suggested in the directive: (a) terminate monitoring, (b) continue monitoring if activities are trending toward success (with or without changes to the monitoring approach), and (c) consider alternative actions.
- Specify "trigger levels" and decisions that will be made if triggers are exceeded. The draft plan briefly mentioned trigger levels, but did not include explicit thresholds nor specify decisions that would ensue. For surface and groundwater, promulgated water quality criteria are available that can be used as the basis for establishing trigger levels and decision criteria. However, criteria are not available for marsh surface soils, which creates an additional technical hurdle for this medium. The Navy is proposing to write the final monitoring plan assuming that trigger levels for marsh surface soil will be available before the time the next round of samples are collected. The Navy will further evaluate this issue and expects to prepare a technical position paper for review and approval by the regulatory agencies. At this time, it is likely that protective concentrations for soil will be developed using existing site data and back-calculations that employ standard food-chain models and hazard quotients based on accepted toxicity reference values

In addition, the Navy will provide a summary table that outlines the main elements of each of the proposed monitoring components.

4. Comment: **The decision making process is not clear regarding the type of actions to be taken following a statistical evaluation. Monitoring objectives and performance criteria are presented for soil, groundwater and surface water data. Comparisons of detected concentrations to water quality criteria will also be conducted for the groundwater and surface water results. The Draft Monitoring Plan provides information about the statistical evaluation methods for the data, but does not identify what type of actions should be taken based on the outcome of the statistical evaluations. For example, if temporal changes are identified for groundwater concentrations, how will that impact the current monitoring program - will monitoring increase or decrease? Further discussion regarding how inconsistencies between the results from the multiple lines of evaluation for each objective is recommended, particularly what possible actions could be taken. It is recognized that it may be difficult to assess all possible outcomes from the statistical evaluations, however, we do believe that 'generalized responses' could be presented so that an outline of the entire decision making process is included in the Monitoring Plan.**

Response: Please see the response to EPA general comment 3. The Navy acknowledges that it may not be possible to address all contingencies in cases where multiple lines of evidence provide inconclusive or conflicting results. As suggested in the comment, it may be necessary to provide generalized responses in terms of potential options in those cases where decision making is not linear or straightforward.

5. Comment: **Multiple years of post remediation monitoring have already occurred at RASSs 1 and 2. However, a minimal amount of this data is summarized in the monitoring plan. A range of statistical methods are proposed for the data evaluation, but these discussions raise concern that the data sets may not be sufficient to draw conclusions with acceptable statistical significance and power.**

In the absence of detailed site data, uncertainties associated with data processing and interpretation are expected. However, in light of the availability of previous monitoring data, the discussions of both performance criteria and statistical methods should be more focused. Moreover, it would seem that including the existing data set during the statistical review would better focus the currently proposed monitoring program to fill existing data gaps. Also, it is unclear whether the same statistical methodologies described in the Draft Monitoring Plan were employed during the 5 years of post-remedial monitoring. It would be helpful if the proposed performance criteria and statistical methodologies were actually applied to the example data sets using existing monitoring data. The Monitoring Plan should be revised to include information about existing data, the statistical methodology used to review existing data, and application of the proposed methods to existing data sets.

Response: The purpose of the monitoring plan is to outline the general framework of the Navy's proposed design as well as specific details on the monitoring objectives, decision criteria, and potential actions that will be taken based on the results. The existing database for the monitoring completed to date is extensive and this information has been thoroughly analyzed and presented in the individual annual reports as well as the 5-year review report. The statistical methods proposed in the current monitoring plan are closely aligned with those used to evaluate the existing data and summarized in previous reports. In the interest of efficiency and to focus the plan on future monitoring, the Navy did not include additional summaries or analysis of the existing data in the current plan. Some reevaluation of the existing data is anticipated as part of the analysis the Navy will undertake after each new round of sampling.

SPECIFIC COMMENTS

1. **Comment:** **<u>Section 2.0, Selection of Monitoring Objectives, Page 2-1</u>: It is not appropriate to state that the primary study question, "Are populations of the special status species proposed for monitoring impacted by contaminants left in place at the Litigation Area?" is not amenable to testing. The implication that many years of data are needed to estimate densities with any degree of certainty only provides more justification to continue conducting plant and wildlife surveys. As reported in the Five-Year Review, useful information was obtained by conducting plant and wildlife surveys such as the success of revegetation efforts, SMHM actively recolonizing the remediated areas of RASSs 1 and 2, and a statistically significant increase in black rail numbers during the 5 years following remediation. Furthermore, if it is still believed that this question is not amenable to testing, then it appears that the study question has not been developed properly. Step 2 of the DQO process is designed to "define the question that the study will attempt to resolve and identify the alternative actions that may be taken based on the outcome of the study" (EPA 1994). Please revise the Monitoring Plan to include plant and wildlife surveys and define the question that the study will resolve.**

   Response: Please see the response to EPA general comment 1.

2. **Comment:** **<u>Section 2.0, Selection of Monitoring Objectives, Page 2-2</u>: The three monitoring objectives selected for the Draft Monitoring Plan including an assessment of the status and trends for metals concentrations within the passive remediation area at RASSs 1 (Unit 2) and 2 (Unit 2), metals concentrations in surface water (Units 9 and 10), and metals concentrations in groundwater are not adequate. U.S. EPA and other agencies have consistently recommended (in their comments on the Five-Year Review and at meetings with the Navy during the past three years) that until additional remedial actions are conducted the monitoring objectives**

should be consistent with those developed for the 5 year review. It is unclear why areas specifically of concern to the agencies are not proposed for monitoring and monitoring components specifically requested by the agencies are not included. U.S. EPA is particularly concerned about the following issues that needs to be addressed in the Monitoring Plan:

- **Surface water sampling results should be compared on an individual location basis to AWQC. Results should also be compared to the post-remediation 5 year monitoring results to address changes relative to existing data.**
- **Biological monitoring of small mammals to evaluate exposure to marsh surface contamination. Analysis of hair (for SMHM) and hair plus internal tissue (non-listed small mammals) should be used to evaluate the degree of exposure.**
- **Further justification that sediment accretion rate of 2.5 mm/yr will prevents ecological exposure, and additional measurements (i.e., cores) to confirm that the marsh is still accreting sediment.**
- **Bioavailability of metals**
- **Revegetation success of native plant species**
- **California black rail nesting success**
- **Changes in land use**
- **Survey for presence/absence of fish and invertebrates**
- **Health of ecosystem as a whole**

Response: Please see the response to EPA general comment 1. Additional responses to specific issues not addressed previously are provided below.

- The Navy's proposed approach for evaluating surface water chemistry includes comparison of results at individual sampling locations with the AWQC as well as comparison of averages calculated for individual reaches of the slough. Evaluation of average concentrations is in keeping with the principals EPA set forth for estimating exposure conditions in the context of risk assessments. That is, aquatic receptors are exposed to contaminant concentrations averaged over both time and space.

- The Navy does not believe that analysis of hair and tissue samples is needed to evaluate whether SMHM and other non-listed small mammals are exposed to metals in soil and plant tissue from the marsh surface. The BERA concluded that exposure of small mammals to surface soil in the marsh likely results in unacceptable risk at selected locations where high bioavailable concentrations of metals are present. Therefore, measurement of hair and tissue burdens of metals would not yield significant new information on whether receptors are exposed. Most importantly, however, this information does not lend itself to clear and unambiguous interpretation on the potential for either lethal or sublethal effects. The Navy's current position is that risk to receptors exposed to metals on the marsh surface is not at sufficient levels to warrant remedial action. Therefore, burden is high before specialized studies can be added: they must yield unequivocal information in terms of significant unacceptable risk. This burden is especially high for invasive studies that have the potential to disrupt habitat via the sampling process or to result in mortality to endangered species.

3. Comment: **<u>Section 2.0, Selection of Monitoring Objectives, Page 2-3</u>: U.S. EPA agrees that the monitoring program should be evaluated with each new round of sampling to reassess the overall goals and performance of the program. However, in order for these management decisions to be made, monitoring objectives must be focused to provide information that will support one of three conclusions related to the success of the site activity being addressed by the monitoring plan (OSWER 2004). The Draft Monitoring Plan states that the DQO process was used to focus monitoring objectives, however, monitoring for significant changes in metals concentrations consistently detected above acceptable levels alone, will not produce inputs appropriate for deciding whether site activities are adequate for protecting human health and the environment. The Monitoring Plan should be revised to focus monitoring objectives so that information gathered will support one of three management decisions including 1) termination of monitoring and site activities and proceeding with the relevant regulatory process; 2) continuation of monitoring if site activities are trending toward success; 3) evaluation of both site activity and the monitoring plan to determine factors responsible for monitoring results and to revise the monitoring plan or site activity accordingly (OSWER 2004).**

Response: The Navy concurs. Please see the response to EPA general comment 3.

4. Comment: **<u>Section 3.1.2, Monitoring Objectives and Performance Criteria, Page 3-4</u>: It is unclear how statistical methods will be used to evaluate soil data. It is understood that the performance of the passive remediation for soil will be assessed with respect to both temporal and spatial criteria and that a separate Sampling and Analysis Plan will be prepared. However, additional clarification is needed to better understand how the statistical methods will be specifically applied to soil data. Additional information is requested regarding how the sampling locations are being selected for each round of soil sampling, particularly with regard to the locations of the temporal samples. Specifically, please address the following:**

- **Will RASS 1 and 2 each be considered as separate areas, and is a separate statistical evaluation expected for each area?**
- **The sampling will be conducted on a 100 x 100 ft grid pattern, and four samples will be collected from each grid. How were the dimensions determined? Was the existing post remediation monitoring data (currently known spatial variability) used to define that grid?**
- **It is understood that 4 samples will be collected from each grid; these are called replicate samples in the Monitoring Plan. Why are these not considered discrete samples, especially considering the size of the grid? If they are replicates, will the data from the four samples be averaged (or otherwise summarized) prior to performing the statistical evaluations?**
- **Will small-scale spatial changes be assessed based on the data from the four samples from a single grid or based on data from adjacent grids? How close do samples need to be in order to be considered a group of adjacent samples?**
- **Is the intent of the temporal evaluation to assess concentrations at the same (x, y, z) location between sampling events, or for the entire grid?**

Response: The sampling locations and a 100- by 100-foot grid were chosen as part of the original post-remediation sampling program and have been retained in the current plan to facilitate comparison of existing and future data. Several modifications are being proposed in the final plan for sampling surface soil in the marsh (see the response to EPA general comment 1). The Navy is proposing separate statistical evaluations for results for samples collected in RASS 1 and 2. Each analysis will consider individual sampling locations as well as locations pooled within and between the passive and active remediation areas of each RASS.

The original monitoring plan, as well as evaluations conducted during each year of post-remediation sampling, did not attempt to examine small-scale spatial variability, as least at scales much smaller than an individual spatial unit. That is, individual locations, defined as 100- by 100-foot square grids, provided replicate measurements used to calculate average exposure conditions at the scale of a spatial unit. The original design was never intended to describe variation in concentrations of metals at the scale of a 100- by 100-foot grid. This level of detail would have required sampling replicate sub-locations within each grid during each year of sampling, rather than sampling a random quadrat from each grid during each year of sampling, which has been the protocol up to this point. The Navy's proposed modification for the final plan will allow for an assessment of variation at the scale of an individual location. Again, location in this context is operationally defined as a 100- by 100-foot area, and samples collected within this area are treated as subsamples. As EPA suggests, these subsamples could be treated as discrete samples in certain calculations. However, significant spatial autocorrelation could present additional obstacles for calculating area-wide averages and confidence limits at the scale of a spatial unit or for pooled locations within the passive and active remediation areas. The Navy acknowledges that there are advantages and disadvantages to each alternative for evaluating spatial information in the monitoring design, and will remain open to agency input on this issue.

5. Comment: **<u>Section 3.1.4, Study Design, Page 3-10</u>: It is not acceptable that certain contaminated sections of the Litigation Area are excluded from monitoring. According to Figures 93 and 94 in the Five-Year Review areas that pose unacceptable risk to fish, benthic invertebrates, black rails, and the SNHM include Units 7 (ditch), 9 (slough), 10 (slough), and 11 (slough). The Draft Monitoring Plan proposes sampling at locations in Units 6 and 12 only. Under CERCLA, contamination that potentially poses unacceptable risk must be monitored if it remains in place. Since no remedial actions have occurred since the finalization of the Five-Year Review, it appears that the monitoring objectives used in the Five-Year Review still apply. The recommendations and follow-up actions in the Five-Year Review (Page 10-3) suggest that future monitoring should focus on areas of concern, such as areas where unacceptable risk or continued migration is expected. Please revise the Monitoring Plan to include soil and sediment sampling at Units 7, 9, 10, and 11.**

Response: Please see the response to EPA general comment 1 for an explanation of the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation.

6. **Comment:** **<u>Section 3.1.4, Study Design, Page 3-10</u>: The monitoring Plan should clearly discuss the frequency for collecting soil or sediment samples. Also, it is unclear if the Navy was planning on preparing a Sampling and Analysis Plan (SAP) following the finalization of the Monitoring Plan (there is NOT a SAP shown in the June 2004 Draft Site Management Plan Annual Amendment associated with the Litigation Area Monitoring Plan), however, the Draft Monitoring Plan should have include this information.**

Response: Please see the response to EPA general comments 1 and 3. The final plan will include a SAP.

7. **Comment:** **<u>Section 3.2.2, Monitoring Objectives and Performance Criteria, Page 3-15</u>: It is not clear why the average concentrations of dissolved metals will be compared to promulgated AWQC using the cited equation (Zar 1996). Although it does not seem appropriate to compare average concentrations of metals in surface water, it is more unclear why these comparisons are being made. The Draft Monitoring Plan does not include trigger levels for the results obtained from this comparison. For example, if a significant detectable difference (MDD) is found between an average metals concentration and the AWQC what does this mean in terms of monitoring and remediation? Since there are so few surface water monitoring locations and it is easy to compare data to threshold levels (i.e., promulgated surface water criteria), the Monitoring Plan should include a point-by-point comparison of monitoring results across all years of monitoring.**

Response: Please see the response to EPA general comment 2.

8. **Comment:** **<u>Section 3.24, Study Design, Page 3-18:</u> The placement of the surface water samples does not capture the contamination present at the Litigation Area. According to Figures 38 through 43 of the Five-Year Review, metals were detected in surface water at concentrations greater than AWQC at Units 5, 7, 10, 11, and 13. However, the Draft Monitoring Plan only proposes to collect samples from Units 9 and 10 to monitor metals in surface water. These 4 locations in Units 9 and 10 are scarcely adequate compared to the post-remediation monitoring which encompassed the ditches and sloughs at the Litigation Area, specifically since no additional remediation has been conducted at this site. At a minimum, please include additional surface water sampling locations at the Unit 7 ditches and the Unit 11 slough. It is recommended that a surface water sampling location be added downstream of the Unit 7 ditches within the Unit 10 slough in order to monitor for possible contamination migration out of the ditches (i.e., move sample Unit 10-S downstream or add another sample). It is also recommended that a surface water sampling location be added**

downstream of Unit 6 within the Unit 10 slough (i.e., move sample Unit 10-N downstream past Unit 6 slough/Lost Slough confluence).

Response: Please see the response to EPA general comment 1 for an explanation of the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation. The Navy's response to EPA general comment 1 also explains the value of focusing surface water monitoring in the main reach of Lost Slough.

9. Comment: **<u>Section 3.2.4, Study Design, Page 3-18</u>: Both short and long term concentration trends will be determined for surface water locations. This is in addition to comparisons of concentrations to water quality criteria, and an assessment of concentrations between dry and wet seasons. Although the specific details of the comparison methods (ANOVA, Wilcoxan rank sum test) are not known, the size of the expected data set is small (see U.S. EPA's comment above on surface water sample numbers and locations). Please provide additional detail regarding how the data will be processed, specifically addressing whether data from wet and dry seasons be combined, particularly with regard to the assessment of long-term temporal trends.**

Response: The final plan will address some of these issues, although the Navy acknowledges that sample-size issues will present challenges for certain comparisons. The Navy's plan for analyzing the monitoring data is intended to be comprehensive as well as flexible. An effort will be made to find the optimal approach for discerning both spatial and temporal trends in the data and may include minor changes to the analysis strategy after each round of sampling. Both the monitoring design and analysis strategy are adaptive, and the Navy will consider agency input on both as the plan is implemented over time.

10. Comment: **<u>Section 3.3.1, Background, Page 3-19</u>: It is unclear how the results of the October 2003 groundwater sampling will be incorporated into the monitoring Plan. The text indicates that the results are being evaluated and will be summarized in the June 2004 Technical Memorandum. However, it does not explain if and how these results will affect the Monitoring Plan. Please provide this information in the text of this section.**

Response: The data from October 2003 will be treated as existing information in the database, in the same way as data collected during each year of the post-remediation monitoring. To the extent that this information is applicable, it will be combined with the existing post-remediation monitoring data in all future assessments of spatial and temporal trends.

11. Comment: **<u>Section 3.3.4, Study Design, Page 3-23</u>: Similar to surface water, both short and long term concentration trends will be determined for groundwater, and a comparison will also be made to water quality criteria. Section 3.3.4 indicates that samples will be collected at "5-year intervals." However, no information is presented regarding how many rounds of sampling will be conducted. Moreover, there is no discussion regarding the appropriateness of this monitoring frequency. It is not appropriate to sample groundwater at 5 year intervals if only because this will not provide information adequate for determining trends during the next 5 year review. Please revise the Monitoring Plan to indicate that the 23 groundwater monitoring wells will be sampled 3 times during the same time of year (i.e. wet or dry season to be comparable with existing data) next 5 year period. Please provide additional clarification of the expected size of the groundwater data set that will be used to assess the monitoring objectives, specifically addressing the expected period of groundwater monitoring prior to application of the performance criteria, and the expected list of parameters that will undergo this evaluation.**

Response: As discussed in the response to EPA general comment 1, the Navy proposes significant changes in the final monitoring plan. The Navy proposes to install three new groundwater wells, two along the berm that separates Navy and Honeywell property, and one southwest of the berm in RASS 2, near existing well RO2AG009. These wells will be deeper than the 23 existing monitoring wells and will extend into the deep aquifer. The Navy's new proposal for groundwater monitoring includes the following components:

- All 23 existing wells, plus the three new deep wells, will be sampled every 3 years (in lieu of the 5-year intervals of the draft plan) for analysis of total metals. All samples will be collected during a single round during the wet season using low-flow collection techniques and will be analyzed for total metals.
- Annual sampling will be conducted for a subset of wells after the next round of sampling. The subset will be designated as "sentinel" wells, and will be composed of two groups: wells located near the border of the property that have the potential to measure ongoing migration from off-site sources, and any wells that show an increasing trend in concentrations of metals based on the previous two rounds of sampling (that is, the 2003 data and data collected during the next round of sampling) or where one or more ambient water quality criteria was exceeded. The sentinel wells will be identified after the results of the next round of sampling have been evaluated.

12. Comment: **<u>Appendix A, Summary of the Proposed Monitoring Plan for the Litigation Area - Working Draft December 17, 2003, Page A-15</u>: A finalized summary table for the monitoring planned at the Litigation Area is not included in the Draft Monitoring Plan. The working draft summary table provided is not adequate partially because it is not finalized, and partially because it does not contain specific information regarding the sampling design. This information should presently be available as the working draft indicates that it will be determined using the DQO process and input from the agencies. Please include a summary table of the proposed monitoring plan in the revised Monitoring Plan.**

Response: As indicated in the response to EPA general comment 3, the Navy will provide an updated summary table in the final plan.

RESPONSES TO THE FISH AND WILDLIFE SERVICE COMMENTS

GENERAL COMMENTS

1. Comment: **The Service previously commented (letter dated January 26, 2004) on the preliminary proposals for monitoring that the Navy provided and is pleased that the Navy incorporated several suggestions, including both seasons and three sampling events for surface water monitoring. However, the Service still has concerns that many of these areas require active investigation and remediation, in addition to ongoing monitoring, and has residual concerns regarding the specific details of the ongoing monitoring proposed.**

Response: The Navy acknowledges FWS concern and has significantly modified the final monitoring plan (see response to EPA general comments 1, 3, and 11). The Navy is reviewing the information contained in the draft FS, although no decision has been made at this time on the final selection of remedial alternatives for the areas investigated.

2. Comment: **The Service reiterates the concerns detailed in the March 31, 2004, letter regarding the need for further evaluation and remediation of the marsh surface area, in addition to the remedial actions for the ditches, Lost Slough, and Nichols Creek. The black rail, salt marsh harvest mouse (harvest mouse), and the rare marsh plants primarily occur in or utilize the marsh surface, and therefore, reduction in the marsh surface contamination is needed to reduce exposure and potential risk to these species.**

Response: Please see the response to EPA general comment 1 for a description of the Navy's proposal to conduct whole-body tissue analysis for one or more invertebrate species and the seeds from one or more plant species to address the FWS's comments regarding data gaps in the risk assessment conducted for the black rail. This response also outlines the Navy's proposal for continued vegetation monitoring by adding a new component

designed to track landscape-scale changes in site conditions. Based on results presented in the BERA and responses provided to the Fish and Wildlife Service's letter of March 31, 2004, the Navy is not considering remediation as an option for the marsh surface at the present time.

3. Comment: **As currently proposed by the Navy in this document and in the Draft Litigation Area Feasibility Study, no remediation is proposed for Lost Slough and monitoring is only proposed for Units 9 and 10. The Service recommends remedial actions occur throughout Lost Slough (Units 9, 10, 11) to address unacceptable risks to ecological receptors. The Service hopes that the Navy will concur and complete the necessary remediation and subsequent post-remediation monitoring. In the absence of such actions, the proposed monitoring plan should be revised to add surface water monitoring within Unit 11 at a minimum of three sampling events, two locations, and both wet and dry seasons. The Unit 11 section of Lost Slough generally has higher concentrations of metals than Unit 9 and provides habitat for ecological receptors, in addition to being a potential pathway to downstream sections of Lost Slough and potentially to Suisun Bay.**

Response: Please see the response to EPA general comment 1 for an explanation of the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation. The Navy is reevaluating findings presented in the draft FS, although no decision has been made at this time on the final selection of remedial alternatives for the areas under investigation.

4. Comment: **As stated by the Service in several previous letters, the gradual burial of contaminated sediments by cleaner sediments is based on very limited data (three cores from 1999) with estimated net deposition rates of 2.5 mm per year that do not account for local mobilization or re-deposition of contaminated sediment. Even with this accretion rate, only 12.5 cm (5 inches) of sediment will be deposited in 50 years, a depth of cover unlikely to prevent ecological exposure. Therefore, the Service recommends that sediment accretion not be considered as a factor in decision-making given the large uncertainty and minimal short-term improvements involved.**

Response: The Navy concurs. Please see the second to last paragraph of the Navy's response to EPA general comment 1.

SPECIFIC COMMENTS

5. Comment: **The Navy proposes statistical tests to test for significant changes in concentrations between sampling events. The absence of a significant change in concentrations is in itself a concern given the currently elevated concentrations that pose unacceptable risks to ecological receptors. The lack of a long-term change would also provide evidence against the Navy's hypothesis of gradually decreasing**

concentrations by sediment accretion, which was a factor in the recommendations for no further action. Both an increase in concentrations and no change in the currently elevated concentrations over time should trigger further evaluation to address ongoing or increased risk to ecological receptors.

Response: Please see the response to EPA general comment 3 for changes the Navy proposes in the monitoring objectives and the specification of decision rules and decisions. The scenario in which, for example, no significant decreasing trend (or simply, no change, as indicated in the comment) is reported, is expected to trigger a specific response or outcome if the stated performance criteria are not achieved. Therefore, the Navy envisions that all three potential outcomes (no change, decreasing trend, or increasing trend) will be addressed appropriately with the revised decision rules that appear in the final plan.

6. Comment: **Surface water sampling results should be compared on an individual location basis to the Ambient Water Quality Criteria (AWQC) as site-wide averages will provide no information regarding specific reaches that might be impacted. Results should also be compared to the previous post-remediation, 5-year monitoring results to address changes relative to existing data.**

Response: Please see the response to EPA specific comment 2.

7. Comment: **The Service recommends a new sample grid be added to the east of grid number 078 to provide adequate coverage in this area of highest arsenic sediment concentrations.**

Response: The Navy concurs and has included an additional sampling grid in the final monitoring plan.

8. Comment: **The Navy's use of the terms "location" to refer to a 100 ft by 100 ft grid and "replicates" for the four locations from the 50 ft by 50 ft quadrants of each grid is confusing and inaccurate. A sample location typically refers to the specific site from which the sample was taken rather than a large area from which four different samples are taken. Sample replicates represent a number of samples taken in the same location or very closely nearby to address sample variability. In contrast, the proposed samples taken from each quadrant represent unique values that may be quite heterogeneous given the nature of soil/sediment contamination and the 50 ft distance between samples. These individual quadrant samples should be specifically located on maps and individually listed on tables in addition to the grid averages. Furthermore, the individual quadrant samples should be compared between sampling events to address differences in existing concentrations and proximity to ditches or sloughs that would not be accounted for with the grid averages.**

Response: The Navy points out that the term "location" is operationally defined based on the objectives in the original post-remediation monitoring plan. Please see the Navy's response to EPA specific comment 4.

9. Comment: **The Service previously recommended ongoing monitoring of small mammals, particularly the harvest mouse, for exposure to marsh surface contamination. The Service has concerns that the Navy's statements regarding minimization of exposure by sediment accretion and depth of contamination have not been sufficiently supported by scientific evidence. The Service agrees with the Navy's decision to assume presence without population monitoring, however, small mammal trapping also provides an opportunity to monitor small mammal exposure through tissue sampling. Analysis of hair (harvest mouse), and hair and internal tissue (for non-listed small mammals) can be used to evaluate the degree of exposure. Therefore, the Service requests that the Navy re-consider its decision to eliminate all biological monitoring.**

Response: The Navy is pleased that the FWS concurs that continued population monitoring of the salt marsh harvest mouse is unlikely to provide significant new information to support management of the site. Please see the response to EPA specific comment 2, which explains why the Navy has reservations about the analysis of hair and tissue samples to confirm exposure. The Navy, however, remains open to discussing other proposals from FWS that may yield new and unequivocal information that the salt marsh harvest mouse is exposed to substantially greater risk than was estimated in the BERA. The Navy believes that its proposal (see the response to EPA general comment 1) to evaluate landscape-scale changes in site conditions will provide early warning of potential deleterious changes in habitat quality. Thus, the proposed approach will yield useful information on several key factors that influence the health and size of mouse populations.

10. Comment: **The Service's previous comment (4E, Appendix A Page A-1 1) regarding the need to evaluate risk to black rail from marsh surface exposure is not adequately addressed by the Navy's assumption of ongoing black rail presence. The absence of a risk evaluation that estimates risk to black rail from marsh surface exposure is a substantial data gap that prevents informed, accurate determinations regarding current risk and ongoing risk based on future monitoring results.**

Response: The Navy agrees that data gaps exist in the assessment of risk to the rail and has added a monitoring component to allow for additional food chain modeling to assess risk from ingestion of sediment and prey from the marsh surface. The Navy is also currently evaluating methods that could be used to establish cleanup levels for contaminated sediment in the ditches and slough. If remediation of sediment is recommended after the FS is complete, it is likely that additional evaluation of risk to the black rail will be included in the approach used to establish cleanup levels for sediment.

RESPONSES TO CRC COMMENTS

The Draft Monitoring Plan proposes to discontinue any future plant/animal surveys. In addition groundwater and sediment samples would be collected every five years instead of annually. Surface Water would be sampled more frequently, six times per year, but from fewer locations, four instead of 134.

GENERAL COMMENTS

1. Comment: **<u>Need for Comprehensive Monitoring Plan</u> – The Draft Monitoring Plan appears to be prepared separately from the monitoring proposed in the Draft Supplemental Feasibility Study. The Final Monitoring Plan should be comprehensive and incorporate all Litigation Area monitoring activities.**

Response: Please see the response to EPA general comment 1, which explains the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation.

2. Comment: ***Identify "Triggers" and Decision Rules* – The Draft Monitoring Plan does not include "triggers" that would lead to further removal actions or to a discontinuation or decrease in the frequency of monitoring. The lack of "triggers" was a principle issue raised with previous monitoring activities in the Litigation Area. The failure of the Draft Monitoring Plan to correct an identified problem with past monitoring is disconcerting. The Final Monitoring Plan should identify unambiguous "triggers" or decision rules so the community will have a yardstick to measure the "protectiveness" of past and future remedial actions.**

Response: The Navy concurs and has made substantial changes to the final monitoring plan. Please see the Navy's response to EPA general comments 1 and 3.

3. Comment: **<u>Monitoring for Trespassers</u> – Trespassing in RASS 4 was acknowledged in the Five-Year Report. The Draft Monitoring Plan does not include monitoring activities to ensure that this trespasser exposure pathway is eliminated. The Final Monitoring Plan should propose monitoring activities that document the success of actions taken to eliminate this exposure pathway.**

Response: The Navy is adding signage and repairing fences as a means to further reduce or eliminate trespassing. Moreover, agency concerns regarding the potential risk of areas of semilithified soil in RASS 4 were recently addressed in a data gaps investigation, and there was no evidence that these areas pose unacceptable risk given the current and future use for this portion of the site.

4. Comment: **<u>Benthic Sampling</u> – The lack of data on the diversity and population of benthic organisms, has made evaluation of additional removal actions in the Supplemental Feasibility Study problematic. Sampling of benthic organisms provides an indirect assessment of the potential impact to endangered species. The Final Monitoring Plan should propose benthic sampling to indirectly evaluate impacts to wildlife.**

Response: The Navy has investigated the feasibility and utility of conducting full-scale benthic community monitoring, and has concluded that benthic analysis would not be cost effective and would not yield significant useful information at the present time. Slough sediments do not currently support large numbers or a high diversity of benthic species. Conditions in the slough that affect habitat quality for benthic species have changed little over the course of the post-remediation monitoring program, and it is unlikely that a benthic monitoring program would yield any new information to aid decision making at the site. However, the Navy feels that this decision should be reevaluated in the future if significant remediation is undertaken at the Litigation Area, as changes in benthic community structure may be a useful indicator for measuring recovery over time. The Navy is also currently evaluating methods that could be used to establish cleanup levels for contaminated sediment in the ditches and slough. If remediation of sediment is recommended after the FS is complete, it is likely that additional evaluation of existing benthic data or collection of new data would be included in the approach used to establish cleanup levels for sediment.

Proposed Soil/Sediment Sampling

5. Comment: **<u>Testing of Assumptions</u> – A key assumption in the passive remediation areas is that contaminated sediment is being covered by "cleaner" sediment that is deposited on the marsh surface at a rate of 2.5 mm/yr, or about one inch every ten years. The Draft Monitoring Plan does not test this assumption.**

Response: The Navy has studied several options and has concluded that it is technically infeasible to measure accretion rates on the marsh surface over the short term (that is, annually or over periods of several years); therefore, monitoring the rate of accretion is not proposed for inclusion in the Navy's monitoring program at the current time. The Navy acknowledges that the slow rates of accretion previously estimated are not likely to contribute to a measurable reduction in risk to ecological receptors exposed to marsh surface soil in the near term.

6. **Comment:** **Soil Sampling Locations – The Draft Monitoring Plan proposed collecting soil samples from 12 locations in Unit 12 (RASS 2), to be consistent with the sample locations included in the first five years of post-remediation monitoring. The Five-Year Report, however, indicates that 20 locations in Unit 12 were sampled annually. Sample locations R02SS148, R02SS149, and R02SS271 are among the eight previous sample locations at Unit 12 that are not proposed for sampling in the Draft Monitoring Plan. These three sample locations are located in the active remediation area. Based on the assumption that clean soil was used as backfill in active remediation areas, one must conclude that the monitoring results from these three sample locations demonstrate that Unit 12 has become recontaminated. The Final Monitoring Plan should include a rationale on why these sample locations at Unit 12 (RASS 2) that indicate the continued spread of contamination into remediated areas were excluded from future monitoring plans. On its face it looks like these sample locations were excluded because future samples from these locations would continue to demonstrate the failure of the remedy at Unit 12 (RASS 2).**

Response: The sample sizes proposed for Unit 12 (RASS 2) in the draft monitoring plan included only the portion of this spatial unit where passive remediation was implemented. The Navy concurs with this comment, and has revised the final plan to include additional locations where chemicals in marsh soils have continued to be measured at elevated levels. (See the response to EPA general comment 1.)

7. **Comment:** **<u>Number of Soils Samples</u> – The Draft Monitoring Report statistical analysis indicates that the number of sample locations proposed would not be able to detect a difference between a set of soil samples with ambient concentrations, and a set of samples with contaminant concentration that indicate wildlife impacts are likely (effects range-median, or ER-M) Additional sample locations should be proposed in the Final Monitoring Plan to enable a distinction to be made between ambient levels of contamination and harmful levels of contamination.**

Response: Please see the response to EPA general comment 1 for details of the Navy's proposal to collect additional samples on the marsh surface.

8. **Comment:** **<u>Unit 7 Ditch Sampling</u> – Unit 7 Ditch is shown as a passive remediation area in Figure 3-2, Future Soil Sampling Locations Litigation Area. The Draft Monitoring Plan does not propose any sediment samples be collected from this area. The 20 locations in Unit 7 ditches used to collect sediment samples annually during the first five years of monitoring should be included in the Final Monitoring Plan to evaluate this passive remediation area.**

Response: Please see the response to EPA general comment 1, which explains the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation.

Proposed Surface Water Sampling

9. Comment: **<u>Suggested Revision</u> – The following statement from the Draft Monitoring Plan is not supported by site data: *"In both the northern and central marsh ditch units (Unit 3 and 7) all the post-remediation average total metal concentrations were lower than preremediation surface water concentrations."* (Draft Monitoring Plan, p. 3-13)**

Response: The comparison of average concentrations of total metal preremediation and post-remediation is based on data presented in Table 19 of Appendix D of the 5-year review report. The statement the reviewer is citing is supported by the results presented in Table 19.

10. Comment: **<u>Surface Water Monitoring Timing</u> – The Draft Monitoring Plan proposes surface water monitoring during the wet and dry season. This monitoring should be timed so that it occurs during the Pacific Flyway migration and during the periods when Suisun Bay is an active fish nursery to monitor potential impacts to endangered species.**

Response: The Navy will further study this request and will evaluate whether it will be logistically feasible to schedule the wet and dry sampling events to correspond to the two events referenced by the reviewer.

11. Comment: **<u>Surface Water Analyses</u> – In order to demonstrate compliance with Ambient Water Quality Criteria surface water analyses should include general water chemistry in addition to the metals of concern.**

Response: Surface water samples will be collected for analysis of the full suite of total and dissolved metals as well as for pH, temperature, conductivity, and total suspended solids.

Proposed Groundwater Sampling

12. Comment: **<u>Groundwater/Surface Water Interaction</u> – CRC had previously raised concerns with the tidal groundwater level fluctuation of 0.4 feet in monitoring well 2AG09 (RASS 2), which contains zinc concentrations 100 times the ambient water quality criteria. This contradicts the Draft Monitoring Plan that states: *"interaction between groundwater and surface water appears to minimal."* (p. 3-19).**

Response: The basis for the comment that interaction between groundwater and surface water appears to minimal in well 2AG09 is the lack of variation in salinity at this well measured in the tidal influence study (Tetra Tech 1997). Over a 112-hour monitoring period, electrical conductivity (a measure of salinity) in well 2AG09 remained essentially constant (5.95 +/- 0.01 milliSiemens/centimeter [mS/cm]) while the electrical conductivity of surface water flooding the marsh varied from 8.40 to 11.53 mS/cm (see Tetra Tech 1997, Figure 15). During this same period, the water level in well 2AG09 varied by 0.42 feet. Because the water level changed in response to the tide, but the electrical conductivity of the water did not vary, the variation in water level was interpreted as a pressure wave rather than direct exchange of groundwater with surface water.

13. Comment: **<u>Groundwater Use</u> – The high levels of total dissolved solids (TDS) measured in some Litigation Area monitoring wells appears to be the result of chemical releases (zinc chloride, copper sulfate) rather than seawater infiltration. The final monitoring plan should incorporate analyses to distinguish between high concentrations of TDS in wells impacted by chemical releases, and those impacted by seawater intrusion.**

Response: TDS concentrations in Litigation Area monitoring wells range from 520 milligrams per liter (mg/L) in well 3MG14 to 2,840 mg/L in well 1PG05 (Tetra Tech 1997, Appendix A). In contrast, the maximum concentrations of zinc and copper detected in samples from Litigation Area monitoring wells was 34.3 mg/L (zinc in well 2AG09, March 1994) and 0.13 mg/L (copper in well 2MG22 in November 1989). The most recent measurements for zinc and copper in samples from these wells were order of magnitude or more lower than the maxima cited above. It is clear that the observed concentrations of TDS cannot be accounted for by chemical releases of zinc and copper salts. The final monitoring plan will distinguish between sea water and zinc and copper salts as possible sources of dissolved solids by measuring concentrations of metals.

The Navy notes that seawater infiltration is not thought to be the cause of the TDS concentrations in groundwater at the Litigation Area that are significantly higher than nearby surface water, as suggested above. Instead, the higher TDS concentrations in groundwater relative to surface water are thought to be caused by evaporative concentration of salts contained in the water that floods the marsh surface approximately twice daily. This hypothesis is supported by data on oxygen and hydrogen isotopes discussed in the tidal influence study (Tetra Tech 1997).

14. Comment: **<u>Adequacy of Existing Monitoring Wells</u> – The existing groundwater wells do not appear adequate to monitoring site groundwater. The RWQCB indicated that metal contamination is found in General Chemical site at depths of 50 feet indicating a downward gradient for groundwater. Deeper wells should be installed to evaluate the impact of contamination on deeper groundwater. In addition, additional monitoring wells are needed to determine the source of zinc contamination in well 2AG09.**

Response: The Navy intends to install three deep monitoring wells to evaluate water quality in deeper aquifers. The Navy believes that the zinc contamination in well 2AG09 is sufficiently defined by the railroad tracks and by three wells within 250 feet of well 2AG09 (2AG08, 2MG20, and 2MG22). Well 3AG10 and 3MG11 demonstrate that the elevated concentrations of zinc observed at 2AG09 do not extend south of the railroad tracks.

15. Comment: **<u>Groundwater Monitoring Frequency</u> – The Draft Monitoring Plan proposes a statistical methodology for determining short and long-term trends in groundwater concentrations. This statistical analysis should be applied to the existing groundwater sample result database to demonstrate currently established trends. The variations in groundwater metal concentrations during previous sampling events indicate that a change in groundwater sampling frequency to once every five years will likely not result in the identifying short- or long-term concentrations trends. The Final Monitoring Report should identify monitoring frequencies for each well based on the trends established by existing data.**

Response: Please see the response to EPA specific comment 11 for details on the Navy's proposed modifications to the groundwater monitoring strategy. Sampling frequency (that is, 3-year intervals versus annual sampling for sentinel wells) will be determined, in part, by examining trends for individual monitoring wells over the previous two rounds of sampling (October 2003 and the next round of sampling). No seasonal variation in concentrations of metals has been observed in the 20 different groundwater sampling events that have been conducted to date in the Litigation Area.

16. Comment: **<u>Groundwater Minerals</u> – General mineral analysis should be included with all groundwater samples.**

Response: Groundwater samples will be analyzed for the full suite of total metals (low-flow sampling) as well as for pH, temperature, conductivity, and total suspended solids. The general mineral concentration in groundwater will not be used to make remedial decisions about the site; therefore, the Navy does not propose to measure general mineral content of Litigation Area groundwater. Groundwater hardness can be assessed using concentrations of calcium and magnesium, which will be measured as part of the standard suite of metals.

17. Comment: **<u>Monitoring Proposed for RASS 4</u> – The only monitoring proposed for RASS 4 is groundwater monitoring. CRC's review of the Five-Year Report indicated that RASS 4 should be incorporated into Site 31 based on the similarities of the chemicals of concerns, and the topography that suggests run-off from Site 31 to RASS 4. In the interest of efficiency it would appear appropriate that future groundwater monitoring at RASS 4 be conducted in conjunction with future investigations of Site 31.**

Response: The Navy will consider this recommendation. However, Site 31 and RASS 4 are in separate phases of the CERCLA process, with RASS 4 in the post remedial action long-term monitoring phase, and Site 31 in the remedial investigation phase. The frequency and type of future groundwater sampling appropriate for each site are different, as the objectives for long-term monitoring samples versus remedial investigation samples are different. Where possible, the Navy will attempt to coordinate those separate field efforts. However the Navy has established, in consultation with the regulatory agencies and in accordance with the Federal Facilities Agreement, a site management plan schedule. The Navy plans to meet the schedule targets outlined in this schedule; EPA must approve any revisions to this schedule. The Navy has established schedules in the site management plan based on site priorities established in consultation with the regulatory agencies and in accordance with the Federal Facilities Agreement between EPA and the Navy. In the current schedule (dated August 12, 2004), the next monitoring event proposed for RASS 4 is scheduled to occur between November 15, 2004, and September 12, 2005, and the next field investigations planned for Site 31 are scheduled to occur between June 2005 and June 2006.

CLOSING

The principle concerns identified during CRC's review of the Draft Monitoring Plan included the lack of decision rules; statements about sediment, surface water and groundwater quality that are contradicted by existing data; and, the limited frequency and scope of proposed monitoring activities. As much of the monitoring is to support passive remediation, CRC would expect the scope and frequency of sampling to be more substantial than if contaminant removal or active remediation was performed. The Draft Monitoring Report is a disappointment in the respect that it will not provide results that the community can use to assess whether current and future removal actions in the Litigation Area are a success or failure.

RESPONSES TO REGIONAL WATER QUALITY CONTROL BOARD COMMENTS

GENERAL COMMENTS

1. **Comment:** **Water Board staff recommends that the Navy outlines the purpose of the monitoring program. Monitoring is usually implemented to either observe the efficacy of specific remedial actions or to insure that impacts to the environment are not extended beyond specific spatial and temporal points of compliance. It is unclear how the proposed monitoring program fits into these paradigms.**

   Response: Changes to the final monitoring plan include revised statements on program objectives and decision criteria. Please see the Navy's response to EPA general comment 1.

2. **Comment:** **The Navy could provide an itemized budget for the cost of the proposed monitoring program over the proposed period. The Navy might want to outline how these funds could alternatively be expanded to remediate contamination in soils/ sediments and groundwater at the site.**

   Response: The relative costs and benefits of monitoring and other remedial alternatives are more appropriately considered in the context of an FS. The Navy, however, appreciates this comment, and considers the tradeoffs between monitoring and remediation in its internal assessment of options for long-term management of the Litigation Area.

3. **Comment:** **The Navy states that monitoring objectives will aid in making management decisions at the Litigation Area. The text needs to clarify what these management decisions could be. The Navy fails to define trigger mechanisms linked to the monitoring program. It is conceivable that upon monitoring activities, unacceptable impacts to the environment are characterized. In case this conjecture develops, Water Board staff recommends the implementation of remedial activities. These actions should be efficiently deployed to further prevent impacts to the environment.**

   Response: The final monitoring plan reflects substantial revisions to the draft, based on this comment. Please see the Navy's response to EPA general comment 3.

4. **Comment:** **The Navy needs to elucidate how the proposed monitoring program fits in the general site remedial impacts management in light of minimal observed changes in contaminant concentrations in soils and sediments over the five years postremediation monitoring. More specifically, the report does not clarify the function of the monitoring program within the proposed remedial activities outlined in the recently submitted Feasibility Study (Draft Supplemental Feasibility Study for the Litigation Area, TtEMI, March 2004). Furthermore, the**

Navy needs to take a holistic approach to this monitoring program to include active neighboring industrial facilities. Finally, this program needs to include monitoring points found at the boundaries between the DoD (Department of Defense) and private/State properties.

Response: The Navy has incorporated changes to the final monitoring plan that address the Water Board's comments concerning objectives of the monitoring program (see Navy's response to EPA general comments 3). The Navy does not have the legal authority to collect samples on non-Navy property.

5. Comment: The Navy needs to state the surface and groundwater beneficial uses following the 1995 San Francisco Bay Basin Plan.

Response: The Navy has summarized surface and groundwater beneficial uses below.

Beneficial Use	Description of Applicability
Agricultural Supply	Groundwater and surface water at the site are not appropriate for agricultural supply due to the high concentration of TDS.
Areas of Special Biological Significance	The area of the site is not identified as one of special biological significance in the basin plan.
Cold Freshwater Habitat	The Litigation Area sites do not provide potential cold freshwater habitat suitable for supporting trout, salmon, or steelhead fisheries.
Ocean, Commercial, and Sport Fishing	The site does not offer any potential for ocean or commercial fishing. At present, there is no public access for sport fishing in the Litigation Area sites.
Estuarine Habitat	The Litigation Area offers estuarine habitat.
Freshwater Replenishment	Groundwater and surface water at the site is not likely to replenish freshwater due to the high concentration of TDS.
Groundwater Recharge	Freshwater recharge of groundwater is not likely due to the high concentration of TDS at the site.
Industrial Service Supply	Shallow groundwater resources at the Litigation Area sites do not offer a reasonable source of industrial service supply water because of the low yield of the shallow water bearing formations (Bay Mud) in the area.
Marine Habitat	The Litigation Area Sites do not offer a significant source of water to marine habitats because they are not located near the Pacific Ocean.
Fish Migration	The Litigation Area sites do not offer significant water resources for fish migration.
Municipal And Domestic Supply	The Litigation Area sites do not offer water resources for municipal and domestic water supply due to the high TDS of groundwater.
Navigation	The Litigation Area sites do not have any existing waterway uses for navigation.
Industrial Process Supply	Shallow groundwater resources at the Litigation Area sites do not offer a reasonable source of industrial process supply water because of the low yield of the shallow water bearing formations (Bay Mud) in the area. A deep groundwater aquifer provides a potential industrial supply source.
Preservation Of Rare and Endangered Species	The Litigation Area sites do support preservation of rare and endangered plant and animal species.
Water Contact Recreation	The Litigation Area sites do not offer open bodies of water suitable for water contact recreation.
Noncontact Water Recreation	The Litigation Area sites do not offer open bodies of water suitable for noncontact water recreation.

Beneficial Use	Description of Applicability
Shellfish Harvesting	The Litigation Area sites do not offer tidal flats with potential for shellfish harvesting.
Fish Spawning	The RASS 1 sloughs in the Litigation Area do offer significant water resources for fish spawning.
Warm Freshwater Habitat	The Litigation Area sites do not offer warm freshwater resources (lakes or reservoirs).
Wildlife Habitat	The Litigation Area sites do offer use of water resources that support wildlife.

6. Comment: Please provide the site use history, environmental health characterization for the Navy property found northeast of RASS 4 (Remedial Action Subsite). Could this piece of property be used as a wetland reference site? Provide the basis for not including this property in the proposed monitoring program.

Response: The parcel northwest of RASS 4 is not included in the proposed monitoring program, as it is outside the boundary of the Litigation Area sites and RASS 4. In addition, it has not been the focus of any investigations to date under the CERCLA program at NWS SBD Concord. Sites were identified for inclusion in the Installation Restoration Program as a result of a comprehensive review of former site uses and identification of any potential site uses that would indicate a potential CERCLA release in the Initial Assessment Study for NWS SBD Concord. The parcel in question was not identified as one that warranted investigation (Ecology and Environment 1983).

SPECIFIC COMMENTS

1. Comment: <u>Section 1.0, Introduction, p 1-1</u>: Water Board staff recommends adding the sampling of surface water quality of the mosquito ditches in the monitoring program. This recommendation is based on the finding that concentrations of metals in surface water from the mosquito ditches are generally higher than concentrations in water from Lost Slough.

Response: Please see the response to EPA general comment 1, which explains the Navy's rationale for preparing separate monitoring plans for areas addressed by the ongoing FS and areas that are not currently being considered for remediation.

2. Comment: <u>Section 2.0, Selection of Monitoring Objectives, p 2-1</u>:

- **The Navy needs to illustrate what non-environmental factors might drive biological populations variations in the study area. Furthermore, the Navy needs to compare the population impacts these driving mechanisms have with environmentally triggered effects.**

- **It is essential that the Navy includes monitoring of groundwater potability at the proposed monitoring points. Please review SWRCB (State Water Resources Control Board) Resolution 88-63 to obtain a definition of potability.**
- **The Navy needs to clarify the purpose of sampling only total metals in some areas while in others total and dissolved metals concentrations are proposed.**

Response: As specified under CERCLA, the focus of the risk assessment is on chemical contamination, rather than on physical, biological, or other non-chemical stressors. Total and dissolved metals will be measured in surface water samples to distinguish between the fraction of metals associated with suspended solids and the fraction that exists in the dissolved state. The AWQC are based on dissolved metals. Only total metals will be analyzed as part of the groundwater monitoring program, using the low-flow sampling protocol. The Navy will evaluate groundwater potability per the State Water Resources Control Board (SWRCB) Resolution 88-63.

3. Comment: **<u>Section 3.1.1, Background, p 3-3</u>:**

- **Quantify the lateral and vertical distributions of metals in soils and sediments at the site.**
- **Provide the regulatory basis to the benchmarks used to define impact contamination at the site.**
- **Establish how an inferred sediment accretion rate of 2.5 mm/yr efficiently isolates contaminated sediments from biotic exposure.**

Response: Monitoring of marsh surface soil will focus on the 0- to 0.50-foot below ground surface (bgs) depth interval, which is the horizon where the greatest exposure to ecological receptors is likely to occur. The lateral extent of concentrations of metals in soil is defined by the existing network of sampling locations originally proposed for the site. (Locations have been added based on adjustments to the monitoring program made as part of the annual post-remediation sampling.) The only ecological benchmarks for the Litigation Area that are promulgated standards are the chronic and acute water quality criteria. The effects range-low (ER-L) and effects range-median (ER-M) are screening-level benchmarks. The Navy plans to further evaluate other benchmarks that might be appropriate to use in developing performance criteria to monitor surface soil in the marsh. The Navy expects to prepare a technical white paper on this subject for agency review and concurrence before the next round of sampling. Please see the last item under EPA general comment 1 for the Navy's response to the portion of this comment that concerns sediment accretion on the marsh surface.

4. **Comment:** **<u>Section 3.1.2, Monitoring Objectives and Performance Criteria, p 3-4</u>: Define the purpose of monitoring Units 2, 6 and portions of 12 located in the passive remediation area RASS 1.**

Response: As discussed in the Navy's response to EPA general comments 1 and 3, the final monitoring plan contains a number of key changes, including sampling all areas on the marsh surface where elevated concentrations of arsenic and other metals remain. The monitoring objectives were also restated to conform to recommendations from EPA's new directive on design of monitoring programs. The Navy is not proposing to sample Unit 2 as part of the current long-term monitoring plan.

5. **Comment:** **<u>Section 3.2.2, Monitoring Objectives and Performance Criteria, p 3-15</u>: The Navy needs to clarify the purpose of choosing Lost Slough Spatial Units 9 for monitoring. This area did not yield frequent Ambient Water Quality Criteria exceedances. However areas such as the mosquito ditches, Units 5, 7 and 11 (RASS 1) are not currently proposed for monitoring. These units demonstrated troublesome water quality exceedances.**

Response: Please see the Navy's response to EPA general comment 1.

6. **Comment:** **<u>Section 3.3.1, Background, p 3-21</u>:**

- **The Navy needs to scientifically demonstrate with site collected data how they determined that hydrocarbon detected in groundwater at the site are naturally occurring. Has the Navy performed silica gel cleanup on groundwater samples taken for TPH (Total Petroleum Hydrocarbon) analysis?**
- **Map the adjacent property wells.**
- **Due to groundwater impacts affecting the deep sandy aquifer detected at the adjacent properties and similar contaminants affecting water quality on Navy property, Water Board staff recommends characterizing groundwater quality in the confined aquifer.**

Response: The basis for the Navy's contention that the motor oil-range hydrocarbons observed in groundwater at the Litigation Area in October 1996 are naturally occurring is that low concentrations of hydrocarbons (less than 0.4 mg/L) were observed in 10 of the 11 wells sampled, including wells in RASS 4, about 2,500 feet east of the Litigation Area marsh. The diffuse presence of low-level hydrocarbons over such a large area suggests that a single discrete source is not the cause, and that a more diffuse natural source is more likely. The analytical laboratory noted that the majority of the results did not show the characteristic range of peaks expected for a hydrocarbon fuel, and did not indicate the presence of a fuel. Furthermore, the components of hydrocarbon fuel that are known to be of concern to human and ecological receptors (benzene, toluene, ethylbenzene, xylenes, polycyclic aromatic hydrocarbons,

and other volatile and semivolatile organic compounds [VOC and SVOC]) were tested for but were not detected. No VOCs or SVOCs were detected in any of the 11 wells sampled.

At the time that this groundwater sampling was done, silica gel cleanup, although available, was not standard practice for analysis of groundwater for total petroleum hydrocarbons. It was not used for these analyses.

The Navy has mapped the wells on its own property, but has not mapped wells or other features on neighboring properties.

The Navy intends to install three deeper monitoring wells to characterize groundwater quality in the deeper aquifer. The Navy will not characterize the deeper aquifer as confined until the hydrogeologic relationship between the surficial aquifer and the deeper aquifer is known.

7. Comment: **Section 3.3.2, Monitoring Objectives and Performance Criteria, p 3-22:**

- **State where the monitoring locations will be sampled.**
- **Justify the focus of the groundwater monitoring in the eastern section of the site.**

Response: As stated in the response to EPA specific comment 11, the Navy is proposing to sample all of the existing site-wide monitoring wells on a 3-year schedule, and will perform annual sampling of a subset of "sentinel" wells. Sentinel wells will be selected to better track ongoing migration of contamination from neighboring property, as well as to monitor wells where increasing trends have been shown based on the previous two rounds of monitoring. The eastern portion and boundary of the site will be emphasized as part of the sentinel well monitoring, as this area has received the greatest impact from off-site sources of contamination.

8. Comment: **Figure 1-1, Vicinity Map: Outline the RASS (Remedial Area Subsite) areas on the figure.**

Response: The Navy has incorporated this change in the final plan.

9. Comment: **Figure 3-7, Groundwater Sampling Locations:**

- **Map all groundwater monitoring wells found at the site.**
- **Provide groundwater monitoring wells specifications (depth, screen intervals, diameter) on the figure.**

Response: All groundwater-monitoring wells at the site are shown on Figure C-3. Figure C-5 shows the most recent groundwater contour map. Figure C-6 details each well and its depth, screen intervals, and diameter. Any missing information will be provided in the first annual technical memorandum for the monitoring.

REFERENCES

Ecology and Environment. 1983. Initial Assessment Study of Naval Weapons Station Concord, California. Naval Energy and Support Facility. June.

Tetra Tech EM Inc. (Tetra Tech). 1997. "Technical Memorandum: Tidal Influence Study and Post-Remediation Groundwater Monitoring, Litigation Area." July 22.

Tetra Tech. 2003. Final Five-Year Periodic Review Assessment Litigation Area. Naval Weapons Stations Seal Beach Detachment Concord, Concord, California. June 30.

U.S. Environmental Protection Agency (EPA). 1994. Final Guidance for the Data Quality Objectives Process. United States Environmental Protection Agency Quality Assurance Management Staff. Washington D.C. EPA600R96055. September 1994.

EPA. 2004. Office of Solid Waste and Emergency Response (OSWER). Guidance for Monitoring at Hazardous Waste Sites: Framework for Monitoring Plan Development and Implementation. OSWER Directive No. 9355.4-28. January 2004.

Zar, J. H. 1996. *Biostatistical Analysis*. Third Edition, Prentice-Hall, Inc. Upper Saddle River, New Jersey.

APPENDIX C
SAMPLING AND ANALYSIS PLAN
(FIELD SAMPLING PLAN/QUALITY ASSURANCE PROJECT PLAN)

GENERAL SERVICES ADMINISTRATION
CONTRACT NO. 10F-0076K
ORDER NO. N62474-03-F-4023
GSA.105.00023

Final
Sampling and Analysis Plan
(Field Sampling Plan/Quality Assurance Project Plan)

MONITORING PLAN
LITIGATION AREA

Naval Weapons Station Seal Beach Detachment Concord
Concord, California

October 13, 2004

Prepared for

DEPARTMENT OF THE NAVY
Engineering Field Activity West
Daly City, California

Prepared by

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FINAL
SAMPLING AND ANALYSIS PLAN
(FIELD SAMPLING PLAN/QUALITY ASSURANCE PROJECT PLAN)
MONITORING PLAN
LITIGATION AREA
NAVAL WEAPONS STATION SEAL BEACH DETACHMENT CONCORD
CONCORD, CALIFORNIA

GENERAL SERVICES ADMINISTRATION
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GSA.105.00023

Prepared for:

DEPARTMENT OF THE NAVY

REVIEW AND APPROVAL

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TABLE C-1: EPA QA/R-5 QAPP ELEMENTS

Monitoring Plan Litigation Area, Naval Weapons Station Seal Beach Detachment, Concord

U.S. EPA QA/R-5 QAPP Element		Tetra Tech Sampling and Analysis Plan	
A1	Title and Approval Sheet	Title and Approval Sheet	
A2	Table of Contents	Table of Contents	
A3	Distribution List	Distribution List	
A4	Project/Task Organization	1.4	Project Organization
A5	Problem Definition/Background	1.1	Problem Definition and Background
A6	Project/Task Description	1.2	Project Description
A7	Quality Objectives and Criteria	1.3	Quality Objectives and Criteria
A8	Special Training/Certification	1.5	Special Training and Certification
A9	Documents and Records	1.6	Documents and Records
B1	Sampling Process Design	2.1	Sampling Process Design
B2	Sampling Methods	2.2	Sampling Methods
B3	Sample Handling and Custody	2.3	Sample Handling and Custody
B4	Analytical Methods	2.4	Analytical Methods
B5	Quality Control	2.5	Quality Control
B6	Instrument/Equipment Testing, Inspection, and Maintenance	2.6	Equipment Testing, Inspection, and Maintenance
B7	Instrument/Equipment Calibration and Frequency	2.7	Instrument Calibration and Frequency
B8	Inspection/Acceptance of Supplies and Consumables	2.8	Inspection and Acceptance of Supplies and Consumables
B9	Non-direct Measurements	2.9	Non-Direct Measurements
B10	Data Management	2.10	Data Management
C1	Assessment and Response Actions	3.1	Assessment and Response Actions
C2	Reports to Management	3.2	Reports to Management
D1	Data Review, Verification, and Validation	4.1	Data Review, Verification, and Validation
D2	Validation and Verification Methods	4.2	Reconciliation with User Requirements
D3	Reconciliation with User Requirements		

Notes:

QAPP Quality assurance project plan
Tetra Tech Tetra Tech EM Inc.
U.S. EPA U.S. Environmental Protection Agency

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ACRONYMS AND ABBREVIATIONS

µg/kg	Microgram per kilogram
ASTM	American Society for Testing and Materials
AWQC	Ambient Water Quality Criteria
BERA	Baseline ecological risk assessment
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CLP	Contract laboratory program
COC	Chemicals of concern
CPC	Chemical Pigment Company
CPR	Cardiopulmonary resuscitation
DHS	Department of Health Services
DO	Delivery Order
DQA	Data quality assessment
DQO	Data quality objective
EDD	Electronic data deliverable
ELAP	Environmental Laboratory Accreditation Program
EPA	U.S. Environmental Protection Agency
ER-M	Effects range-median
FS	Feasibility study
FSP	Field Sampling Plan
FTL	Field team leader
GSA	General Services Administration
HHRA	Human health risk assessment
ID	Identification
IDW	Investigation-derived waste
IRCDQM	Installation Restoration Chemical Data Quality Manual
L	Liter
L/min	Liter per minute
LCS	Laboratory control sample
LIMS	Laboratory information management system
LOE	Line of evidence

MDL	Method detection limit
mg/kg	Milligram per kilogram
mL	Milliliter
MS	Matrix spike
MSD	Matrix spike duplicate
msl	Mean sea level
MSR	Monthly status report
Navy	U.S. Department of the Navy
NEDTS	Navy Environmental Data Transfer Standards
NFESC	Naval Facilities Engineering Service Center
NOAA	National Oceanic and Atmospheric Administration
NWS SBD	Naval Weapons Station Seal Beach Detachment
OSHA	Occupational Safety and Health Administration
PARCC	Precision, accuracy, representativeness, completeness, and comparability
PCB	Polychlorinated biphenyl
PE	Performance evaluation
PPE	Personal protective equipment
PRC	PRC Environmental Management, Inc.
PRRL	Project-required reporting limit
PVC	Polyvinyl chloride
QA	Quality assurance
QA/QC	Quality assurance and quality control
QAPP	Quality assurance project plan
QC	Quality control
QEA	Qualitative ecological assessment
RAP	Remedial action plan
RASS	Remedial action sub-site
RI	Remedial investigation
ROD	Record of Decision
RPD	Relative percent difference
RPM	Remedial project manager
RWQCB	Regional Water Quality Control Board
SAMTRAK	Tetra Tech's sample tracking database
SAP	Sampling and analysis plan
SDG	Sample delivery group

SOP	Standard operating procedure
SOW	Statement of work
SPTC	Southern Pacific Transportation Company
SQL	Sample quantitation limit
SVOC	Semivolatile organic compound
TDS	Total dissolved solids
TER	Technical evaluation report
TIC	Tentatively identified compound
TOC	Total organic carbon
TPH	Total petroleum hydrocarbon
TPH-e	Total petroleum hydrocarbon-extractable
TPH-p	Total petroleum hydrocarbon-purgeable
TSA	Technical systems audit
TSS	Total suspended solids
Tetra Tech	Tetra Tech EM Inc.
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
VOC	Volatile organic compound
WOE	Weight of evidence

1.0 PROJECT DESCRIPTION AND MANAGEMENT

Tetra Tech EM Inc. (Tetra Tech) received Delivery Order (DO) No. N62474-03-F-4023 under the General Services Administration (GSA) Contract No. 10F-0076K. This DO is in support of the Naval Facilities Engineering Command, Engineering Field Activity West, which is responsible for conducting the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) response action under the U.S. Department of Navy's Installation Restoration Program at the Naval Weapons Station Seal Beach Detachment (NWS SBD) Concord, California. The DO requires Tetra Tech to prepare a long-term monitoring program for the remedial action sub-sites (RASS) located in the Tidal Area section of NWS SBD Concord. The RASSs are located in a portion of the NWS SBD Concord Tidal Area known as the Litigation Area (Figure C-1).

Tetra Tech prepared this sampling and analysis plan (SAP), consisting of a field sampling plan (FSP) and quality assurance project plan (QAPP) in an integrated format, to support monitoring at the Litigation Area. The purpose of the long-term monitoring is to continue to assess portions of the site where elevated concentrations of metals remain. The monitoring will also address data gaps identified in the baseline ecological risk assessment (BERA) that was based on 5 years of post-remediation monitoring and concerns raised by regulatory agencies (Tetra Tech 2003). Data from the long-term monitoring will assist the Navy in further characterizing potential risk from elevated metals concentrations in soil and water to on- and off-site aquatic and terrestrial receptors; further investigating potential migration of off-site sources of contamination into groundwater; refining existing food chain modeling for the California Black Rail; and assuring that no large-scale damage to vegetation is occurring on the marsh surface. The long-term monitoring results will be presented in annual technical evaluation reports (TER).

Table C-1 follows the approval page at the beginning of this SAP. The table provides information on how this SAP addresses all QAPP elements currently required by the U.S. Environmental Protection Agency (EPA) QA/R-5 guidance document (EPA 2001).

In this document, figures and tables (excluding Table C-1) are located after the references. Attachment A contains Method, Precision and Accuracy Goals, Attachment B contains Standard Operating Procedures, Attachment C contains all Field Forms, Attachment D lists Project-Required Reporting Limits, and Attachment E lists Navy-approved laboratories for sample analysis.

1.1 PROBLEM DEFINITION AND BACKGROUND

This section describes the following:

- Purpose of the Monitoring (Section 1.1.1)
- Problem to be Solved (Section 1.1.2)
- Facility Background (Section 1.1.3)
- Site Descriptions (Section 1.1.4)
- Physical Setting (Section 1.1.5)
- Summary of Previous Investigations (Section 1.1.6)
- Principal Decision Makers (Section 1.1.7)
- Technical or Regulatory Standards (Section 1.1.8)

1.1.1 Purpose of the Monitoring

The purpose of this long-term monitoring at the Litigation Area is to obtain additional information needed to refine characterization of potential contaminant sources and ecological risk in areas that continue to register elevated concentrations of metals. The Navy continues to be concerned that the adjoining chemical companies and railroad properties may be ongoing sources of contamination to RASSs 1 and 3. The Navy also acknowledges agency concerns about ongoing elevated concentrations of metals in certain locations of marsh soil, surface water, and groundwater. The Navy further understands that these levels could pose unacceptable risk to ecological receptors. This investigation will be conducted to further evaluate whether risk to ecological receptors is so great that actions other than monitoring are warranted and to resolve any remaining data gaps in the BERA before concerns can be addressed about the protectiveness of the present remedy within the Litigation Area. The Navy intends to re-evaluate its monitoring design after each sampling event, with two goals in mind: to conform with CERCLA monitoring guidance when chemicals of concern (COC) at concentrations that exceed benchmarks are left in place, and continue to assess whether actions more or less protective than monitoring should be occurring in each instance where benchmarks are exceeded.

Samples of soil, surface water, and groundwater will be collected to achieve these goals. In addition, groundwater wells will be installed and sampled to evaluate whether the deep aquifer is contaminated. Biotic samples will also be collected to fill gaps outlined in the 2003 BERA document, and aerial photographs will be taken to track landscape level changes in vegetation. Based on the various sampling results, the Navy will consider a series of alternative actions in each case, including but not limited to: no further action, continued monitoring, focused monitoring, and/or the feasibility study process. Interim results of this long-term monitoring will be discussed in TERs every year in which sampling occurs. In each case, sampling by the Navy will be discontinued when all stakeholders agree to an alternative action or results for samples in the medium are no longer exceeding benchmarks. After the fifth year of sampling, a periodic review assessment will be conducted to evaluate the need for further monitoring or actions at the site.

1.1.2 Problem to Be Solved

Five years of post-remediation monitoring and a BERA identified six metal COCs (arsenic, cadmium, copper, lead, selenium, and zinc) that require further assessment in the RASSs. A long-term monitoring program is being proposed to continue to assess portions of the site where elevated concentrations of metals remain, as well as to address data gaps identified in the BERA and concerns raised by the regulatory agencies in their comments on the draft monitoring plan. The broad objectives of the monitoring plan include assessing compliance with regulatory requirements (primarily surface and groundwater components), evaluating the effectiveness of prior remedial actions (primarily for selected locations on the marsh surface), and assessing site conditions and ongoing risk to ecological receptors. Figures C-2 and C-3 identify monitoring areas and proposed sampling locations.

1.1.2.1 Surface Water in the Main Reach of Lost Slough

Concentrations of several COCs in surface water have consistently exceeded the ambient water quality criteria (AWQC) during the 5 years of post-remediation monitoring. Continued monitoring of dissolved and total metals in the main reach (Unit 10) and western arm (Unit 11) of Lost Slough is needed to assess the AWQC that were exceeded, detect potentially significant increases in the magnitude of risk to aquatic receptors and wildlife, and assess the potential for off site transport of metals to Suisun Bay.

1.1.2.2 Groundwater Sampling

Concentrations of several COCs in groundwater have consistently exceeded the AWQC during the 5 years of post-remediation monitoring. Continued periodic (every 3 years) monitoring of concentrations of total metals in the existing network of 23 monitoring wells will be conducted to assess whether the AWQC have been exceeded as well as the potential for unacceptable risk to ecological receptors posed by contaminated groundwater. More frequent monitoring (annual) of a subgroup of wells along the border of the Navy property will detect potential migration of contamination from offsite sources. Annual monitoring will also be conducted on wells where analytical results consistently exceed the AWQC or show increasing trends in metal concentrations over time.

1.1.2.3 Deep Aquifer Groundwater Well Sampling

Although the existing network of monitoring wells adequately characterizes contaminant concentrations in the shallow aquifer, groundwater in the deep aquifer has not been analyzed for contamination. Installation of several new, deeper wells along the eastern border of the property adjacent to offsite industrial operations will allow detection of potential migration of contaminants from these potential sources via the deep aquifer.

1.1.2.4 RASS 1 and 2 Soil Sampling

Elevated concentrations of some metals still occur in the soil at some locations on the marsh surface. Continued monitoring at locations with the most elevated levels will allow the Navy to characterize the potential for ongoing unacceptable risk to ecological receptors. Sampling will occur every 5 years unless results indicate a significant increase or decrease in contaminant concentrations.

1.1.2.5 BERA California Black Rail Food Chain Modeling Data Gap

The BERA conducted as part of the 5-year assessment review for the Litigation Area, as well as comments received from the regulatory agencies, identified characterization of exposure to contaminated soil and prey on the marsh surface as a data gap in assessing risk to the California Black Rail. Data on tissue burdens of metals in prey of the Black Rail are needed to fill this data gap and refine the results of the food chain modeling conducted in the BERA.

1.1.2.6 Marsh Surface Vegetation Monitoring

The Navy requires an efficient means of monitoring landscape-scale changes in site conditions that could have negative impacts on plants and wildlife. Factors associated with habitat suitability, including both plant cover and forage quality, are believed to be key to explaining observed trends for several populations of special status species, such as the California Black Rail and the salt marsh harvest mouse. The proposed monitoring will allow the Navy to detect significant large-scale changes in vegetation and other surface features at the site that could provide early warning that the habitat is deteriorating for these species.

1.1.3 Facility Background

NWS SBD Concord is in north-central Contra Costa County, 30 miles northeast of San Francisco, California (Figure C-1). The Navy facility operates an ocean-shipping terminal to transfer ordnance from trucks or railcars to ships and from ships to land transportation vehicles. The facility is bounded on the north by Suisun Bay, on the south and west by the City of Concord (population 116,000), and on the east by private land and the City of Pittsburg. It encompasses almost 13,000 acres in two holdings: the Inland Area and the Tidal Area.

In the late 1960s and the early 1970s, the Navy purchased several parcels of land to create a buffer zone around the Tidal Area. Eight of those parcels, which cover a total of 307 acres, were subsequently found to be contaminated with metals resulting primarily from waste disposal and historical spills from off-site neighboring chemical companies; some smaller on-site historical (non-Navy) sources were also located in several parcels. The Navy did not conduct any activities in these parcels that contributed contamination. The parcels are now referred to as the Litigation Area because the Navy has been involved in extensive litigation with owners of adjacent properties to recover remediation costs for these contaminated sites.

The U.S. Army Corps of Engineers (USACE) completed a remedial investigation (RI) (Lee and others 1986, 1988) and a feasibility study (FS) (Cullinane and others 1988) and recommended remediation focused on six metals (arsenic, copper, cadmium, lead, selenium, and zinc). The Navy completed four cleanup actions, referred to as remedial actions. Each of the four sites that were cleaned up is called a remedial action subsite, or RASS; they include RASSs 1 (210 acres), 2 (13 acres), 3 (71 acres), and 4 (13 acres). Remediation of these sites was limited because they include wetland areas that provide habitat for several threatened and endangered species. Only the most contaminated soils at each RASS were removed during the cleanup actions. Some contaminated soils were left in place in response to concerns associated with the destruction of extensive wetland habitat at the site.

The Navy and the USACE developed a monitoring plan as part of the remedial design to evaluate the success of the remedial actions and to assess migration and effects of contaminants left in place (Lee and others 1989). The monitoring plan called for sampling and analyzing several parameters (both chemical and ecological) before, during, and after remedial actions were conducted.

The Navy completed 5 years of postremediation monitoring before the post-remediation 5-year periodic review was initiated. The main purposes of the 5-year review were to evaluate the implementation and the effectiveness of the selected remedy and to assess whether any additional actions are necessary. The 5-year review was based on data collected during preremediation and postremediation monitoring, new data collected in October 2000 to fill data gaps identified during development of the approach for the 5-year review, a file review, a BERA, and a screening level human health risk assessment (HHRA). The findings and conclusions of the 5-year review are contained in the final report issued in June 2003 (Tetra Tech 2003).

The 5-year review concluded that the Navy had selected and implemented remedial actions in a manner consistent with the National Contingency Plan. In addition, restoration of remediated areas generally met the criteria for success, and the Navy conducted the pre-, during-, and post-remediation monitoring required by the Record of Decision (ROD). The site is currently protective of human health based on its continued use as a buffer zone with limited access; concerns about trespassers in RASS 4 were noted. The 5-year review concluded that the remedy was not fully protective of the environment in RASSs 1 and 3, although it was protective of the environment in RASSs 2 and 4. The lack of protectiveness in RASS 1 was based on high levels of metals in ditches and sloughs in the southern portion of RASS 1 that may pose a risk to ecological receptors. In RASS 3, the lack of protectiveness was based on concerns about migration of contaminants from the Nichols Creek drainage to the wetland in RASS 1. The Navy is currently conducting a supplemental feasibility study (FS) to address the issues of protectiveness in RASSs 1 and 3.

The 5-year review process also identified data gaps focused on further characterizing potential off-site sources of contamination to the Litigation Area or providing further chemical characterization of areas within the site. The data gap report concluded that there was potential contaminant migration via groundwater from alum ponds on adjacent properties owned by Honeywell International, Inc. (Tetra Tech 2004). Further groundwater monitoring was recommended since some concentrations of metals were higher in this 2003 sampling event than they had been in the previous 1996 sampling event.

Comprehensive long-term monitoring is needed in the Litigation Area for two reasons: first, because post-remediation and data gap monitoring have indicated continued elevated metal levels in all abiotic media and possible site re-contamination caused by ongoing activities at neighboring facilities; and second, because some contamination in RASSs 1 and 2 at levels above unacceptable risk to some assessment endpoint species has been left in place. Planning for this long-term monitoring is the subject of this SAP (FSP/QAPP).

1.1.4 Site Descriptions

NWS SDB Concord lies 10 miles west of the confluence of the Sacramento and San Joaquin rivers. That confluence forms the delta region, where there are more than 600 miles of interconnected and meandering tidal waterways. Drainage from NWS SDB Concord flows almost exclusively northward into Suisun Bay. The Litigation Area is composed of tidal and nontidal wetlands and upland habitats.

1.1.4.1 RASS 1

RASS 1 is primarily a brackish, tidally influenced emergent marsh. The mean elevation of RASS 1 is 3 feet above mean sea level (msl). Wetland areas in RASSs 1 and 2, delineated by USACE in 1991, were defined as areas less than 5 feet in elevation (above msl). The elevation of RASS 1 is generally less than 5 feet; therefore, the entire area is a wetland. The marsh surface usually is damp to dry; however, from several inches to 2 feet of water is present throughout RASS 1 after extreme high tides or heavy rains. The RASS 1 marsh includes tidal slough channels and a network of mosquito abatement ditches that transect the site.

1.1.4.2 RASS 2

RASS 2 consists of brackish, tidally influenced, emergent marsh and an upland transition vegetation zone that extends south to the Southern Pacific Transportation Company (SPTC) railroad track (Figure C-2). The northwestern one-third of RASS 2 is a wetland with a mean elevation of approximately 3 feet above msl. The remaining two-thirds of RASS 2 consists of relatively flat uplands with a mean elevation of approximately 7 feet above msl. The wetland area has a thick marsh-grass surface layer, with a root mat some 2 to 4 inches thick at the soil horizon. The upland area has patchy vegetative cover, consisting of nonnative grass and shrubs.

1.1.4.3 RASS 3

RASS 3 is primarily an upland area. A small area of robust, emergent, tidally influenced marsh in the northwestern portion of RASS 3 was deepened and expanded during remediation to form a ponded area. Nichols Creek, an ephemeral stream, runs through RASS 3 to the marsh area and subsequently drains into the extensive system of mosquito abatement ditches and sloughs in RASS 1, which in turn discharges to Suisun Bay. The wetland area of RASS 3, delineated by USACE in 1991, is roughly defined as the area encompassing Nichols Creek, which corresponds to the remediated area of RASS 3. Elevations in RASS 3

range from 27 feet above msl in the southeastern area to 5 feet above msl in the northwestern area. The upland area has patchy vegetative cover, consisting of nonnative grasses and shrubs. Seasonal rains and extreme high tides cause water to pond in the northwestern portion of the site.

1.1.4.4 RASS 4

RASS 4 is primarily an upland area, with a small palustrine, robust, emergent marsh in the eastern portion of the site (O'Neil 1988). The nontidal wetland area of RASS 4, delineated by USACE in 1991, is roughly defined as the area encompassing the easternmost portion of the RASS, directly north of Port Chicago Highway (Figure C-2). The elevation of RASS 4 ranges from 3 feet above msl in the eastern wetland area to a mean of 20 feet above msl in the western upland area. The upland area has patchy vegetative cover, consisting of grass and bushes. Heavy rains may cause several inches of water to pond at the eastern portion of the site.

1.1.5 Physical Setting

The following sections briefly describe of the environmental setting of the Litigation Area, including geology and soils, hydrology, groundwater, and ecology.

1.1.5.1 Geology and Soils

The geology at the Litigation Area is dominated by Pleistocene and Holocene geomorphology. The subsurface zone consists of interfingering alluvial and estuarine depositional environments. Footslopes, flood plains, and marsh or wetland areas of Quaternary age characterize the Litigation Area. Terraced Pleistocene alluvial fans and flood plain deposits form the footslopes. Pleistocene deposits are overlain by Holocene flood plain deposits that consist of unconsolidated sands, silts, gravels, and clays.

Holocene alluvial material has been overlain by fine-grained silt and clay, mixed with organic materials that make up what is locally known as Bay Mud in the wetland areas adjacent to Suisun Bay. The wetland soil is Joice Muck series. In the system of the National Cooperative Soil Survey, the wetland soil is clastic, euic, thermic Terric Medisaprists. The upland soil (on terrace deposits of alluvium) is classified as Antioch loam (fine, montmorillonite, thermic Typic natrixeralfs) or Capay clay (fine, montmorillonite, thermic Typic chromoxererts).

The Bay Muds are further defined as younger Bay Mud and older Bay Mud. The lithology of Quaternary older Bay Mud includes stiff, gray, silty clay, sand, and gravel. Younger Bay Mud is a dark gray to dark brown organic clay that contains a minor amount of peat and clayey sand. The younger Bay Mud is estuarine and marine silty clay that commonly ranges from normally consolidated to underconsolidated and soft to weak and varies in thickness from 15 to 50 feet. Most surface areas of RASS 1 and a portion of RASS 2 are primarily underlain by younger Bay Mud and silty peat, a highly compressible fibrous soil that contains 30 to 75 percent organic materials. Both Bay Mud and silty peat are typical of bay-margin marshes.

The upper 6 inches of soil in the upland areas of RASSs 3 and 4 is soft to medium-stiff, wet to saturated, clayey silt. The surface soil in most of RASS 3 is dry and very hard in the dry season.

1.1.5.2 Hydrology

The Litigation Area, which lies on the southern margin of Suisun Bay, includes more than 200 acres of tidal marsh. A small seasonal stream (Nichols Creek) drains a local watershed in the Los Medanos Hills south of the site and discharges into the marsh. The hydrology of the marsh is characterized by the complex interplay of tides, currents, surface water runoff, evapotranspiration, and weather.

Surface water bodies in the Litigation Area consist of the natural slough (referred to as Lost Slough) and tributaries that meander throughout the marsh, the network of man-made mosquito abatement ditches in RASS 1, a ponded area that was created by the remedial action at the western end of RASS 3, and a seasonal stream (Nichols Creek) that drains into the pond in RASS 3 and discharges to the wetlands at RASS 1 at low tide. RASS 1 is flat marsh incised by a natural slough, tributaries, and an extensive network of mosquito abatement ditches. The pond at RASS 3 is hydraulically connected to RASS 1; both are tidally influenced. The base of the pond at RASS 3 is elevated relative to the slough and ditches, but a submerged embankment prevents complete drainage of the pond. Nichols Creek is a narrow, seasonal creek that drains a small, undeveloped upland watershed of approximately 1 square mile in the Los Medanos Hills south of the site and passes along the western boundary of the property of the Chemical and Pigment Company before it enters RASS 3 (Cullinane and others 1988).

1.1.5.3 Groundwater

Groundwater at the Litigation Area occurs in a shallow unconfined water-bearing zone that is predominantly composed of silty clays. Water occurs at elevations of 3 to 5 feet above msl over most of the Litigation Area. Because of changes in surface elevations, depth to water ranges from about 5 feet below grade in the tidal marsh area to 45 feet below grade in the extreme southern part of the Litigation Area. Groundwater generally flows to the northwest near the tidal marsh, but a persistent groundwater mound in the area where Nichols Road crosses the railroad tracks causes groundwater to flow west and southwest in the southern part of the Litigation Area. Groundwater flow in RASS 4 is highly variable and has been directed toward the northeast, south, southeast, and west at various times, with no apparent seasonal cause of changes in flow direction.

Few water supply wells are present in the area, and satisfactory yields can generally be obtained only by drilling deeper bedrock wells. Groundwater generally exhibits relatively high concentrations of total dissolved solids (TDS), hardness, chlorides, and iron, especially when compared with the parameters for available surface water in the area. The groundwater is not a potential source of drinking water because of its relatively high salinity throughout most of the Litigation Area (PRC Environmental Management, Inc. [PRC] 1997a).

1.1.5.4 Ecology

Suisun Bay is a transition zone between the marine influence of San Francisco Bay and the freshwater influence of the Sacramento and San Joaquin rivers. The lower wetland portion of the Litigation Area, particularly in RASSs 1 and 2, is a dynamic marsh habitat characterized by vegetation that tolerates frequent inundation by brackish water. The drier upland portions of the Litigation Area, particularly RASSs 3 and 4, are essentially disturbed grasslands, except for a small freshwater marsh in RASS 4 and a small pond at the western end of RASS 3. The pond at RASS 3 is tidally influenced and has been colonized by plant and animal species characteristic of freshwater and brackish marshes. A more complete description of habitats and species is presented in the qualitative ecological assessment (QEA) (PRC 1997b).

Several threatened and endangered species are known to occur at NWS SBD Concord. Species of concern observed at the Litigation Area include the salt marsh harvest mouse (*Reithrodontomys megalotis*) (federally and state-listed endangered species), California Black Rail (*Laterallus jamaicensis*) (state-listed threatened species), Delta tule pea (*Lathyrus jepsonii*), soft bird's beak (*Cordylanthus mollis*), Mason's lilaeopsis (*Lilaeopsis masonii*), and Suisun marsh aster (*Aster lentus*). A more complete description of special-status species observed or expected to occur at the Litigation Area is provided in the QEA (PRC 1997b).

1.1.6 Summary of Previous Investigations

As described in Section 1.1.3, the Navy acquired the Litigation Area property in the 1970s from several different owners. This area was subsequently found to be contaminated with metals, resulting primarily from waste disposal and historical spills from off-site neighboring chemical companies; some smaller on-site historical (non-Navy) sources were also located in several parcels. RASS 1 through 4 were identified in an RI/FS completed by USACE in 1988; the RI identified six metals (arsenic, cadmium, copper, lead, selenium, and zinc) as chemicals of concern, and the FS recommended remedial alternatives and criteria for soil cleanup in each RASS. On April 6, 1989, the Navy issued a final remedial action plan (RAP) and signed a ROD.

The remedy identified in the RAP and ROD included active removal of the most contaminated soil from a portion of each site and passive remediation and long-term monitoring of contaminants left in place. Some contaminated soil was left in place to avoid destroying sensitive habitat because the Litigation Area includes wetlands that provide habitat for several threatened or endangered species. Active remediation (removal and disposal of contaminated soil) was conducted between 1992 and 1995; site revegetation was completed by 1996. The Navy implemented a monitoring plan as part of its remedial design to assess migration and the effects of contaminants left in place. A QEA was conducted in 1996 to evaluate the nature and extent of organic contaminants and to confirm that the six metals of concern were the primary ecological risk drivers at the site (PRC 1997b). The Navy completed 5 years of post-remediation monitoring before the 5-year review was initiated in 2000.

The 5-year postremediation review is a statutory requirement under CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986, in cases where (1) contaminants are left in place and (2) the ROD was signed after October 1986. The components of the 5-year review were developed in collaboration with the regulatory and trustee agencies and were documented in a work plan. The main purpose of the 5-year review was to evaluate the implementation and the effectiveness of the selected remedy and to assess whether any additional actions are necessary. The Navy also agreed to conduct a screening-level HHRA and a BERA to evaluate whether contamination by metals left at the site presents an ongoing threat. The 5-year review was based on data collected during preremediation and postremediation monitoring, the QEA conducted from 1995 to 1997, and new data collected in October 2000 to fill data gaps identified during the development of the approach for the 5-year review.

Based on the findings of the 5-year review, the Navy acknowledged that the remedy is not fully protective of the environment in RASSs 1 and 3. The Navy conducted an additional data gap investigation in 2003 to further evaluate ongoing off-site sources and to resolve any on-site data gaps before concerns could be addressed about the protectiveness of the remedy in the Litigation Area. This additional investigation concluded that there is some evidence that recontamination may be occurring via groundwater migration from off site sources (Tetra Tech 2004).

1.1.7 Principal Decision Makers

Principal decision makers include the Navy, and the regulatory and trustee agencies. The data collected from this monitoring plan will be used to evaluate ongoing contaminant concentrations that exceed benchmarks in abiotic media and identify the appropriate future action for the Litigation Area.

1.1.8 Technical or Regulatory Standards

Analytical results for soil, surface water and groundwater samples collected during this investigation will be compared with analytical results collected as part of the 5-year monitoring program and the results for the data gap samples to document changes in site conditions or concentrations that exceed previously measured values. In some cases, analytical results will be compared with available toxicity-based benchmarks or criteria. The following criteria or benchmarks were selected for this investigation to identify project-required reporting limits (PRRL):

- Toxicological benchmarks for soil developed by the Oak Ridge National Laboratory for plants, invertebrates, and wildlife (Efroymson and others 1997a, 1997b, and 1997c)
- The lower of the freshwater or saltwater chronic AWQC developed by the EPA. The Navy and regulatory agencies had identified appropriate water quality screening benchmarks based on previously promulgated standards for inorganic chemicals at the Litigation Area (EPA 1998, 2000a; Regional Water Quality Control Board [RWQCB] 1995

- The lowest reporting limit using standard methods available for tissue samples will be used as the PRRL. There is no promulgated standard for tissue residue values, which will be used in the food chain model. The PRRL values are low enough for use in the model, since residue numbers lower than the PRRLs would indicate a lower risk than is currently estimated in the model

Screening benchmarks and PRRLs are provided in Attachment D.

1.2 PROJECT DESCRIPTION

The following subsections discuss the objectives and measurements of all elements of the initial sampling event. Table C-2 presents a schedule of sampling, analysis, and reporting for the first 5 years of monitoring.

1.2.1 Project Objectives

As stated in Section 1.1, the objective of the monitoring plan is to collect information needed to evaluate and characterize continued potential exposure to and current health of ecological receptors in remediated and unremediated areas that are still showing elevated concentrations of metals. The objective can be divided into six sampling elements. The six sampling elements and their associated monitoring objectives are described below.

1. **Surface Water Monitoring in the Main Reach of Lost Slough.** Determine whether AWQC are being exceeded; if any AWQC are exceeded, determine the potential for unacceptable risk to aquatic receptors and wildlife, and the potential for off site transport of metals to Suisun Bay.
2. **Groundwater Monitoring.** Determine whether AWQC values are being exceeded; if any AWQC are exceeded, determine spatial and temporal trends to characterize potential risk to ecological receptors and to try to assess whether there is ongoing contamination from off-site sources.
3. **Deep Aquifer Groundwater Well Installation and Sampling.** Determine whether contaminants are migrating via the deep aquifer from off-site sources on the eastern border of the Litigation Area.
4. **RASS 1 and 2 Soil Sampling.** Determine whether elevated levels of COCs remain in soils on the marsh surface; if elevated levels are still found, determine the potential for ongoing unacceptable risk to plants and wildlife on the marsh surface.
5. **BERA California Black Rail Food Chain Modeling Data Gap.** Determine total metals concentrations in plant and terrestrial invertebrate prey of the California Black Rail and model potential exposure to the bird from ingestion of plant and terrestrial invertebrate prey.

6. **Marsh Surface Vegetation Monitoring.** Determine whether landscape-scale changes in the vegetation cover on the marsh surface are occurring. Evaluate whether any changes indicate positive or negative influences and combine these results with other monitoring data to make decisions regarding future actions on the marsh surface.

1.2.2 Project Measurements

To meet the monitoring plan objectives, the following measurements will be conducted to complete the sampling elements:

1. **Surface Water Monitoring in the Main Reach of Lost Slough.** Annually, surface water will be sampled during the wet and dry seasons in spatial units (also called reaches) 9 and 10 of RASS 1, which comprise the main reach of Lost Slough. Samples will be collected at the bottom third, middle third, and top third of both reaches. For each of the sampling years, samples will be collected three times, 1 to 2 weeks apart, during the wet season and three times, 1 to 2 weeks apart, during the dry season. Samples will be collected from the center of the channel at mid-depth during an out-going tide. The water samples will be analyzed for total and dissolved metals (the full suite contract laboratory program [CLP] metals), pH (field measurement), temperature (field measurement), conductivity (field measurement) and total suspended solids (TSS).

2. **Groundwater Monitoring.** A single sample from each of the 23 existing monitoring wells will be collected during the wet season in the first monitoring year and every 3 years after. Samples will be analyzed for total metals (the full suite of CLP metals), temperature (field measurement), pH (field measurement), conductivity (field measurement), TDS and TSS. Based on levels of metals in samples from the wells, a group of sentinel wells will be designated and will be sampled annually for the same analytes. Samples will be collected using a low-flow technique if possible.

3. **Deep Aquifer Groundwater Well Installation and Sampling.** Three new groundwater-monitoring wells, which will extend into the deep aquifer, will be installed on Navy property along the border adjacent to Honeywell (Figure C-3). Detailed lithologic logging of the wells will be performed to assess the presence of preferential flow pathways. Synoptic water-level measurements will be taken for the new wells to calculate the direction of flow in the deep aquifer.

   The deep wells will be considered sentinel wells and will accordingly be sampled annually for the same analytes as the other groundwater wells. However, in the first year, they will be sampled for the full suite of contaminants (hexavalent chromium, volatile organic compounds [VOC], semivolatile organic compounds [SVOC], polychlorinated biphenyls [PCB], pesticides, herbicides, extractable total petroleum hydrocarbons [TPH-e] and purgeable total petroleum hydrocarbons [TPH-p]) to ensure that there are no COCs in the water.

4. **RASS 1 and 2 Soil Sampling.** A total of 32 soil sites (31 existing and one new) will be sampled every 5 years for analysis of total metals (the full suite of CLP metals), pH, and total organic carbon (TOC). Each site encompasses a 100- by 100-foot grid that will be sampled in four locations (one per 50- by 50-foot quadrant) per sampling event. In total, 128 samples and four equipment rinsate samples will be collected. Samples will be collected at the surface (0 to 0.5 feet below ground surface [bgs]). Sampling locations (Figure C-3) were selected based on areas where effects range-median (ER-M) values for COCs have been exceeded previously, if either one or both of the following were true for a site in any one or more years of post-remediation sampling: (1) ER-M (Arsenic) > 1; and (2) mean ER-M quotient > 1.5.

5. **BERA California Black Rail Food Chain Modeling Data Gap.** Known Black Rail prey tissue (terrestrial invertebrates and seeds) will be collected from three separate areas that are collocated with soils that have historically shown high levels of metal contaminants. Prey species will be segregated during sampling and depending on the amount of biomass collected and species will either be analyzed separately or will be pooled for analysis. However, a minimum of at least three samples of at least two food categories, insects and seeds, will be analyzed separately. If possible, analysis will focus on prey with the greatest potential for bioaccumulation of the COCs. Prey will be analyzed for whole body concentrations of metals and for percent moisture content.

6. **Marsh Surface Vegetation Monitoring.** In the first year of sampling, aerial photos of the entire marsh surface will be taken and analyzed to map plant communities and their relative cover areas. If deemed technically feasible and cost effective, this approach will create a permanent record of the relative cover of different vegetation communities (and other surface features at the site) and will allow the Navy to assess whether significant changes are occurring over time. Aerial photos will be taken and analyzed every 3 years during the dry season.

1.3 QUALITY OBJECTIVES AND CRITERIA

The following sections present the data quality objectives (DQO) and measurement quality objectives identified for this project.

1.3.1 Data Quality Objectives

DQOs are qualitative and quantitative statements developed through the seven-step DQO process (EPA 2000b, 2000c). The DQOs clarify the study objective, define the most appropriate data to collect and the conditions under which to collect the data, and specify tolerable limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support decision-making. The DQOs are used to develop a scientific and resource-effective design for data collection. The seven steps of the DQO process for this project are presented in Table C-3.

1.3.2 Measurement Quality Objectives

All analytical results will be evaluated in accordance with precision, accuracy, representativeness, completeness, and comparability (PARCC) parameters to document the quality of the data and to ensure that the data are of sufficient quality to meet the project objectives. Of these PARCC parameters, precision and accuracy will be evaluated quantitatively through the collection of the quality control (QC) samples listed in Table C-4. Precision and accuracy goals for these QC samples are listed in Attachment A.

The following sections describe each of the PARCC parameters and how they will be assessed within this project.

1.3.2.1 Precision

Precision is the degree of mutual agreement between individual measurements of the same property under similar conditions. Combined field and laboratory precision is evaluated by collecting and analyzing field duplicates and then calculating the variance between the samples, typically as a relative percent difference (RPD).

$$RPD = \frac{|A - B|}{(A + B)/2} \quad x \quad 100\%$$

where:

A	=	First duplicate concentration
B	=	Second duplicate concentration

Field sampling precision is evaluated by analyzing field duplicate samples. Because it is not practical to obtain true field duplicate soil samples, field duplicates will be collected only for groundwater and surface water for this project. Field duplicates will also be analyzed for prey tissue if volumes collected allow.

Laboratory analytical precision is evaluated by analyzing laboratory duplicates or matrix spikes (MS) and matrix spike duplicates (MSD). For this project, MS/MSD samples will be generated for all analytes. The results of the analysis of each MS/MSD pair will be used to calculate an RPD for evaluating precision.

1.3.2.2 Accuracy

Accuracy is the degree of agreement between an analytical measurement and a reference accepted as a true value. The accuracy of a measurement system can be affected by errors introduced by field contamination, sample preservation, sample handling, sample preparation, and analytical techniques. A program of sample spiking will be conducted to evaluate laboratory accuracy. This program includes analysis of the MS and MSD samples, laboratory control samples (LCS) or blank spikes, surrogate standards, and method blanks. MS and MSD samples

will be prepared and analyzed at a frequency of 5 percent for all samples. LCS or blank spikes are also analyzed at a frequency of 5 percent. The result of the spiked samples is used to calculate the percent recovery for evaluating accuracy.

$$\text{Percent Recovery} = \frac{S - C}{T} \times 100$$

where

S	=	Measured spike sample concentration
C	=	Sample concentration
T	=	True or actual concentration of the spike

Attachment A presents accuracy goals for the data gaps investigation based on the percent recovery of matrix and surrogate spikes. Results that fall outside the accuracy goals will be further evaluated on the basis of other QC samples.

1.3.2.3 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent the characteristics of a population, variations in a parameter at a sampling point, or an environmental condition that they are intended to represent. For this project, representative data will be obtained through careful selection of sampling locations and analytical parameters. Representative data will also be obtained through proper collection and handling of samples to avoid interference and minimize contamination.

Representativeness of data will also be ensured through the consistent application of established field and laboratory procedures. Field blanks (if appropriate) and laboratory blank samples will be evaluated for the presence of contaminants to aid in evaluating the representativeness of sample results. Data determined to be non-representative, by comparison with existing data, will be used only if accompanied by appropriate qualifiers and limits of uncertainty.

1.3.2.4 Completeness

Completeness is a measure of the percentage of project-specific data that are valid. Valid data are obtained when samples are collected and analyzed in accordance with QC procedures outlined in this SAP, and when none of the QC criteria that affect data usability are exceeded. When all data validation is completed, the percent completeness value will be calculated by dividing the number of useable sample results by the total number of sample results planned for this investigation.

As discussed further in Section 4.2, completeness will also be evaluated as part of the data quality assessment process (EPA 2000d). This evaluation will help determine whether any limitations are associated with the decisions to be made based on the data collected.

1.3.2.5 Comparability

Comparability expresses the confidence with which one data set can be compared with another. Comparability of data will be achieved by consistently following standard field and laboratory procedures and by using standard measurement units in reporting analytical data.

1.3.2.6 Detection and Quantitation Limits

The method detection limit (MDL) is the minimum concentration of an analyte that can be reliably distinguished from background noise for a specific analytical method. The quantitation limit represents the lowest concentration of an analyte that can be accurately and reproducibly quantified in a given sample matrix. PRRL are contractually specified maximum quantitation limits for specific analytical methods and sample matrices, such as soil or water, and are typically several times the MDL to allow for matrix effects. PRRLs, which are established by Tetra Tech in the scope of work for subcontract laboratories, are set to establish minimum criteria for laboratory performance; actual laboratory quantitation limits may be substantially lower.

For this project, standard analytical methods have been selected so that the PRRLs for target analytes are generally below the applicable regulatory screening criteria or available toxicity-based benchmark. For aqueous media (groundwater, surface water and quality control samples) the lower of the freshwater or marine chronic AWQC were used to assess PRRLs (Marshack 2000; EPA 2002); some older AWQC for metals were also selected that had been accepted with the agencies as appropriate for the site and were used during the 5-year review (Tetra Tech 2002). The lower of the effects range-low or available soil or wildlife preliminary remediation goals were used for soil (Long and Morgan 1990; Long and others 1995; Efroymson and others 1997a, 1997b).

Attachment D, Tables D-1 through D-4 compare the PRRLs for the selected standard analytical methods for aqueous and bulk media with relevant criteria or toxicological benchmarks for water and soil. These comparisons show that the selected analytical methods and associated PRRLs are generally capable of quantifying contaminants of concern at or below the applicable screening values in most cases. The specific exceptions include selected analytes; however, these exceptions have been judged acceptable for the following reasons.

In comparing the PRRLs with screening criteria or benchmarks, however, it is important to note that actual laboratory quantitation limits may be lower than PRRLs and that estimates of analyte concentrations down to MDLs can typically be provided to allow comparisons to screening levels that are below PRRLs.

- For SVOCs and pesticides, the investigation is intended as a screening-level study of groundwater and the standard methods are considered adequate to identify contaminated groundwater.

- Monitoring will use total Aroclor concentrations and will compare total concentrations to previously measured concentrations of 1.5 milligrams per kilogram (mg/kg) that indicated little or no risk; the standard methods are considered adequate for this evaluation.
- The standard methods have been used for previous investigations for metals; the newly collected data will primarily be compared with previously measured concentrations rather than to screening values, so the standard methods are considered adequate.

Samples analyzed for PCBs, VOCs, SVOCs, and metals will be reported for this project as estimated values if concentrations are less than PRRLs. This procedure is being adopted to help ensure that analytical results can effectively be compared with screening values for certain compounds where the PRRL is near or below the screening value. This procedure also will help to ensure that subsequent statistical evaluations of the data will not be biased by high-value non-detect results. It is anticipated that estimated concentrations would be used in the data analysis.

1.4 PROJECT ORGANIZATION

Table C-5 presents the responsibilities and contact information for key personnel involved in field investigation activities at the NWS SDB Concord Litigation Area. In some cases, more than one responsibility has been assigned to a person. Figure C-4 presents the organization of the project team.

1.5 SPECIAL TRAINING AND CERTIFICATION

This section outlines the training and certification required to complete the activities described in this SAP. The following sections describe the requirements for Tetra Tech and subcontractor personnel working on site.

1.5.1 Health and Safety Training

Tetra Tech personnel who work at hazardous waste project sites are required to meet the Occupational Safety and Health Administration (OSHA) training requirements defined in Title 29 *Code of Federal Regulations* (29 *CFR*) Part 1910.120(e). These requirements include: (1) 40 hours of formal off-site instruction; (2) a minimum of 3 days of actual on-site field experience under the supervision of a trained and experienced field supervisor; and (3) 8 hours of annual refresher training.

Field personnel who directly supervise employees engaged in hazardous waste operations also receive at least 8 additional hours of specialized supervisor training. The supervisor training covers Navy health and safety program requirements, training requirements, personal protective equipment (PPE) requirements, spill containment program, and health-hazard monitoring procedures and techniques. At least one member of every Tetra Tech field team will maintain

current certification in the American Red Cross "Multimedia First Aid" and "Cardiopulmonary Resuscitation (CPR) Modular," or equivalent.

Copies of Tetra Tech's health and safety training records, including course completion certifications for the initial and refresher health and safety training, specialized supervisor training, and first aid and CPR training, are maintained in project files.

Before work begins at a specific hazardous waste project site, Tetra Tech personnel are required to undergo site-specific training that thoroughly covers the following areas:

- Names of personnel and alternates responsible for health and safety at a hazardous waste project site
- Health and safety hazards present on site
- Selection of the appropriate personal protection levels
- Correct use of PPE
- Work practices to minimize risks from hazards
- Safe use of engineering controls and equipment on site
- Medical surveillance requirements, including recognition of symptoms and signs that might indicate overexposure to hazardous substances
- Contents of the basewide health and safety plan (Tetra Tech 1998)

1.5.2 Subcontractor Training

Subcontractors who work on site will certify that their employees have been trained for work on hazardous waste project sites. Training will meet OSHA requirements defined in 29 *CFR* 1910.120(e). Before work begins at the project site, subcontractors will submit copies of the training certification for each employee to Tetra Tech.

All employees of associate and professional services firms and technical services subcontractors will attend a safety briefing and complete the "Safety Meeting Sign-Off Sheet" before conducting on-site work. This briefing covers the topics described in Section 1.5.1 and is conducted by the Tetra Tech on-site health and safety coordinator or other qualified person.

Subcontractors are responsible for conducting their own safety briefings. Tetra Tech personnel may audit these briefings.

1.6 DOCUMENTS AND RECORDS

Documentation is critical for evaluating the success of any environmental data collection activity. The following sections discuss the requirements for documenting field activities and for

preparing laboratory data packages. This section also describes reports that will be generated as a result of this project.

1.6.1 Field Documentation

Complete and accurate documentation is essential to demonstrate that field measurement and sampling procedures are carried out as described in the SAP. Field personnel will use permanently bound field logbooks with sequentially numbered pages to record and document field activities. The logbook will list the contract name and number, the DO number, the site name, and the names of subcontractors, the service client, and the project manager. At a minimum, the following information will be recorded in the field logbook:

- Name and affiliation of all on-site personnel or visitors
- Weather conditions during the field activity
- Summary of daily activities and significant events
- Notes of conversations with coordinating officials
- References to other field logbooks or forms that contain specific information
- Discussions of problems encountered and their resolution
- Discussions of deviations from the SAP or other governing documents
- Description of all photographs taken

The field team will also use the various field forms included in Attachment C to record field activities.

1.6.2 Summary Data Package

The subcontracted laboratory will prepare summary data packages in accordance with the instructions provided in the EPA CLP statements of work (SOW) (EPA 1999, 2000e). The summary data package will consist of a case narrative, copies of all associated chain-of-custody forms, sample results, and quality assurance (QA) and QC summaries. The case narrative will include the following information:

- Subcontractor name, project name, DO number, project order number, sample delivery group (SDG) number, and a table that cross-references client and laboratory sample identification (ID) numbers
- Detailed documentation of all sample shipping and receiving, preparation, analytical, and quality deficiencies
- Thorough explanation of all instances of manual integration
- Copies of all associated nonconformance and corrective action forms that will describe the nature of the deficiency and the corrective action taken

- Copies of all associated sample receipt notices

Additional summary data package requirements are outlined in Table C-6. The subcontracting laboratory will provide Tetra Tech with two copies on CD of the summary data package within 21 days after it receives the last sample in the SDG.

1.6.3 Full Data Package

When a full data package is required, the laboratory and soil gas subcontractors will prepare data packages in accordance with the instructions provided in the EPA CLP SOW (EPA 1999, 2000e). Full data packages will contain all of the information from the summary data package and all associated raw data. Full data package requirements are outlined in Table C-6. Full data packages are due to Tetra Tech within 21 days after the last sample in the SDG is received. The subcontractor will deliver two copies on CD of the full data package.

1.6.4 Data Package Format

The subcontracted laboratory will provide electronic data deliverables (EDDs) for all analytical results. An automated laboratory information management system (LIMS) must be used to produce the EDDs. Manual creation of the deliverable (data entry by hand) is unacceptable. The laboratory will verify EDDs internally before they are issued. The EDDs will correspond exactly to the hard-copy data. No duplicate data will be submitted. EDDs will be delivered in a format compatible with Navy Electronic Data Deliverable. Results that should be included in all EDDs are as follows:

- Target analyte results for each sample and associated analytical methods requested on the chain-of-custody form
- Method and instrument blanks and preparation and calibration blank results reported for the SDG
- Percent recoveries for the spike compounds in the MS, MSDs, blank spikes, or LCSs
- Matrix duplicate results reported for the SDG
- All re-analysis, re-extractions, or dilutions reported for the SDG, including those associated with samples and the specified laboratory QC samples

Electronic and hard copy data must be retained for a minimum of 3 and 10 years, respectively, after final data have been submitted. The subcontractor will use an electronic storage device capable of recording data for long-term, off-line storage. Raw data will be retained on an electronic data archival system.

1.6.5 Reports Generated

Annual TERs will be prepared to present an evaluation and summary of the new data collected for RASS 1, 2, 3, and 4. The goal of the TERs is to summarize the data collected during each monitoring event and evaluate potential future actions for each site.

2.0 DATA GENERATION AND ACQUISITION

This section describes the requirements for the following:

- Sampling Process Design (Section 2.1)
- Sampling Methods (Section 2.2.)
- Sample Handling and Custody (Section 2.3)
- Analytical Methods (Section 2.4)
- Quality Control (Section 2.5)
- Equipment Testing, Inspection, and Maintenance (Section 2.6)
- Instrument Calibration and Frequency (Section 2.7)
- Inspection and Acceptance of Supplies and Consumables (Section 2.8)
- Non-direct Measurements (Section 2.9)
- Data Management (Section 2.10)

2.1 SAMPLING PROCESS DESIGN

This section describes the sampling process design for the Litigation Area monitoring plan. Each component of monitoring to be evaluated is discussed in the following sections. Soil, surface water, groundwater sampling, prey monitoring, and aerial photography are all discussed in this section.

The number of samples, sample types, analytes and sampling rationale for the monitoring plan are summarized by monitoring component in Tables C-7 and C-8. Table C-7 includes samples collected for quality control and to characterize investigation-derived waste (IDW). Proposed sample locations are shown on Figure C-3.

2.1.1 Surface Water Monitoring in the Main Reach of Lost Slough

Units 9 and 10 of the main slough will each be sampled at three locations twice annually, in the wet and dry seasons, during outgoing tides for analysis of dissolved and total metals. There will be three sampling events per season, bringing the total number of samples to 36. An attempt will be made to sample during the Pacific Flyway migration and during periods when Suisun Bay is

an active fish nursery to monitor potential impacts to endangered species. Samples will be collected for analysis of the full suite of total and dissolved metals, as well as for pH, temperature, conductivity, and TSS.

2.1.2 Groundwater Monitoring

All 23 existing monitoring wells in RASSs 1 through 4 will be sampled once, during the wet season, in the initial investigation year. Based on the 2003 analytical data and the initial sampling event in this plan, sentinel wells will be selected for annual sampling during the wet season based on the following criteria: (1) wells located near the border of the property that have the potential to measure ongoing migration from offsite sources (wells R03MG023, R01AG003, and R01MG001); (2) any wells that show an increasing trend in concentrations of metals based on two rounds of sampling (the first round being the 2003 sampling event, the second being the first sampling event conducted as part of this investigation); or (3) one or more ambient water quality criteria that have been significantly exceeded. Groundwater will be analyzed for total metals total dissolved solids and total suspended solids. Temperature, pH, and electrical conductivity will be measured in the field. The proposed analytical suite for the new wells is presented in Table C-7. Well statistics for the 23 wells are detailed in Figure C-7.

2.1.3 Deep Aquifer Groundwater Monitoring Well Installation and Sampling

Three new deep aquifer monitoring wells (R01DG024, R01DG025, and R02DG026) will be installed and sampled in the first year of monitoring. Lithology in the Litigation Area marsh at depths more than about 15 feet bgs has not been defined by the existing wells. Drilling and continuous lithologic logging will penetrate to a depth of 60 feet. Figure C-5 and Figure C-6 represent wet and dry season groundwater contour maps, respectively, of the most recently sampled wells. The new deep wells will be screened in a deep aquifer (if present). In the first year and annually after, the wells will be sampled for analysis of total metals, total dissolved solids, and total suspended solids. They will be sampled using low-flow rate sampling techniques in a sampling event conducted annually during the wet season. The wells will also be sampled for analysis of temperature, pH, and electrical conductivity using field measurements. In the first year only, these three wells will also be sampled for analysis of VOCs, SVOCs, TPHs (extractable and purgeable), PCBs, and pesticides and herbicides.

2.1.4 RASS 1 and 2 Soil Sampling

The Navy will collect samples every 5 years, the first of which will be at locations detailed in Figure C-3, to assess short- and long-term trends as well as small- and large-scale spatial changes and patterns for soils in all active and passive remediation areas that still register elevated levels of chemicals of concern. Sampling locations were selected using the rationale outlined in Section 1.2.2. As a result of agency comments, an additional location (R01SS308) was added to fill a spatial data gap near an area where elevated concentrations of metals have been measured. The new sampling location is marked on Figure C-3 for ready identification. To be consistent with previous sampling events, each sampling location was assigned a 100-foot by 100-foot grid sampled in four locations, one per 50-foot by 50-foot quadrant. Each location will be tested for total metals, pH and TOC. All samples will be collected from

the top 0.50 foot (bgs) of the soil. Figure C-3 shows the grids broken down into quadrants. Based on findings from the initial sampling, sampling locations will be selected for the next sampling round 5 years later. Sampling will focus on locations where contaminant concentrations are still exceeding ecological benchmarks.

2.1.5 BERA California Black Rail Food Chain Modeling Data Gap

Black Rail prey tissue (terrestrial invertebrate and seed) will be collected in three previously established surface soil locations and, if possible, one location will be selected for a second analysis on prey tissue to assess the variability of results. All terrestrial invertebrate and seed species will initially be identified and segregated by species in the field, but will be combined if necessary to achieve mass requirements for the analyses to be performed (whole body metals and percent moisture). The order of precedence for combining tissues will be to first combine terrestrial invertebrate tissues and seed tissues separately, and then, if necessary, to combine all tissues, for any given site. If not enough tissue is generated for all testing, tests will be eliminated in the following order, first to last: field duplicates, segregated plant and terrestrial invertebrate tests, and segregated soil site tests (that is, tissues from multiple sampling sites will be combined), and percent moisture.

2.1.6 Marsh Surface Vegetation Monitoring

A pilot study will be conducted to evaluate alternative designs and data collection methods for assessing landscape-scale changes in site conditions. The pilot study will be conducted as part of the first year sampling event and will be used to establish the design parameters for subsequent monitoring events. The Navy will evaluate the feasibility of using aerial photographs as a means to provide coarse or landscape-scale resolution of dominant vegetation types across the site (as well as changes in other surface features). Ground surveys will be used to evaluate the accuracy in identifying selected vegetation types based on features identified in the photographs. If deemed technically feasible and cost effective, this approach will create a permanent record of the relative cover of various vegetation communities (and other surface features at the site) and will allow the Navy to assess whether significant changes are occurring over time.

The Navy will also evaluate the utility of establishing a network of permanent photo points in selected areas of the site to provide better resolution of changes in vegetation and other surface features at a finer spatial scale. Existing vegetation maps, analysis of aerial photographs, and results of previous wildlife studies will be used to define candidate areas for establishing permanent photo points.

Landscape-scale changes in site conditions will be assessed every 3 years.

2.2 SAMPLING METHODS

This section describes the procedures for sample collection, including sampling methods and equipment, monitoring well installation, lithologic logging, sample preservation requirements, decontamination procedures, and management of IDW.

2.2.1 Sampling Methods and Equipment

Sampling methods and equipment are described in this section as follows:

- Collection of surface water samples (Section 2.2.1.1)
- Deep aquifer groundwater well installation and development (Sections 2.2.1.2)
- Monitoring well borehole lithologic logging (Section 2.2.1.3)
- Groundwater sampling techniques (Section 2.2.1.4)
- Collection of surface soil samples (Section 2.2.1.5)
- Prey tissue collection (Section 2.2.1.6)
- Aerial photography (Section 2.2.1.7)

2.2.1.1 Collection of Surface Water Samples

Surface water will be collected at the locations shown on Figure C-3. They will be collected after high tide and before low tide to ensure that they are representative of surface water flowing out of, rather than into, the slough. Surface water will be collected from the center of the slough, adjacent to the reference stake. The locations will be sampled in order from downstream to upstream, to prevent sediment disturbed at one location from affecting sampling at an adjacent sampling location.

The following procedures will be used at each surface water sampling location:

- A pre-cleaned sample container will be filled by dipping the container into the surface water.
- Unrepresentative material (such as floating organic material) will be removed when practical.
- For unfiltered samples, surface water will be transferred to a new water sample container that is pre-preserved with nitric acid to ensure a pH of less than 2.
- For filtered samples, surface water samples will be filtered in the field using disposable, 0.45 micron filter units (such as Nalgene filters). The filtered samples will then be transferred from the filter unit to a new water sample container that is pre-preserved with nitric acid to ensure a pH of less than 2.

- The outside of the sample containers will be cleaned with a paper towel, then the containers will be capped and labeled.
- The sample collection will be documented in a field logbook and a chain-of-custody record.

2.2.1.2 Deep Aquifer Groundwater Monitoring Well Installation and Development

Three new deep aquifer groundwater monitoring wells will be installed on Navy property. Well locations were chosen based on the limited existing data on groundwater flow from the wells screened in a deep aquifer at Honeywell (PZ-3B, PZ-6B, and PZ-8B). Water levels from three dry season water level surveys show that groundwater flowed northeast, more or less directly toward the shoreline of Suisun Bay during the dry season. Water levels from the single wet season water level survey showed that groundwater flowed to the northwest, subparallel to the shoreline. Based on these flow directions, two wells (R01DG024 and R01DG025) will be installed along the berm that separates Navy and Honeywell property and one well (R02DG026) will be installed at the southern end of the Litigation Area. Locations of the wells are shown on Figure C-3. All three of the wells will be installed adjacent to existing shallow monitoring wells to allow evaluation of vertical hydraulic gradients.

The wells will be installed according to the procedures specified in Tetra Tech Standard Operating Procedure (SOP) 20, Revision No. 3, "Monitoring Well Installation" (Attachment B). A brief description of the procedure for monitoring well installation is outlined in the following text.

The monitoring well boring will be installed with 8-1/4-inch, steel, hollow-stem augers. Split-spoon samples for lithologic logging will be collected continuously from the surface to the total depth of the boring, and a detailed lithologic log of each boring will be prepared by the field geologist. (General procedures for lithologic logging are described in Section 2.2.1.4.) The well will be constructed of 2-inch-diameter, schedule-40 polyvinyl chloride (PVC) pipe. The well screen will be 10-feet long, 2-inch-diameter, schedule 40 PVC with 0.010-inch slot-size to allow suitable recharge in low-permeability formations and to allow seasonal water table fluctuations. Existing information from the deep wells at Honeywell indicates that a deeper aquifer is present at 40 to 50 feet bgs. The new wells will be screened across the top of this deeper aquifer. A shorter, 5-foot long well screen may be used if a thin (2 to 5 feet thick) seam of sand is identified during borehole lithologic logging. The filter pack will consist of coarsely graded sand that will be installed by pouring from the surface through the interval from 1 foot below to 1 foot above the well screen. The sand will be poured slowly, and the level of the sand will be periodically tested with a weighted steel tape to prevent bridging. A 2-foot-thick impermeable seal consisting of bentonite pellets will be installed at the top of the filter pack, and the annular space from the top of the bentonite seal to the surface will be filled with cement-bentonite grout, emplaced with a tremmie pipe from the bottom of the open annular space to the surface. The monitoring well's surface completion will consist of a concrete pad with a steel outer protective casing that rises approximately 2 feet above grade to protect the PVC well casing. The well will be secured with a padlock.

Well development is an integral step of monitoring well installation to remove the finer-grained material — clay and silt — from the geologic formation near the well screen and filter pack.

After construction, each monitoring well will be developed to maximize yield and minimize the turbidity of the water. The new monitoring wells will be developed using the mechanical surging technique specified in Tetra Tech SOP 21, "Monitoring Well Development" (Attachment B). This mechanical surging technique is briefly described in the following text.

Wells will be developed with a surge block and pump technique until the wells yield clear water that is free of turbidity and suspended solids, or until in the opinion of Tetra Tech's field geologist, further development will not significantly improve the clarity of the water.

The well will be swabbed progressively from top to bottom with a surge block a minimum of three times to agitate sediment within the casing, remove fines from the sand pack, and seat the sand pack firmly in place. Each time the well is swabbed the surge block will be gently raised and lowered inside the casing below the water table for a minimum of 10 minutes or 40 strokes. This action will create flow reversals through the screen slots and agitate the fine-grained materials within the well and the sand pack. After surging has been completed, at least three well volumes of groundwater will be bailed or pumped (when possible) from the well to remove the fines that were agitated into suspension during surging and to ensure that groundwater entering the well will be representative of groundwater in the aquifer. The bailed water will be monitored with a water quality meter for physical parameters, including temperature, conductivity, pH, turbidity, and dissolved oxygen.

If the lithologic logging indicates that an interval of 5 or more feet of aquifer material (material that is composed primarily of sand or gravel) is present beneath the water table aquifer, and is separated from the water table aquifer by at least 3 feet of low-permeability material (material composed primarily of clay, silt, or silt/clay mixtures), then the well will be installed with a 5-foot screen across the top of the deeper aquifer. If a deeper aquifer that meets the above conditions is not present, no monitoring well will be installed, and the entire boring will be pressure-grouted from the bottom of the boring to the surface with cement-bentonite grout emplaced with a tremmie pipe that extends to the bottom.

Purged well water will be collected on site in 55-gallon drums and managed as investigation-derived waste according to the procedures described in Section 2.2.3.

2.2.1.3 Monitoring Well Borehole Lithologic Logging

Lithology observed during drilling of all wells will be described by the field geologist according to American Society for Testing and Materials (ASTM) Standard D 2488-90, which is based on the Unified Soil Classification System (USCS). The following information, as appropriate, will be recorded on a standard boring log form (Attachment C) at each change in lithology observed or at least every 5 feet:

- Well designation
- Well location
- Drilling and sampling methods used

- Dates and times drilling was started and completed
- Names of field geologist and driller
- Depth at which groundwater was first encountered
- Sampling depth
- Blow counts, if appropriate
- Sample description, including sample color, texture, lithology, USCS classification
- Variations in drilling rates and rig behavior
- Signature of observer

2.2.1.4 Groundwater Sampling Techniques

As described in Section 2.1.3, one initial round of groundwater samples will be collected to measure total metals, TSS, and pH in 23 existing Litigation Area wells and the three new deep aquifer wells. The new deep wells will be sampled for hexavalent chromium, VOCs, SVOCs, PCBs, pesticides, herbicides, TPH-e and TPH-p.

Low flow-rate purging techniques will be used, where technically feasible, to obtain groundwater samples from wells. Low flow-rate purging will be considered technically infeasible if the drawdown does not stabilize at a discharge rate of 0.1 liter per minute or higher. A principal objective of low flow rate purging is to avoid entraining silt- and clay-sized particles in groundwater samples by purging wells at low velocities. Low flow-rate purging is intended to establish direct flow from the aquifer to the sample container at velocities and flow conditions comparable to in situ flow velocities. By using low flow rate purging techniques, the sampling process more closely matches natural groundwater flow conditions and transport of suspended solids, and analytical problems and uncertainties caused by turbidity are reduced. Low flow-rate purging and sampling will be accomplished using dedicated bladder pumps for all wells to be sampled for VOCs and for wells that cannot be sampled with peristaltic pumps because of depths to water greater than 25 feet bgs. Wells that will not be sampled for VOCs and with depths to water of less than 25 feet bgs will be sampled using peristaltic pumps. Based on water levels measured in November 1996 and 2003, water levels in wells 3MG06, 3MG13, 3MG14, 3MG23, and 4MG15 are expected be more than 25 feet bgs, and dedicated bladder pumps will be installed in these wells. The field procedure for low flow-rate sampling techniques is described as follows:

1. The breathing zone will be monitored with a photoionization detector when each well cap is removed, and the reading will be compared with the background reading for the site to select the appropriate level of personal protection.
2. The depth to water will be measured with an electric-sounder water level meter to determine the equilibrium water level.

3. For wells to be sampled using peristaltic pumps, a weighted Tygon or polyethylene tube will be gently lowered into the well to a depth of 3.5 feet below the equilibrium water level or 2 feet below the top of the well screen (whichever is greater) and secured to the outer well casing with tape or plastic ties.

4. Well purging will be initiated slowly and increased gradually to a rate of approximately 0.15 liter per minute (L/min). Purge water stabilization parameters, including pH, temperature, electrical conductivity, dissolved oxygen, and turbidity, will be measured at intervals of a minimum of 1 liter (L) and will be recorded on well sampling sheets or in field notebooks. Purge water will be discharged into a container of known volume, and the volume of water purged will be measured and recorded on well sampling sheets. If the drawdown of the water level is 0.3 foot or greater at a pumping rate of 0.1 L/min, the modified low flow-rate sampling procedure described in number 5 below will be initiated. If the water level drawdown is less than 0.3 foot at that pumping rate and the water level is stable, the rate will be increased to the maximum at which a static water level is obtained (up to 0.25 L/min), the well will be allowed to stabilize, and samples will be collected.

5. The low permeability of the geologic materials in the Litigation Area may not allow a discharge rate of 0.1 L/min without continuing drawdown, requiring a modified low flow-rate sampling procedure to stimulate recharge. When drawdown is more than 0.33 foot at a discharge rate of 0.1 L/min, the following modified low-flow rate sampling technique will be attempted: The pump rate will be increased to a maximum of 1 L/min, and the water level will be drawn down to 1.5 to 3 feet from the equilibrium water level. The pumping rate will then be adjusted within the range of 0.1 to 0.25 L/min until the water level in the well is stable and the recharge rate matches the discharge rate. If the water level continues to decrease at a pumping rate of 0.1 L/min, low-flow rate purging will be considered technically unfeasible, and the well will be purged by the alternative technique described in the following text.

6. The purge water will be considered stabilized after a minimum of eight measurements (8 L purged) have been collected and three successive measurements of each of the stabilization parameters that fall within the following ranges:

   - pH: ± 0.1 pH unit
   - Electrical conductivity: ± 3 percent
   - Temperature: ± 0.5 °C
   - Dissolved oxygen: ± 0.2 milligrams per liter
   - Turbidity: ± 15 percent relative percent difference or three successive measurements of less than 15 nephelometric turbidity units

7. Well stabilization parameters will be expected to asymptotically approach a constant value as the purge water begins to stabilize. If well stabilization parameters are within the ranges specified previously, but still appear to be approaching an asymptotic value, well purging will be continued until the purge water appears to be at equilibrium or until a maximum of 20 L has been purged from the well.

Alternative Purging Technique: The 1996 sampling event showed that recharge was inadequate in about half of the wells in the marsh at the Litigation Area and was unable to support the minimum purging rate of 100 milliliters per minute recommended by Puls and Powell (1992). In cases where low flow-rate purging is technically infeasible because of low recharge rates, the well will be pumped dry and allowed to recharge overnight. For wells to be sampled using peristaltic pumps, a weighted Tygon or polyethylene tube will be gently lowered into the well to a depth of 3.5 feet below the equilibrium water level or 2 feet below the top of the well screen (whichever is greater) and secured to the outer well casing with tape or plastic ties. The well will be sampled at a pumping rate of 0.15 L/min using peristaltic pumps or dedicated bladder pumps after the well has recovered to within 80 percent of the initial water level, but not later than 24 hours the well was purged. Well stabilization parameters will be measured as described in Step 6 above and recorded on well sampling sheets or in field notebooks. Purged water will be placed in 55-gallon drums at the IDW area until the water is transported off site for disposal.

Groundwater samples from the initial sampling of each deep aquifer well will be analyzed for metals, VOCs, SVOCs, chlorinated herbicides, pesticides, PCBs, TPH-e and TPH-p, TSS, and TDS. Thereafter, wells will be sampled for analysis of metals, TDS, and TSS only, unless organic contaminants are detected at concentrations of concern, as determined in consultation with the regulatory agencies. The following procedures will be followed in collecting groundwater samples from monitoring wells and piezometers after purging has been completed:

1. Measuring and sampling equipment will be decontaminated before samples are collected from each location.
2. During sampling, well purging equipment will be positioned so that potential sources of VOCs, such as vehicles, gasoline engines, or fuel tanks, are downwind of the location of the well or piezometer.
3. Samples for metals, TSS and pH will be collected directly from the discharge of the pump. The 40-milliliter (mL) vials for analyses for VOCs (three for each analysis) will be filled first. After the bottle has been sealed with a Teflon-lined cap, the bottle will be inverted and tapped lightly to check for air bubbles. No air-filled headspace is allowed in the bottles. The bottles for analysis for metals and TSS will be filled next. Bottles for analysis of SVOCs, pesticides, herbicides, TSS, and TDS will be filled last.
4. Groundwater samples collected for analysis of metals will not be filtered in the field.

Tables C-7 and C-8 present the proposed identification numbers for groundwater samples, depth of samples, and the rationale for each sampling location.

Reusable measuring and sampling equipment will be decontaminated before sampling collection begins and in between each well to prevent cross-contamination. All non-disposable groundwater sampling equipment will be decontaminated in accordance with the procedures specified in Tetra Tech SOP 002, Revision No. 2, “General Equipment Decontamination,” as applicable (Attachment B). Electric-sounder water level meters used during groundwater sampling will be decontaminated before each use by washing the probe and the portion of the

cable directly above the probe with distilled water and wiping the parts clean with a disposable paper towel.

The required volumes of groundwater will be placed in appropriate sample containers for shipment to the laboratory. Purged water will be placed in 55-gallon drums at a designated on-site IDW area until the water is transported off site for disposal.

2.2.1.5 Collection of Surface Soil Samples

Surface soil (0 to 0.5 feet bgs) will be collected at the locations shown on Figure C-3. Sample locations, rationale, and analyses are located in Tables C-7 and C-8. For the new sampling location, the 100-foot by 100-foot grid will initially be surveyed in the field. The northeastern corner of the grid will be marked with a 4-foot T-bar (metal) to help identify the sampling location in the future. The T-bar will be placed in the northwestern, southeastern, or southwestern corner if it is not possible to place the T-bar in the northeastern corner (because of excessive water or other obstruction).

Equipment used to collect these samples may include a combination of hand auger, shovel, trowels, and stainless steel spoons. Stainless steel trowels and spoons will be used to collect soil samples from 0 to 0.5 feet bgs. Clean trowels will be used to excavate surface soil samples and place them in a clean stainless steel bowl for homogenization and then into the sampler container. Table C-9 lists the appropriate sample containers for the project analyses.

Soil sample borings will be back-filled with soil from the sampling location.

All hand augers, trowels, spoons and other re-usable equipment that may come in contact with soil samples will be decontaminated before its first use and in between collection of discrete soil samples. The decontamination procedures described in Section 2.2.2 will be followed. In general, equipment decontamination will follow these four steps: (1) scrubbing with a nylon-bristle brush and with laboratory-grade nonphosphate detergent, (2) rinsing with tap water, (3) rinsing with deionized water, and (4) air drying and wrapping in clean plastic.

2.2.1.6 Prey Tissue Collection

As much tissue as possible will be gathered within the 100-foot x 100-foot grids of each sampling location.

Plant tissue (seeds only) will be gathered using plastic tarps and secateurs. In most cases, target plants (*Scirpus* spp. and *Typha* spp.) will be identified using a field guide and tarps will be laid down at the foot of a plant stand, if possible. Plant seeds will be gathered by hand (using thin work gloves), and seeds that fall will be gathered from the tarp. Seeds will then be weighed on a field scale and placed in plastic ziplock bags. It may be necessary to cut off entire seed-bearing sections of the plants, in which case secateurs will be used. Plant tissue will be rinsed in the laboratory before it is analyzed. If the seeds are extremely dirty in the field, and a marginal

amount of tissue is being recovered (close to 10 grams only), then seeds should be washed in the field to prevent inaccurate weight measurement.

Terrestrial invertebrates (any insect, arthropod or arachnid) will be caught by net or by hand (with gloves) or forceps, identified with a field manual, and segregated, by order, into separate ziplock bags. The invertebrates will then be weighed (the total mass of each order will be recorded in the field notes) and combined into single samples if needed to achieve the minimum sample weight of 70 grams.

2.2.1.7 Aerial Photography

Aerial photography will be used to document the condition of the site as well as to characterize vegetation at the Litigation Area. Individual color and infrared aerial photographs of the Litigation Area at a scale of 1 inch to 200 feet will be taken using a cartographic camera calibrated by the U.S. Geological Survey. The photographs will be taken during an extremely low tide. To account for sun angle, the aerial photography will be completed as close as possible to the midday high sun, to avoid possible shadowing effects.

2.2.2 Decontamination

Drilling equipment, including drill rods, augers, split spoon samplers, and the back end of the drill rig, will be steam cleaned before the deep aquifer monitoring well boring begins at RASS 1 and 2. Hand augers, shovels, trowels, water level meters, and any other equipment that may come in contact with sample media will be decontaminated following the practices listed in Tetra Tech SOP 002 "General Equipment Decontamination" (Attachment B). Nondisposable sampling equipment will be decontaminated before and after each soil sample is collected for analysis. All water derived from decontamination will be collected and temporarily stored on site for characterization as IDW.

2.2.3 Management of Investigation-Derived Waste

IDW will include soil cuttings, purged groundwater, and wastewater from decontamination procedures and collection of equipment rinsate samples. Water and soil IDW will be segregated and stored in U.S. Department of Transportation-approved 55-gallon drums at a designated IDW storage area within the Litigation Area. The lids of the drums will be kept closed and secured at all times when the drums are not in use.

The 55-gallon IDW drums will be labeled with a "pending analysis" sticker that identifies the date of IDW collection, the sampling locations, the sampling personnel, and the waste media. This information will also be recorded in the project logbook.

Environmental samples will provide data that can be used to characterize waste collected during the investigation. Representative samples from the IDW drums, however, may also be collected if they are needed to characterize the waste to identify the most cost-effective disposal methods. One composite soil IDW sample will be analyzed for metals. One composite water IDW sample

will be analyzed for total metals, SVOCs, VOCs, pesticides, herbicides, and PCBs. IDW will be transported off site for disposal at a licensed facility, in accordance with appropriate federal and state regulations and as the results of its analysis indicate is appropriate.

2.2.4 Sample Containers and Holding Times

The type of sample containers to be used for each analysis, the sample volumes required, the preservation requirements, and the maximum holding times for sample extraction and analysis are presented in Table C-9.

2.3 SAMPLE HANDLING AND CUSTODY

The following sections describe sample-handling procedures, including sample identification and labeling, documentation, chain-of-custody, and shipping.

2.3.1 Location and Sample Identification

Location and sample identification (sample ID) systems were developed for the monitoring plan to provide methods for tracking each sample through the collection, analysis, validation, and data reduction processes. These two systems were developed to efficiently identify sample locations and analytical results, as well as to provide a means of submitting blind samples to the laboratory.

Samples submitted to the laboratory will be assigned unique identifiers based on a consecutive alphanumeric code. Each sample station will have a unique field identification number that will facilitate the reporting of information about a specific site or sample. The sample ID numbering system is designed to be compatible with a computerized data management system that includes previous results for samples collected at NWS SBD Concord. The two identification systems, which are described in the following sections, are consistent with the identification systems used at the Litigation Area during the post-remediation monitoring program and the 5-year monitoring program.

2.3.2 Location Identification System

This section describes the location identification system for soil, surface water, monitoring well groundwater, and tissue collection sample locations.

2.3.2.1 Soil, Groundwater, Surface Water and Tissue Collection Location Identification

An 8-character identifier denotes sampling locations as follows:

- The first three characters of the identifier indicate the sampling area:
  - R01 for RASS 1
  - R02 for RASS 2

  - R03 for RASS 3

- The next two characters indicate the type of sampling location:
  - SS for soil (locations that are also being sampled for tissue use the collocated soil location identification and are highlighted in yellow on the map)
  - AG (active remediation area groundwater), MG (monitoring area groundwater), PG (passive remediation area groundwater, or DG (deep groundwater aquifer) for groundwater
  - SH for surface water

- The last three characters consist of the sample location number. Each of the sample locations for RASSs 1, 2, 3 and 4 has been assigned a unique number during post remediation, data gap, and monitoring plan sampling. The sample locations are generally numbered consecutively from west to east, starting from the north westernmost location of the Litigation Area to the southeastern most. Soil and surface water locations are numbered in a separate sequence than groundwater locations.

For example, the location R01SS300 indicates a soil sample location in RASS 1, which is the three hundredth consecutively numbered soil or surface water sampling location in RASSs 1, 2, 3, and 4. The location R02MG020 indicates a groundwater location in RASS 2, which is the twentieth consecutively numbered groundwater well and sampling location in RASSs 1, 2, 3, and 4.

2.3.3 Sample Identification System

The sample ID system used for the remediation monitoring program and data gap evaluation will be employed in this monitoring program, with the exception of soil samples. The sample ID is an 11-character identifier (or a 12-character identifier for soil samples) and coordinates the individual sample with the sampling location, depth, and type. The sample ID, which differs from the sample location identifier, was developed to ensure that samples are sent blind to the laboratory. The 11- or 12-character identifier will be 105-WWW-XX-YYY(-Z), where:

- The first three characters indicate the DO number

- The next three characters (WWW) indicate the sampling area:
  - R01 for RASS 1
  - R02 for RASS 2
  - R03 for RASS 3
  - R04 for RASS 4

- The next two characters (XX) indicate the sample type:
  - SS for soil
  - SW for surface water
  - GW for monitoring well groundwater

  - PL for plant tissue
  - IS for insect tissue

- The next three characters (YYY) are the consecutive sample number, based on the medium sampled. Five types of media will be sampled: soil, surface water, monitoring well groundwater, plant prey tissue, and insect prey tissue. All soil sample types will be numbered consecutively among themselves. Numbers have been assigned to ensure that numbers used in previous sampling events are not repeated in the database.

- The last character (Z) will only be used for soil samples and will indicate the sample quadrant:
  - A for the northwest quadrant
  - B for the northeast quadrant
  - C for the southwest quadrant
  - D for the southeast quadrant

A sample description will be included on each page of the chain-of-custody form, except for the laboratory copy, and will include the sample ID as described above and, if necessary, a descriptive note in parentheses, as in the following examples:

- (0-6″) Denotes top and bottom depth of sample in inches
- (Dup) Denotes duplicate sample
- (Filt) Denotes filtered water sample
- (Rinse) Denotes equipment rinsate blank
- (Source) Denotes decontamination water source blank

2.3.4 Sample Labels

A sample label will be affixed to all sample containers. The label will be completed with the following information, written in indelible ink:

- Project name and location
- Sample ID number
- Date and time of sample collection
- Preservative used
- Sample collector's initials
- Analysis required

After each sample is labeled, it will be refrigerated or placed in a cooler that contains ice to maintain the sample temperature at or below 4 degrees Celsius (ºC), plus or minus 2 ºC.

2.3.5 Sample Documentation

Documentation during sampling is essential to ensure proper sample identification. Field personnel will adhere to the following general guidelines for maintaining field documentation:

- Documentation will be completed in permanent black ink
- All entries will be legible
- Errors will be corrected by crossing out with a single line and then dating and initialing the lineout
- Any serialized documents will be maintained at Tetra Tech and referenced in the site logbook
- Unused portions of pages will be crossed out, and each page will be signed and dated

Section 1.6.1 includes additional information on how Tetra Tech will use logbooks to document field activities. The Tetra Tech field team leader (FTL) is responsible for ensuring that sampling activities are properly documented.

2.3.6 Chain-of-Custody

Field personnel will use standard sample custody procedures to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample will be considered to be in custody if one of the following statements applies:

- It is in a person's physical possession or view.
- It is in a secure area with restricted access.
- It is placed in a container and secured with an official seal such that the sample cannot be reached without breaking the seal.

Chain-of-custody procedures provide an accurate written record that traces the possession of individual samples from the time they are collected in the field to the time they are accepted at the laboratory. The chain-of-custody form (see Attachment C) will be used to document all samples collected and the analysis requested for each sample. Field personnel will record the following information on the chain-of-custody form:

- Project name and number
- Sampling location
- Name and signature of sampler

- Destination of samples (laboratory name)
- Sample ID number
- Date and time of collection
- Number and type of containers filled
- Analysis requested
- Preservatives used (if applicable)
- Filtering (if applicable)
- Sample designation (grab or composite)
- Signatures of individuals involved in custody transfer, including the date and time of transfer
- Air bill number (if applicable)
- Project contact and phone number

Unused lines on the chain-of-custody record will be crossed out. Field personnel will sign chain-of-custody records that are initiated in the field, and the air bill number will be recorded. The form will be placed in a waterproof plastic bag and taped to the inside of the shipping container used to transport the samples. Signed air bills will serve as evidence of custody transfer between field personnel and the courier as well as between the courier and the laboratory. Copies of the chain-of-custody form and the air bill will be retained and filed by field personnel before the containers are shipped.

Laboratory chain of custody begins when samples are received and continues until samples are discarded. Laboratories analyzing samples on this Navy contract must follow custody procedures at least as stringent as are required by the EPA CLP SOWs (EPA 2000d). The laboratory should designate a specific individual as the sample custodian. The custodian will receive all incoming samples, sign the accompanying custody forms, and retain copies of the forms as permanent records. The laboratory sample custodian will record all pertinent information concerning the samples, including the persons delivering the samples, the date and time received, the sample condition at the time of receipt (sealed, unsealed, or broken container; temperature; or other relevant remarks), the sample identification numbers, and any unique laboratory identification numbers for the samples. This information should be entered into a computerized LIMS. When the sample transfer process is complete, the custodian is responsible for maintaining internal logbooks, tracking reports, and other records necessary to maintain custody throughout sample preparation and analysis.

The laboratory will provide a secure storage area for all samples. Access to this area will be restricted to authorized personnel. The custodian will ensure that samples requiring special handling, including samples that are heat- or light-sensitive, radioactive, or have other unusual physical characteristics, will be properly stored and maintained prior to analysis.

2.3.7 Sample Shipment

The following procedures will be implemented when samples collected during this project are shipped to the fixed laboratory:

- The cooler will be filled with bubble wrap, sample bottles, and packing material. Sufficient packing material will be used to prevent sample containers from breaking during shipment. Enough ice will be added to maintain the sample temperature at or below 4 °C, plus or minus 2 °C.
- The chain-of-custody forms will be placed inside a plastic bag. The bag will be sealed and taped to the inside of the cooler lid. The air bill, if required, will be filled out before the samples are handed over to the carrier. The laboratory will be notified if the sampler suspects that the sample contains any substance that would require laboratory personnel to take safety precautions.
- The cooler will be closed and taped shut with nylon-reinforced tape around both ends. If the cooler has a drain, it will be taped shut both inside and outside of the cooler.
- Signed and dated custody seals will be placed on the front and side of each cooler. Wide clear tape will be placed over the seals to prevent accidental breakage.
- The chain-of-custody form will be transported within the taped, sealed cooler. When the cooler is received at the analytical laboratory, laboratory personnel will open the cooler and sign the chain-of-custody record to document transfer of samples.

Multiple coolers may be sent in one shipment to the laboratory. The outside of the coolers will be marked to indicate the number of coolers in the shipment.

2.4 ANALYTICAL METHODS

Table C-9 presents the analytical methods that will be used to analyze samples collected during this investigation, and Attachment A presents the project QA objectives and control limits for the analytical suite established as part of the DQO process (Section 1.3). Table D-1 in Attachment D presents the individual target analytes required for this investigation and their associated PRRLs. The analytical laboratories will attempt to achieve the PRRLs for all the investigative samples collected. If problems occur in achieving the PRRLs, the laboratories will contact the Tetra Tech analytical coordinator immediately and other alternatives will be pursued (such as analyzing an undiluted aliquot and allowing nontarget compound peaks to go off-scale) to achieve acceptable reporting limits. In addition, results below the reporting limit but above the MDL will be reported to a concentration of one-half of the PRRL with appropriate flags to indicate the greater uncertainty associated with these values.

The analytical methods required for this investigation include EPA SW-846 methods (EPA 1996). Protocols for laboratory selection and for ensuring laboratory compliance with project analytical

and quality assurance and quality control (QA/QC) requirements are presented in the following subsections.

2.4.1 Selection of Fixed Laboratories

Fixed laboratories for this investigation will be selected from a list of prequalified laboratories developed by Tetra Tech to support the Navy contract. Prequalification streamlines laboratory selection by reducing the need to compile and review detailed bid and qualification packages for each individual investigation. Prequalification also improves program flexibility by allowing analyses to be directed to a number of different capable laboratories with available capacity at the time samples are collected.

Tetra Tech's laboratory prequalification and selection process relies on (1) a standard procedure to evaluate and prequalify laboratories for work under the contract, and (2) the "Tetra Tech EM Inc. Laboratory Analytical Statement of Work" for the Navy contract (Tetra Tech 2002), a contractual document that specifies standard requirements for analyses that are routinely conducted. Tetra Tech establishes a basic ordering agreement, incorporating and enforcing the laboratory SOW, with each prequalified laboratory. Individual purchase orders can then be written for specific investigations. These aspects of laboratory selection are further described in the following subsections, along with Tetra Tech's procedures for selecting laboratories when project-specific analytical methods or QC requirements are not specifically addressed by the laboratory SOW.

2.4.1.1 Laboratory Evaluation and Prequalification

Laboratories that support the Navy either directly or through subcontracts are evaluated and approved for Navy use by the Naval Facilities Engineering Service Center (NFESC). Laboratories that support Tetra Tech under Navy contracts have been selected from the list of laboratories approved by NFESC and evaluated by Tetra Tech to assure that the laboratory can meet the technical requirements of the laboratory SOW and produce data of acceptable quality. The evaluation of the laboratories is conducted in accordance with the NFESC *Installation Restoration Chemical Data Quality Manual* (IRCDQM) (NFESC 1999). The laboratory evaluation includes the following elements:

- **Certification and Approval.** Laboratories must be currently certified by the California Department of Health Services (DHS) Environmental Laboratory Accreditation Program (ELAP) for analysis of hazardous materials for each method specified. Laboratories must also have or obtain similar approval from NFESC. The California DHS ELAP certification and NFESC approval must be obtained before the laboratory begins work.

- **Performance Evaluation (PE) Samples.** Each laboratory must initially and yearly demonstrate its ability to satisfactorily analyze single-blind PE samples for all analytical services it will provide under Navy contract. At its discretion, Tetra Tech may submit one or more double-blind PE samples at Tetra Tech's cost. When the results for the PE sample are deficient, the laboratory must correct any problems and analyze (at its own cost) a subsequent round of PE samples for the deficient analysis.

- **Audits.** Laboratories must initially and yearly demonstrate their qualifications by submitting to one or more audits by Tetra Tech. The audits may consist of (1) an on-site review of laboratory facilities, personnel, documentation, and procedures, or (2) an off-site review of hardcopy and electronic deliverables, or magnetic tapes. When deficiencies are identified, the laboratory must correct the problem and provide Tetra Tech with a written summary of the corrective action that was taken.

Attachment E provides a current list of subcontractor laboratories that have passed this evaluation program. Each laboratory was evaluated before it was added to the list, and each is reevaluated annually. If a laboratory fails to meet any of the evaluation criteria, it is removed from the list of approved laboratories.

2.4.1.2 Tetra Tech Laboratory Statement of Work

The laboratory SOW establishes standard requirements for the analytical methods that are most commonly used under Navy contracts. For each method, the laboratory SOW specifies standard method-specific target analyte lists and PRRLs; QC samples and associated control limits; calibration requirements; and miscellaneous method performance requirements. The laboratory SOW also specifies standard data package requirements, EDD formats, data qualifiers, and delivery schedules. In addition, the laboratory SOW outlines support services (such as providing sample containers, trip blanks, sample coolers, and custody forms and seals) that are expected of laboratories. The laboratory SOW incorporates Navy QA policy, as well as applicable EPA and state QA guidelines, as appropriate.

Tetra Tech's laboratory SOW is based on EPA CLP methods for VOC, SVOC, pesticides, PCBs, metals, and cyanide. The laboratory SOW also addresses frequently used non-CLP methods for a variety of organic, inorganic, and physical parameters. Non-CLP methods include EPA SW-846 methods; EPA "Methods for Chemical Analysis of Water and Waste"; ASTM methods; and "Standard Methods for the Examination of Water and Waste Water" published by the American Public Health Association, American Water Works Association, and Water Pollution Control Federation. Laboratories on Tetra Tech's prequalified list can elect to provide all or a portion of the analytical services specified in the laboratory SOW.

As noted above, the laboratory SOW is incorporated into all laboratory subcontracts established for analytical services under Navy contracts. Thus, the prequalified laboratories commit to meeting laboratory SOW requirements during the contracting process before they receive samples. Tetra Tech reviews and revises the laboratory SOW regularly to incorporate new

methods and requirements, modifications or updates to existing methods, changes in Navy QA policy or regulatory requirements, and any other necessary corrections or revisions.

2.4.1.3 Laboratory Selection and Oversight

Once project-specific analytical and QA/QC requirements are identified and documented in the SAP, the Tetra Tech analytical coordinator works closely with a Tetra Tech procurement specialist to select a laboratory that can meet these requirements. When project-specific analytical and QC requirements are consistent with Tetra Tech's laboratory SOW, the analytical coordinator identifies one or more prequalified subcontractor laboratories that are capable of performing the work. As part of this process, the analytical coordinator typically contacts the laboratories to discuss the analytical requirements and project schedule. The analytical coordinator then forwards the name of the recommended laboratory (or laboratories) to the Tetra Tech procurement specialist, who issues a purchase order for the work. When analytical requirements are consistent with Tetra Tech's laboratory SOW and multiple prequalified laboratories are capable of performing the work, a specific laboratory is typically selected based on laboratory workload and project schedule considerations.

Tetra Tech follows a similar procedure when project-specific analytical and QC requirements are nonstandard and differ from those specified in Tetra Tech's laboratory SOW. The analytical coordinator contacts analytical laboratories, beginning with those on Tetra Tech's prequalified list, to discuss the analytical and QA/QC requirements in the SAP and to assess the laboratories' ability to meet the requirements. In many cases, Tetra Tech works cooperatively with analytical laboratories to develop and refine appropriate QC requirements for nonstandard analyses or matrixes.

If the analytical coordinator is unable to identify one or more prequalified laboratories that can perform the work, additional laboratories are contacted. In general, the additional laboratories must be evaluated as described in Section 2.4.1.1 before they will be allowed to analyze any samples, although some evaluation steps may be waived for certain investigations and circumstances (for example, unusual analytes, urgent project needs, experimental methods, mobile laboratories, or on-site screening analysis). After additional laboratories have been identified, the analytical coordinator forwards their names to the procurement specialist. The procurement specialist prepares a solicitation package, including the project-specific analytical and QC requirements, and submits the package to the laboratories. The procurement specialist, in cooperation with the analytical coordinator and project manager, then evaluates the proposals that are received and selects a laboratory that meets the requirements and provides the best value to Tetra Tech and the Navy. Finally, the procurement specialist issues a purchase order to the selected laboratory that incorporates the project-specific analytical and QA/QC requirements.

After a laboratory has been selected, the analytical coordinator holds a kickoff meeting with the laboratory project manager. The kickoff meeting is held regardless of whether project-specific analytical and QA/QC requirements are consistent with Tetra Tech's laboratory SOW or are outside the SOW. The Tetra Tech project manager, procurement specialist, and other key project and laboratory staff may also be involved in this meeting. The kickoff meeting includes a review

of analytical and QC requirements in the SAP, the project schedule, and any other logistical support that the laboratory will be expected to provide.

2.4.2 Project Analytical Requirements

For this investigation, one or more pre-qualified subcontractor laboratories will analyze samples of soil and water off site. The laboratories will be selected before the field program begins based on their ability to meet the project analytical and QC requirements as well as their ability to meet the project schedule. The analytical methods selected for the long-term monitoring of the Litigation Area at NWS SBD Concord are standard EPA methods that are described in Tetra Tech's laboratory SOW. All methods are listed in Table C-9 and are from EPA's SW-846 "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, Update III" (EPA 1996).

This SAP documents project-specific QC requirements for the selected analytical methods. Sample volume, preservation, and holding time requirements are specified in Table C-9. Requirements for laboratory QC samples are described in Table C-4 and in Section 2.5. Attachment A includes project-specific precision and accuracy goals for the methods. Finally, project-required reporting limits for each method are documented in Attachment D.

2.5 QUALITY CONTROL

Tetra Tech will assess the quality of field data through regular collection and analysis of field QC samples. Laboratory QC samples will be analyzed in accordance with referenced analytical method protocols to ensure that laboratory procedures and analyses are conducted properly and that the quality of the data is known.

2.5.1 Field Quality Control Samples

QC samples are collected in the field and analyzed to check sampling and analytical precision, accuracy, and representativeness. The following section discusses the types and purposes of field QC samples that will be collected for this project. Table C-10 summarizes the types and frequency of collection of field QC samples.

2.5.1.1 Field Duplicates

To evaluate the precision of field sampling, field duplicate samples are collected at the same time and from the same source as other samples and then submitted as separate samples to the laboratory for analysis. Field duplicates will be collected at a frequency of 10 percent for all water samples. Duplicate samples will be assigned normal sample ID numbers and are submitted blind to the laboratory.

Although field duplicate soil samples are sometimes collected as soil samples from adjacent locations, such soil duplicate samples will not be collected for this project for two reasons. First, since adjacent soil samples incorporate some spatial variability, these samples cannot be

used directly to assess sampling precision. Furthermore, it is not practical to set QC limits for the RPD of such samples, which precludes the use of these samples for QC. Second, while the spatial variability information that can be obtained from adjacent soil samples may be useful in assessing or implementing remedial options, no objectives relating to these data uses have been identified for this project. Rather, it has been determined that this type of information on spatial variability will be obtained during subsequent investigations at this site, if required.

2.5.1.2 Equipment Rinsate Samples

Equipment rinsate samples demonstrate whether decontamination procedures are effective in removing contaminants from the field sampling equipment. The presence of contamination in equipment rinsate samples indicates that cleaning procedures were not effective, allowing for the possibility of cross-contamination. Equipment rinsate samples will be collected during soil sampling at a frequency of once per day of sampling. An equipment rinsate is a sample collected after a sampling device is subjected to standard decontamination procedures. Water will be poured over or through the sampling equipment into a sample container and sent to the laboratory for analysis. Analytically certified, organic-free water will be used for organic parameters; deionized or distilled water will be used for inorganic parameters.

Equipment rinsate samples will be sent blind to the laboratory. During data validation, the results for the equipment rinsate samples will be used to qualify data or to evaluate the levels of analytes in the field samples collected on the same day.

2.5.1.3 Source Water Blank Samples

One source water blank will be collected of the water used for the final decontamination rinse. Tetra Tech anticipates using only one source of water for the final decontamination rinse. The source water blank will be analyzed for all project analytes.

2.5.1.4 Trip Blanks

A trip blank demonstrates that contamination is not originating from sample containers or from any factor during sample transport. A trip blank originates at the laboratory as a 40-mL vial typically used for analysis of VOCs and TPH-p. The vial is filled at the laboratory with reagent-grade, organic-free water. The trip blanks are then transported to the site with the empty containers that will be used for sample collection. The trip blanks are stored at the site until the proposed field samples have been collected. A trip blank will accompany each sample transport container that holds water samples for analysis of VOCs and TPH-p back to the laboratory. The trip blank is not opened until it is returned to the laboratory.

2.5.1.5 Temperature Blanks

A 40-mL vial will be included in each sample transport container including samples for analysis of VOCs and TPH-p. The vial will be filled with water, and will be used by the laboratory to determine the temperature of the samples upon arrival at the laboratory.

2.5.2 Laboratory Quality Control Samples

Laboratory QC samples are prepared and analyzed at the laboratory to evaluate the effectiveness of sample preparation and analysis and to assess analytical precision and accuracy. The types of laboratory QC samples that will be used for this project are discussed in the following sections. Table C-4 presents the required frequencies for laboratory QC samples, and Attachment A presents project-specific precision and accuracy goals for these samples.

2.5.2.1 Method Blanks

Method blanks are prepared to evaluate whether contamination is originating from the reagents used in sample handling, preparation, or analysis. They are critical in distinguishing between low-level field contamination and laboratory contamination. A method blank consists of laboratory analyte-free water and all of the reagents used in the analytical procedure. It is prepared for every analysis in the same manner as a field sample and is processed through all of the analytical steps. Method blanks will be prepared at the frequency prescribed in the individual analytical method or at a rate of 5 percent of the total samples if a frequency is not prescribed in the method.

2.5.2.2 Laboratory Control Samples

LCSs, or blank spikes, originate in the laboratory as deionized or distilled water that has been spiked with standard reference materials of a known concentration. An LCS is analyzed to verify the accuracy of the calibration standards. These internal QC samples are also used to evaluate laboratory accuracy in the presence of matrix interference for field samples. LCSs are processed through the same analytical procedure as field samples. LCSs will be analyzed at the frequency prescribed in the analytical method or at a rate of 5 percent of the total samples if a frequency is not prescribed in the method. If percent recovery results for the LCS or blank spike are outside of the established goals, laboratory-specific protocols will be followed to evaluate the usability of the data.

2.5.2.3 Matrix Spike and Matrix Spike Duplicates

MS/MSD samples measure the efficiency of all the steps in the analytical method in recovering target analytes from an environmental matrix. MS/MSD samples for water matrices require collection of an additional volume of material for laboratory spiking and analysis; for soil matrices, additional sample volume is generally not required. MS/MSD samples will be collected at a frequency of 5 percent for soil, surface water, and groundwater. The percent recoveries will be calculated for each of the spiked analytes and used to evaluate analytical accuracy. The RPD

between spiked samples will be calculated to evaluate precision. Project-specific precision and accuracy goals are presented in Attachment A.

2.5.3 Additional Laboratory Quality Control Procedures

In addition to the analysis of laboratory QC samples, subcontractor laboratories will conduct the QC procedures discussed in the following sections.

2.5.3.1 Method Detection Limit Studies

The MDL is the minimum concentration of a compound that can be measured and reported. The MDL is a specified limit at which there is 99 percent confidence that the concentration of the analyte is greater than zero. The MDL takes into account sample matrix and preparation. The subcontractor laboratory will demonstrate the MDLs for all analyses except inorganic analyses and physical properties test methods.

MDL studies will be conducted annually for soil matrices, or more frequently if any method or instrumentation changes. Each MDL study will consist of seven replicates spiked with all target analytes of interest at concentrations no greater than required quantitation limits. The replicates will be extracted and analyzed in the same manner as routine samples. If multiple instruments are used, each will be included in the MDL study. The MDLs reported will be representative of the least sensitive instrument.

2.5.3.2 Sample Quantitation Limits

Sample quantitation limits (SQLs), also referred to as practical quantitation limits, are PRRLs adjusted for the characteristics of individual samples. The PRRLs presented in Attachment D are chemical-specific levels that a laboratory should be able to routinely detect and quantitate in a given sample matrix. The PRRL is usually defined in the analytical method or in laboratory method documentation. The SQL takes into account changes in the preparation and analytical methodology that may alter the ability to detect an analyte, including changes such as use of a smaller sample aliquot or dilution of the sample extract. Physical characteristics such as sample matrix and percent moisture that may alter the ability to detect the analyte are also considered. The laboratory will calculate and report SQLs for all environmental samples.

2.5.3.3 Control Charts

Control charts document data quality in graphic form for specific method parameters such as surrogate standards and blank spike recoveries. A collection of data points for each parameter is used to statistically calculate means and control limits for a given analytical method. This information is useful in determining whether analytical measurement systems are in control. In addition, control charts provide information about trends over time in specific analytical and preparation methodologies. Although they are not required, Tetra Tech recommends that subcontractor laboratories maintain control charts for organic and inorganic analyses. At a minimum, method-blank surrogate recoveries and blank spike recoveries should be charted for

all organic methods. Blank spike recoveries should be charted for inorganic methods. Control charts should be updated monthly.

2.6 EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

This section outlines the testing, inspection, and maintenance procedures that will be used to keep both field and laboratory equipment in good working condition.

2.6.1 Maintenance of Field Equipment

Preventive maintenance for most field equipment is carried out in accordance with procedures and schedules recommended in (1) the equipment manufacturer's literature or operating manual, or (2) SOPs that describe equipment operation associated with particular applications of the instrument. However, more stringent testing, inspection, and maintenance procedures and schedules may be required when field equipment is used to make critical measurements.

A field instrument that is out of order will be segregated, clearly marked, and not used until it is repaired. The FTL will be notified of equipment malfunctions so that prompt service can be completed quickly or substitute equipment can be obtained. When the condition of equipment is suspect, unscheduled testing, inspection, and maintenance should be conducted. Any significant problems with field equipment will be reported in the daily field QC report.

2.6.2 Maintenance of Laboratory Equipment

Subcontractor laboratories will prepare and follow a maintenance schedule for each instrument used to analyze samples collected for this project. All instruments will be serviced at scheduled intervals necessary to optimize factory specifications. Routine preventive maintenance and major repairs will be documented in a maintenance logbook.

An inventory of items to be kept ready for use in case of instrument failure will be maintained and restocked as needed. The list will include equipment parts subject to frequent failure, parts that have a limited lifetime of optimum performance, and parts that cannot be obtained in a timely manner.

The laboratory's QA plan and written SOPs will describe specific preventive maintenance procedures for equipment maintained by the laboratory. These documents identify the personnel responsible for major, preventive, and daily maintenance procedures, the frequency and type of maintenance performed, and procedures for documenting maintenance activities.

Laboratory equipment malfunctions will require immediate corrective action. Actions should be documented in laboratory logbooks. No other formal documentation is required unless data quality is adversely affected or further corrective action is necessary. On-the-spot corrective actions will be taken as necessary in accordance with the procedures described in the laboratory QA plan and SOPs.

2.7 INSTRUMENT CALIBRATION AND FREQUENCY

The following sections discuss calibration procedures that will be followed to ensure the accuracy of measurements made using field and laboratory equipment.

2.7.1 Calibration of Field Equipment

Field equipment will be calibrated at the beginning of the field effort and at prescribed intervals. The calibration frequency depends on the type and stability of equipment, the intended use of the equipment, and the recommendation of the manufacturer. Detailed calibration procedures for field equipment are available from the specific manufacturers' instruction manuals, and general guidelines are included in Tetra Tech SOPs. All calibration information will be recorded in a field logbook or on field forms. A label that specifies the scheduled date of the next calibration will be attached to the field equipment. If this type of identification is not feasible, equipment calibration records will be readily available for reference.

2.7.2 Calibration of Laboratory Equipment

Laboratory equipment calibration procedures and frequencies will follow the requirements in the reference method in Section 2.4.2 of this SAP. Qualified analysts will calibrate laboratory equipment and document the procedures and results in a logbook.

The laboratory will obtain calibration standards from commercial vendors for inorganic analytes. Stock solutions for surrogate standards and other inorganic mixes will be made from reagent-grade chemicals or as specified in the analytical method. Stock standards will also be used to make intermediate standards that will be used to prepare calibration standards. Special attention will be paid to expiration dating, proper labeling, proper refrigeration, and freedom from contamination. Documentation on receipt, mixing, and use of standards will be recorded in the appropriate laboratory logbook. Logbooks must be permanently bound. Additional specific handling and documentation requirements for the use of standards may be provided in subcontractor laboratory QA plans.

2.8 INSPECTION AND ACCEPTANCE OF SUPPLIES AND CONSUMABLES

Tetra Tech project managers have primary responsibility for identifying the types and quantities of supplies and consumables needed to complete Navy projects and are also responsible for establishing acceptance criteria for these items.

Supplies and consumables can be received either at a Tetra Tech office or at a work site. When supplies are received at an office, the project manager or FTL will sort them according to vendor, check packing slips against purchase orders, and inspect the condition of all supplies before they are accepted for use on a project. If an item does not meet the acceptance criteria, deficiencies will be noted on the packing slip and purchase order, and the item will then be returned to the vendor for replacement or repair.

Procedures for receiving supplies and consumables in the field are similar. When supplies are received, the Tetra Tech project manager or FTL will inspect all items against the acceptance criteria. Any deficiencies or problems will be noted in the field logbook, and deficient items will be returned for immediate replacement.

Analytical laboratories are required to provide certified clean containers for all analyses. These containers must meet EPA standards described in "Specifications and Guidance for Obtaining Contaminant-Free Sampling Containers" (EPA 1992).

2.9 NON-DIRECT MEASUREMENTS

No data for project implementation or decision-making will be obtained from non-direct measurement sources.

2.10 DATA MANAGEMENT

Field and analytical data collected from this project and other environmental investigations at NWS SBD Concord are critical to site characterization efforts, development of the comprehensive conceptual site model, risk assessments, and selection of remedial actions to protect human health and the environment. An information management system is necessary to ensure efficient access so that decisions based on the data can be made in a timely manner.

After the field and laboratory data reports are reviewed and validated, the data will be entered into Tetra Tech's database for NWS SBD Concord. The database contains data for (1) summarizing observations on contamination and geologic conditions, (2) preparing reports and graphics, (3) using with geographic information systems, and (4) transmitting in an electronic format compatible with Navy Environmental Data Transfer Standards (NEDTS). The following sections describe Tetra Tech's data tracking procedures, data pathways, and overall data management strategy for NWS SBD Concord.

2.10.1 Data-Tracking Procedures

All data that are generated in support of the Navy program at NWS SBD Concord are tracked through a database created by Tetra Tech. Information related to receipt and delivery of samples, project order fulfillment, and invoicing for laboratory and validation tasks is stored in the Tetra Tech program, SAMTRAK. All data are filed according to the project number.

2.10.2 Data Pathways

Data are generated from three primary pathways at NWS SBD Concord—data derived from field activities, laboratory analytical data, and validated data. Data from all three pathways must be entered into the NWS SBD Concord database. Data pathways must be established and well documented to evaluate whether the data have been accurately loaded into the database in a timely manner.

Data generated during field activities are recorded using field forms (Attachment C). These forms are reviewed for completeness and accuracy by the analytical coordinator or field team leader. Data from the field forms, including the chain-of-custody form, are entered into SAMTRAK according to the project number.

Data generated during laboratory analysis are recorded in hardcopy and in EDDs after the samples have been analyzed. The laboratory will send the hardcopy on CDs and EDD records to the analytical coordinator. The analytical coordinator reviews the data deliverable for completeness, accuracy, and format. After the format has been approved, the electronic data are manipulated and downloaded into the database. Tetra Tech data entry personnel will then update SAMTRAK with the total number of samples received and number of days required to receive the data.

After validation, the analytical coordinator reviews the data for accuracy. Tetra Tech will then update the database with the appropriate data qualifiers. SAMTRAK is also updated to record associated laboratory and data validation costs.

2.10.3 Data Management Strategy

Tetra Tech's short- and mid-term data management strategies require that the database for NWS SBD Concord be updated monthly. The data consist of chemical and field data from Navy contractors, entered into an Oracle (Version 7.3) database. The database can generate reports using available computer-aided drafting and design and contouring software. All electronic data from this database will be transmitted in a format compatible with NEDTS. Data will be handled in accordance with Southwest Division Environmental Work Instruction #6, which specifies requirements for transmitting data to the Navy.

To satisfy long-term data management goals, the data will be loaded into the database at Tetra Tech for storage, further manipulation, and retrieval after the off-site laboratory and field reports are reviewed and validated. The database will be used to provide data for chemical and geologic analysis and for preparing reports and graphic representations of the data. Additional data acquired from field activities are recorded on field forms (Attachment C) that are reviewed for completeness and accuracy by the analytical coordinator or field team leader. Hard copies of forms, data, and COC forms are filed in a secure storage area according to project and SDG numbers. Laboratory data packages and reports will be archived at Tetra Tech or Navy offices. Laboratories that generated the data will archive hard-copy data for a minimum of 10 years.

3.0 ASSESSMENT AND OVERSIGHT

This section describes the field and laboratory assessments that may be conducted during this project, the individuals responsible for conducting assessments, corrective actions that may be implemented in response to assessment results, and the way quality-related issues will be reported to Tetra Tech and Navy management.

3.1 ASSESSMENT AND RESPONSE ACTIONS

Tetra Tech and the Navy will oversee collection of environmental data using the assessment and audit activities described in the following text. Any problems encountered during an assessment of field investigation or laboratory activities will require appropriate corrective action to ensure that the problems are resolved. This section describes the types of assessments that may be completed, Tetra Tech and Navy responsibilities for conducting the assessments, and corrective action procedures to address problems identified during an assessment.

3.1.1 Field Assessments

Tetra Tech conducts field technical systems audits (TSA) on selected Navy projects to support data quality and encourage continuous improvement in the field systems that involve environmental data collection. The Tetra Tech QA program manager selects projects for field TSAs quarterly based on available resources and the relative significance of the field sampling effort. During the field TSA, the assessor will use personnel interviews, direct observations, and reviews of project-specific documentation to evaluate and document whether procedures specified in the approved SAP are being implemented. The following specific items may be observed during the TSA:

- Availability of approved project plans such as this SAP and the base-wide health and safety plan (Tetra Tech 1998b)
- Documentation of personnel qualifications and training
- Sample collection, identification, preservation, handling, and shipping procedures
- Sampling equipment decontamination
- Equipment calibration and maintenance
- Completeness of logbooks and other field records (including nonconformance documentation)

During the TSA, the Tetra Tech assessor will verbally communicate any significant deficiencies to the FTL for immediate correction. These and all other observations and comments will also be documented in a TSA report. The TSA report will be issued to the Tetra Tech project manager, FTL, program QA manager, and project QA officer in e-mail format within 7 days after the TSA is completed.

The Tetra Tech program QA manager determines the timing and duration of TSAs. Generally, TSAs are conducted early in the project so that any quality issues can be resolved before large amounts of data are collected.

The Navy QA officer may also independently conduct a field assessment of any Tetra Tech project. Items reviewed by the Navy QA officer during a field assessment may be similar to those described above.

3.1.2 Laboratory Assessments

As described in Section 2.4.1, NFESC assesses all laboratories before they are allowed to analyze samples under Navy contracts. Tetra Tech also conducts a pre-award assessment of each laboratory before it is placed on the approved list for performing work under Navy contracts (Attachment E). These assessments include (1) reviews of laboratory certifications, (2) initial and annual demonstrations of the laboratory's ability to satisfactorily analyze single-blind PE samples, and (3) laboratory audits. Laboratory audits may consist of an on-site review of laboratory facilities, personnel, documentation, and procedures, or an off-site evaluation of the ability of the laboratory's data management system to meet contract requirements. Tetra Tech also conducts an assessment when an approved laboratory has been selected for non-routine analyses or when a laboratory that is not on the approved list must be used.

The Navy may audit any laboratory that will analyze samples on this project. The Navy QA officer will determine the need for these audits and will typically conduct the audits before samples are submitted to the laboratory for analysis.

3.1.3 Assessment Responsibilities

Tetra Tech personnel conducting assessments will be independent of the activity being evaluated. The Tetra Tech program QA manager will select the appropriate personnel to conduct each assessment and will assign them responsibilities and deadlines for completing the assessment. These personnel may include the program QA manager, project QA officer, or senior technical staff with relevant expertise and assessment experience.

When an assessment is planned, the Tetra Tech program QA manager selects a lead assessor who is responsible for the following:

- Selecting and preparing the assessment team
- Preparing an assessment plan
- Coordinating and scheduling the assessment with the project team, subcontractor, or other organization being evaluated
- Participating in the assessment
- Coordinating preparation and issuance of assessment reports and corrective action request forms
- Evaluating responses and resulting corrective actions

After the assessment is completed, the lead assessor will submit an audit report to the Tetra Tech program QA manager, project manager, and project QA officer; other personnel may be included in the distribution as appropriate. Assessment findings will also be included in a quality summary report for the project (see Section 3.2.3).

The Navy QA officer is responsible for coordinating all audits that may be conducted by Navy personnel under this project. Audit preparation, completion, and reporting responsibilities for Navy auditors would be similar to those described above.

3.1.4 Field Corrective Action Procedures

Field corrective action procedures will depend on the type and severity of the finding. Tetra Tech classifies assessment findings as either deficiencies or observations. Deficiencies are findings that may have a significant impact on data quality and that will require corrective action. Observations are findings that do not directly affect data quality, but are suggestions for consideration and review.

Project teams are required to respond to deficiencies identified in TSA reports. The project manager, FTL, and project QA officer will meet to discuss the deficiencies and the appropriate steps to resolve each deficiency by:

- Determining when and how the problem developed
- Assigning responsibility for problem investigation and documentation
- Selecting the corrective action to eliminate the problem
- Developing a schedule for completing the corrective action
- Assigning responsibility for implementing the corrective action
- Documenting and verifying that the corrective action has eliminated the problem
- Notifying the Navy of the problem and the corrective action taken

In responding to the TSA report, the project team will include a brief description of each deficiency, the proposed corrective action, the individual responsible for determining and implementing the corrective action, and the completion dates for each corrective action. The project QA officer will use a status report to monitor all corrective actions.

The Tetra Tech program QA manager is responsible for to reviewing proposed corrective actions and verifying that they have been effectively implemented. The program QA manager can require data acquisition to be limited or discontinued until the corrective action is complete and a deficiency is eliminated. The program QA manager can also request the reanalysis of any or all samples and a review of all data acquired since the system was last in control.

3.1.5 Laboratory Corrective Action Procedures

Internal laboratory procedures for corrective action and descriptions of out-of-control situations that require corrective action are contained in laboratory QA plans. At a minimum, corrective action will be implemented when any of the following three conditions occurs: control limits are exceeded, method QC requirements are not met, or sample-holding times are exceeded. The laboratory will report out-of-control situations to the Tetra Tech analytical

coordinator within 2 working days after they are identified. In addition, the laboratory project manager will prepare and submit a corrective action report to the Tetra Tech analytical coordinator. This report will identify the out-of-control situation and the steps that the laboratory has taken to rectify it.

3.2 REPORTS TO MANAGEMENT

Effective management of environmental data collection requires (1) timely assessment and review of all activities and (2) open communication, interaction, and feedback among all project participants. Tetra Tech will use the reports described in the following text to address any project-specific quality issues and to facilitate timely communication of these issues.

3.2.1 Daily Progress Reports

Tetra Tech will prepare a daily progress report to summarize activities throughout the field investigations. This report will describe sampling and field measurements, equipment used, Tetra Tech and subcontractor personnel on site, QA/QC and health and safety activities, problems encountered, corrective actions taken, deviations from the SAP, and explanations for the deviations. The daily progress report is prepared by the field team leader and submitted to the project manager and to the Navy remedial project manager (RPM), if requested. The content of the daily reports will be summarized and included in the final report submitted for the field investigation.

3.2.2 Project Monthly Status Report

The Tetra Tech project manager will prepare a monthly status report (MSR) to be submitted to Tetra Tech's Navy program manager and the Navy RPM. Monthly status reports address project-specific quality issues and facilitate their timely communication. The MSR will include the following quality-related information:

- Project status
- Instrument, equipment, or procedural problems that affect quality and recommended solutions
- Objectives from the previous report that were achieved
- Objectives from the previous report that were not achieved
- Work planned for the next month

If appropriate, Tetra Tech will obtain similar information from subcontractors who are participating in the project and will incorporate the information within the MSR.

3.2.3 Quality Control Summary Report

Tetra Tech will prepare a quality summary report that will be submitted to the Navy RPM with each TER for the monitoring year and will include a summary and evaluation of QA/QC activities, including any field or laboratory assessments, completed during the monitoring events and will indicate the location and duration of storage for the complete data packages. Particular emphasis will be placed on determining whether project DQOs were met and whether data are of adequate quality to support required decisions.

4.0 DATA VALIDATION AND USABILITY

This section describes the procedures that are planned to review, verify, and validate field and laboratory data. This section also discusses procedures for verifying that the data are sufficient to meet DQOs for the project.

4.1 DATA REVIEW, VERIFICATION, AND VALIDATION

Validation and verification of the data generated during field and laboratory activities are essential to obtaining data of defensible and acceptable quality. Verification and validation methods for field and laboratory activities are presented below.

4.1.1 Field Data Verification

Project team personnel will verify field data through reviews of data sets to identify inconsistencies or anomalous values. Any inconsistencies discovered will be resolved as soon as possible by seeking clarification from field personnel responsible for data collection. All field personnel will be responsible for following the sampling and documentation procedures described in this SAP so that defensible and justifiable data are obtained.

Data values that are significantly different from the population are called “outliers.” A systematic effort will be made to identify any outliers or errors before field personnel report the data. Outliers can result from improper sampling or measurement methodology, data transcription errors, calculation errors, or natural causes. Outliers that result from errors found during data verification will be identified and corrected; outliers that cannot be attributed to errors in sampling, measurement, transcription, or calculation will be clearly identified in project reports.

4.1.2 Laboratory Data Verification

Laboratory personnel will verify analytical data at the time of analysis and reporting and through subsequent reviews of the raw data for any nonconformances to the requirements of the analytical method. Laboratory personnel will make a systematic effort to identify any outliers or errors before they report the data. Outliers that result from errors found during data verification will be identified and corrected; outliers that cannot be attributed to errors in analysis, transcription, or calculation will be clearly identified in the case narrative section of the analytical data package.

4.1.3 Laboratory Data Validation

An independent third-party contractor will validate all laboratory data in accordance with current EPA national functional guidelines. The data validation strategy will be consistent with Navy guidelines. For this project, 80 percent of the data will undergo cursory validation, and 20 percent of the data will undergo full validation. Requirements for cursory and full validation are listed below.

4.1.3.1 Cursory Data Validation

Cursory validation will be completed on 80 percent of the summary data packages for analysis of surface water, soil and groundwater samples. The data reviewer is required to notify Tetra Tech and request any missing information needed from the laboratory. Elimination of the data from the review process is not allowed. All data will be qualified as necessary in accordance with established criteria. Data summary packages will consist of sample results and QC summaries, including calibration and internal standard data.

4.1.3.2 Full Data Validation

Full validation will be completed on 20 percent of the full data packages for analysis of surface water, soil and groundwater samples. The data reviewer is required to notify Tetra Tech and request any missing information needed from the laboratory. Elimination of data from the review process is not allowed. All data will continue through the validation process and will be qualified in accordance with established criteria. Full data summary packages will consist of sample results, QC summaries, and all raw data associated with the sample results and QC summaries.

4.1.3.3 Data Validation Criteria

Table C-11 lists the QC criteria that will be reviewed for both cursory and full data validation. The data validation criteria selected from Table C-11 will be consistent with the project-specific analytical methods listed in Section 2.4 of the SAP.

4.2 RECONCILIATION WITH USER REQUIREMENTS

After environmental data have been reviewed, verified, and validated in accordance with the procedures described in Section 4.1, the data must be further evaluated to determine whether DQOs have been met.

To the extent possible, Tetra Tech will follow EPA's data quality assessment (DQA) process to verify that the type, quality, and quantity of data collected are appropriate for their intended use. DQA methods and procedures are outlined in EPA's "Guidance for Data Quality Assessment, Practical Methods for Data Analysis" (2000d). The DQA process includes five steps: (1) review the DQOs and sampling design; (2) conduct a preliminary data review; (3) select a statistical test; (4) verify the assumptions of the statistical test; and (5) draw conclusions from the data.

When the five-step DQA process is not completely followed because the DQOs are qualitative in nature, Tetra Tech will systematically assess data quality and data usability. This assessment will include:

- A review of the sampling design and sampling methods to verify that they were implemented as planned and are adequate to support project objectives
- A review of project-specific data quality indicators for precision, accuracy, representativeness, completeness, comparability, and quantitation limits (defined in Section 1.3.2) to determine whether acceptance criteria have been met
- A review of project-specific DQOs to determine whether they have been achieved by the data collected
- An evaluation of any limitations associated with the decisions to be made based on the data collected. For example, if data completeness is only 90 percent compared to a project-specific completeness objective of 95 percent, the data may still be usable to support a decision, but at a lower level of confidence.

The final report for the project will discuss any potential impacts of these reviews on data usability and will clearly define any limitations associated with the data.

REFERENCES

California Regional Water Quality Control Board (RWQCB). 1995. "San Francisco Bay Basin Water Quality Control Plan." California Regional Quality Control Board – San Francisco Bay Region. June 21.

Cullinane, M.J., C.R. Lee, and L.J. O'Neill. 1988. "Feasibility Study of Contamination Remediation at Naval Weapons Station, Concord, California." U.S. Department of the Army, Waterways Experiment Station, U.S. Army Corps of Engineers (USACE). Miscellaneous Paper EL-86-3. September.

Efroymson, R.A., G.W. Suter, B.E. Sample, D.S. Jones. 1997a. "Preliminary Remediation Goals for Ecological Endpoints." August.

Efroymson, R.A., G.W. Suter, B.E. Sample, A.C. Wooton. 1997b. "Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision ES/ER/TM-85/R3, Oak Ridge National Laboratory, Oak Ridge, Tennessee."

Efroymson, R.A., M.W. Will, and G.W. Suter II. 1997c. "Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision, ES/ER/TM-126/r2, Oak Ridge National Laboratory, Oak Ridge, Tennessee."

IT Corporation. 1993. "Technical Memorandum: Results of Field Investigation Activities, Litigation Sites, Naval Weapons Station, Concord, California." September .

Lee, Charles R., and others. 1986. "Final Report of Remedial Investigation of Contaminant Mobility at Naval Weapons Station, Concord, California." Department of the Army, Waterways Experiment Station, USACE, Miscellaneous Paper EL-86-2. January.

Lee, Charles R., and others. 1988. "Final Report of Remedial Investigation of Contaminant Mobility at Naval Weapons Station, Concord, California, Subtitle Appendix 2.5 – 1987/87 Data."

Lee, Charles R., and others. 1989. "Monitoring Plan for Contamination Remediation at Naval Weapons Station, Concord, California." Department of the Army, Waterways Experiment Station, USACE. April.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. "Incidence of Adverse Biological Effects within Ranges of Chemical Concentrations in Marine and Estuarine Sediments." *Environmental Management.* Volume 19, Number 1. Pages 81-97.

Long, E.R. and L.G. Morgan. 1990. "The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program." Technical Memorandum: National Ocean Service, Office of Oceanography and Marine Assessment No. 52. National Oceanic and Atmospheric Administration (NOAA). Seattle, Washington.

Marshack, J.B. 2000. "A Compilation of Water Quality Goals – August 2000 Edition." Regional Water Quality Control Board (RWQCB).

Naval Facilities Engineering Service Center (NFESC). 1999. "Navy Installation Restoration Chemical Data Quality Manual (IRCDQM)." Special Report SP-2056-ENV. September.

O'Neil, J. 1988. "Final Report of Feasibility Study of Contamination Remediation at Naval Weapons Station, Concord, California, Volume II: Biological Assessment." Department of the Army, Waterways Experiment Station, USACE. July.

PRC Environmental Management, Inc. (PRC). 1994. "Draft Baseline Conditions Report Volume II, Litigation Area Sites, Naval Weapons Station, Concord, California." February 14.

PRC. 1997a. "Technical Memorandum: Tidal Influence Study and Postremediation Groundwater Monitoring, Naval Weapons Station Concord." July 22.

PRC. 1997b. "Qualitative Ecological Assessment, Litigation Area, Naval Weapons Station, Concord, California."

Puls, R. W. and R. M. Powell. 1992. "Acquisition of Representative Ground Water Quality Samples for Metals." *Ground Water Monitoring Review*. Summer 1992. Pages 167 – 176.

Tetra Tech EM Inc. (Tetra Tech). 1997. "Technical Memorandum: Tidal Influence Study and Post-Remediation Groundwater Monitoring, Naval Weapons Station Concord." July 22.

Tetra Tech. 1998. "Final Base-wide Health and Safety Plan, NWSSB Detachment Concord, California." July 7.

Tetra Tech. 2002. "Tetra Tech EM Inc. Laboratory Analytical Statement of Work." January.

Tetra Tech. 2003. "Final 5-year Periodic Review Assessment Report Naval Weapons Station Seal Beach Detachment, Concord, California." June 30.

Tetra Tech. 2004. "Draft Data Gaps Technical Evaluation Report for the Litigation Area, Naval Weapons Station Seal Beach Detachment, Concord, California." June 28.

U.S. Environmental Protection Agency (EPA). 1992. "Specifications and Guidance for Obtaining Contaminant-Free Sampling Containers." OSWER Directive No. 9240.0-05A. April.

EPA. 1996. "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (SW-846), Update III." Office of Solid Waste and Emergency Response. Washington, DC. December.

EPA. 1998. "Quality Criteria for Water." Office of Water. Washington D.C.

EPA. 1999. "U.S. EPA Contract Laboratory Program Statement of Work for Organics Analysis, Multi-Media, Multi-Concentration." Document Number OLM04.2. May.

EPA. 2000a. "Federal Register: Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule." 40 Code of Federal Regulations Part 131. May 18.

EPA. 2000b. "Data Quality Objectives Process for Hazardous Waste Site Investigations (EPA QA/ G-4HW)." Office of Environmental Information. Washington, D.C. EPA/600/R-00/007. January.

EPA. 2000c. "Guidance for the Data Quality Objectives Process, EPA QA/G-4." Office of Environmental Information. Washington, DC. EPA/600/R-96/055. August.

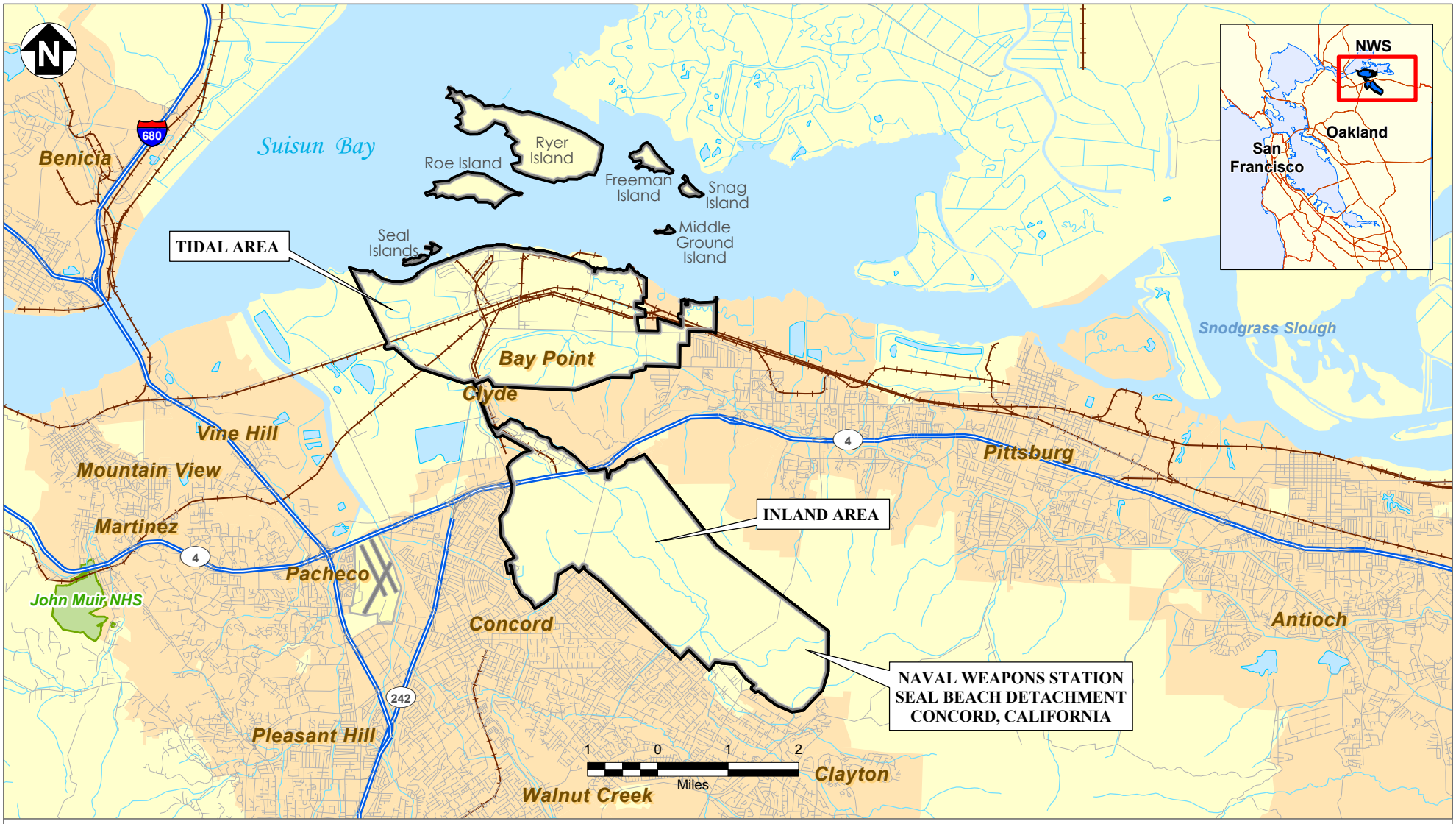
EPA. 2000d. "Guidance for Data Quality Assessment, Practical Methods for Data Analysis, EPA QA/ G-9, QA00 Update." Office of Environmental Information. Washington, D.C. EPA/600/ R-96-084. July.

EPA. 2000e. "Guidance for Data Quality Objectives Process, EPA Q-A/G-4." EPA/600/R-96/055. Office of Environmental Information. Washington, DC. August.

EPA. 2001. "EPA Requirements for Quality Assurance Project Plans, EPA QA/R-5." Office of Environmental Information. Washington, D.C. EPA/240/B-01/003. March.

EPA. 2002. "National Recommended Water Quality by Criteria." EP-822-R-02-047. November.

FIGURES



NAVAL WEAPONS STATION
SEAL BEACH DETACHMENT
CONCORD, CALIFORNIA

Tetra Tech EM Inc.

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE C-1
SITE VICINITY MAP

Monitoring Plan

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Figure C-2

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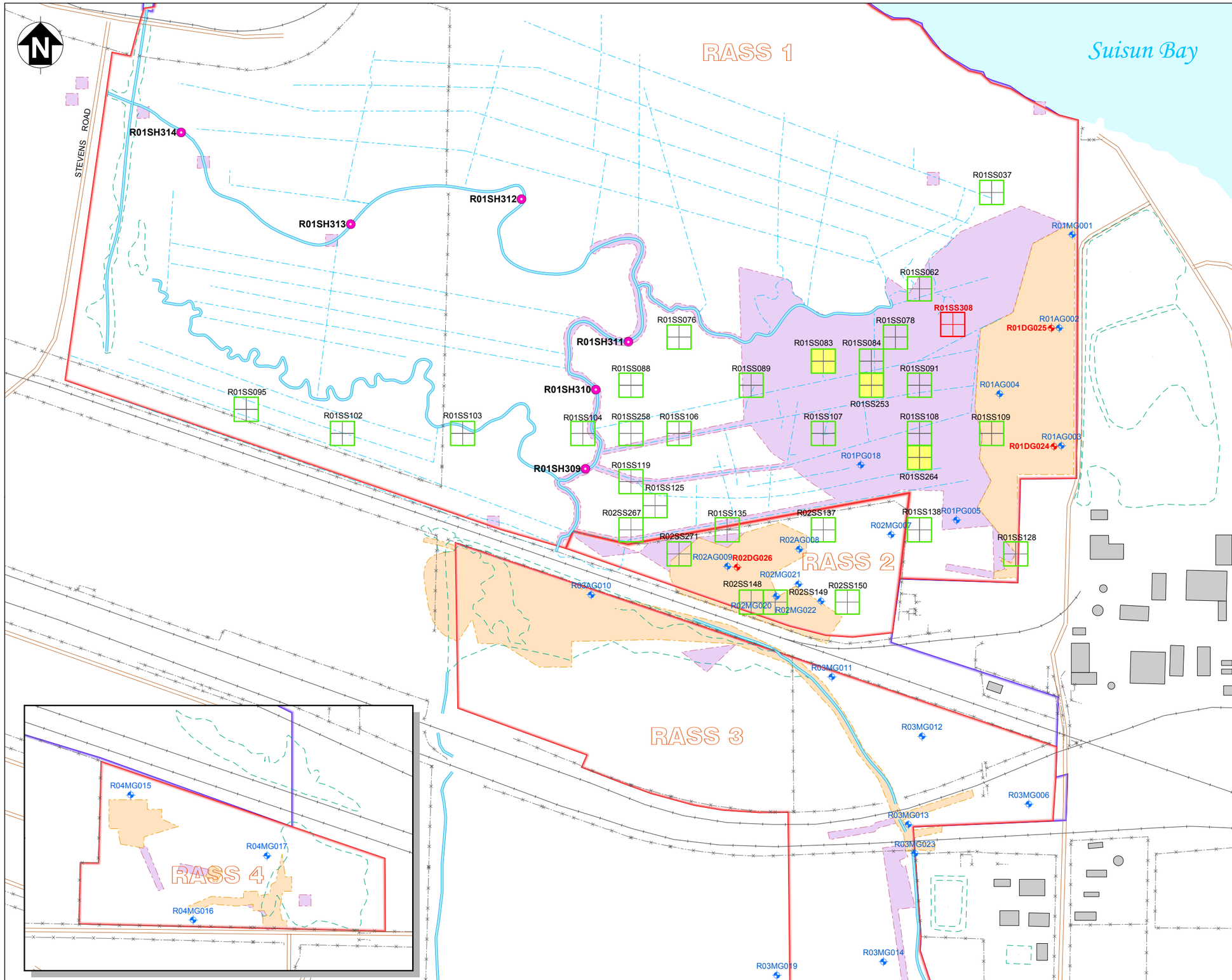

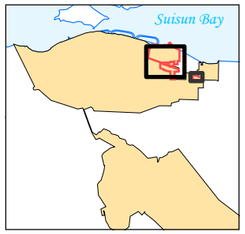

- Proposed Soil Sample Location. One Sample Collected in Each of Four 50x50 Foot Quadrants
- Proposed New Soil Sampling Location
- Proposed Deep Aquifer Monitoring Well
- Existing Groundwater Monitoring Well
- Proposed Surface Water Sampling Location
- Proposed Prey Tissue Sampling Area
- RASS Boundary
- Active Remediation Area
- Passive Remediation Area
- Naval Weapons Station Boundary
- Building
- Road
- Mosquito Ditch
- Railroad
- Fence
- Creek
- Other Surface Feature

Note:
One replicated sample will be collected from a random selected location from sub quadrant (4 samples).

400 0 400
Feet

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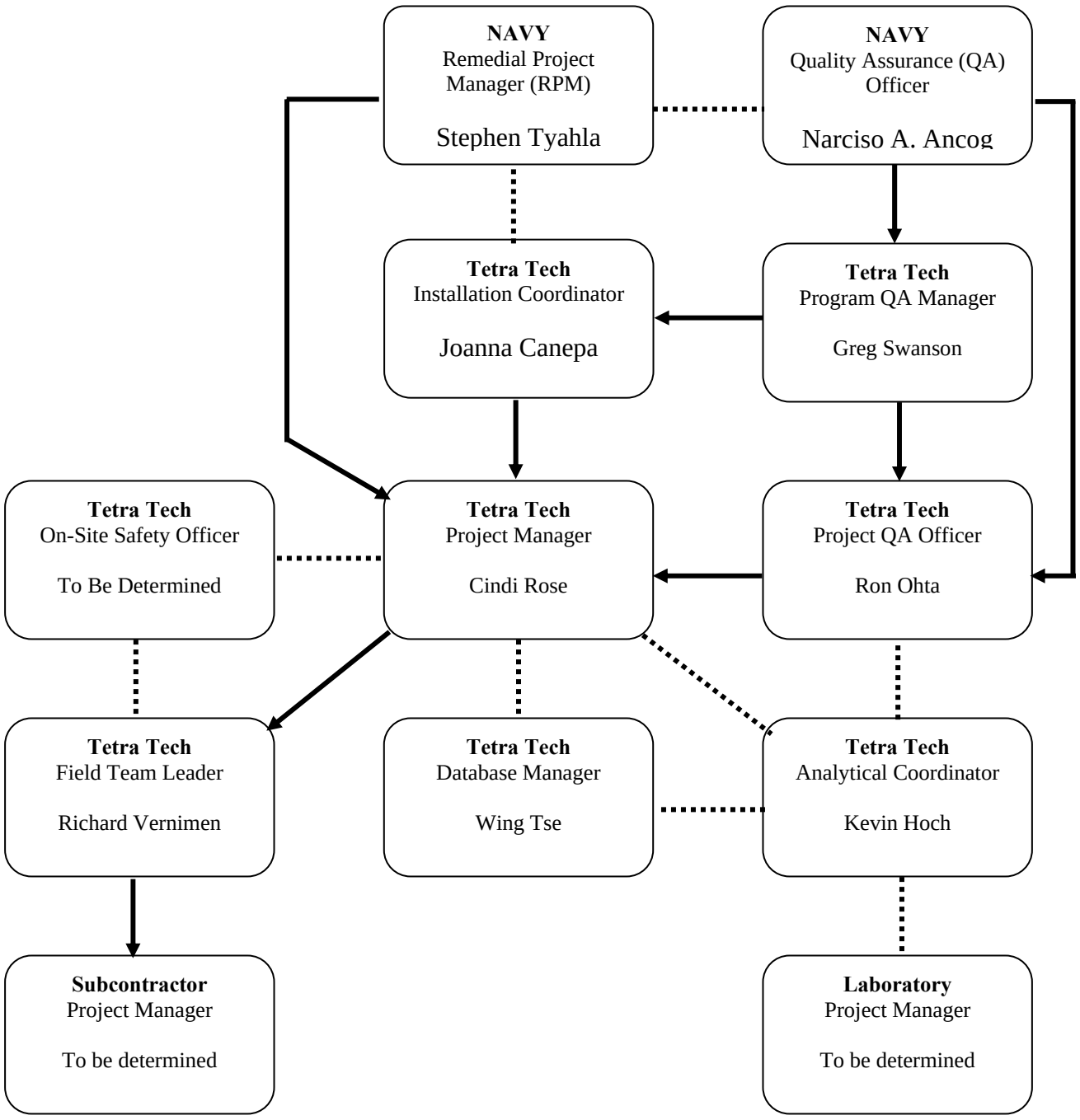
Concord, California
Engineering Field Activity West, Daly City

FIGURE C-3
PROPOSED INITIAL SAMPLING LOCATIONS
LITIGATION AREA

Monitoring Plan

2004-09-10 V:\Concord\Projects\LA_long_term_monit_plan\Prop_Initial_SL.mxd TtEMI-SF Aleksandr Zhuk

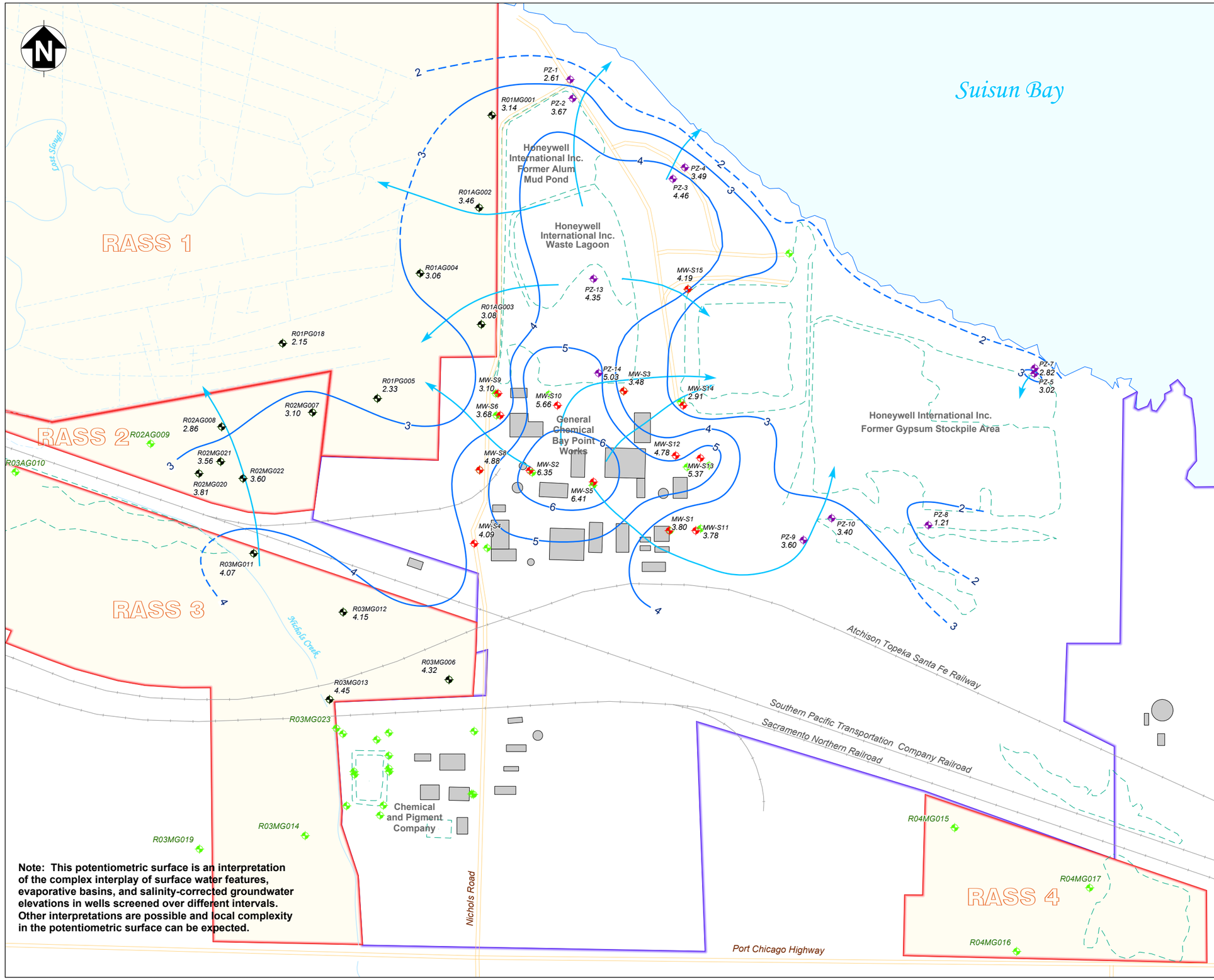


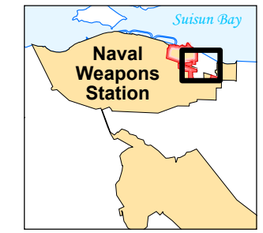
Tetra Tech EM Inc.

Lines of Authority
Lines of Communication

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE C-4
PROJECT TEAM ORGANIZATION CHART
Monitoring Plan, Litigation Area





Notes:
1. Groundwater elevations shown in feet msl.
2. Groundwater elevations were measured and corrected for salinity by CH2M-Hill.
3. msl - Mean sea level.
4. NWS SBD - Naval Weapons Station Seal Beach Detachment.
5. RASS - Remedial action subsite.

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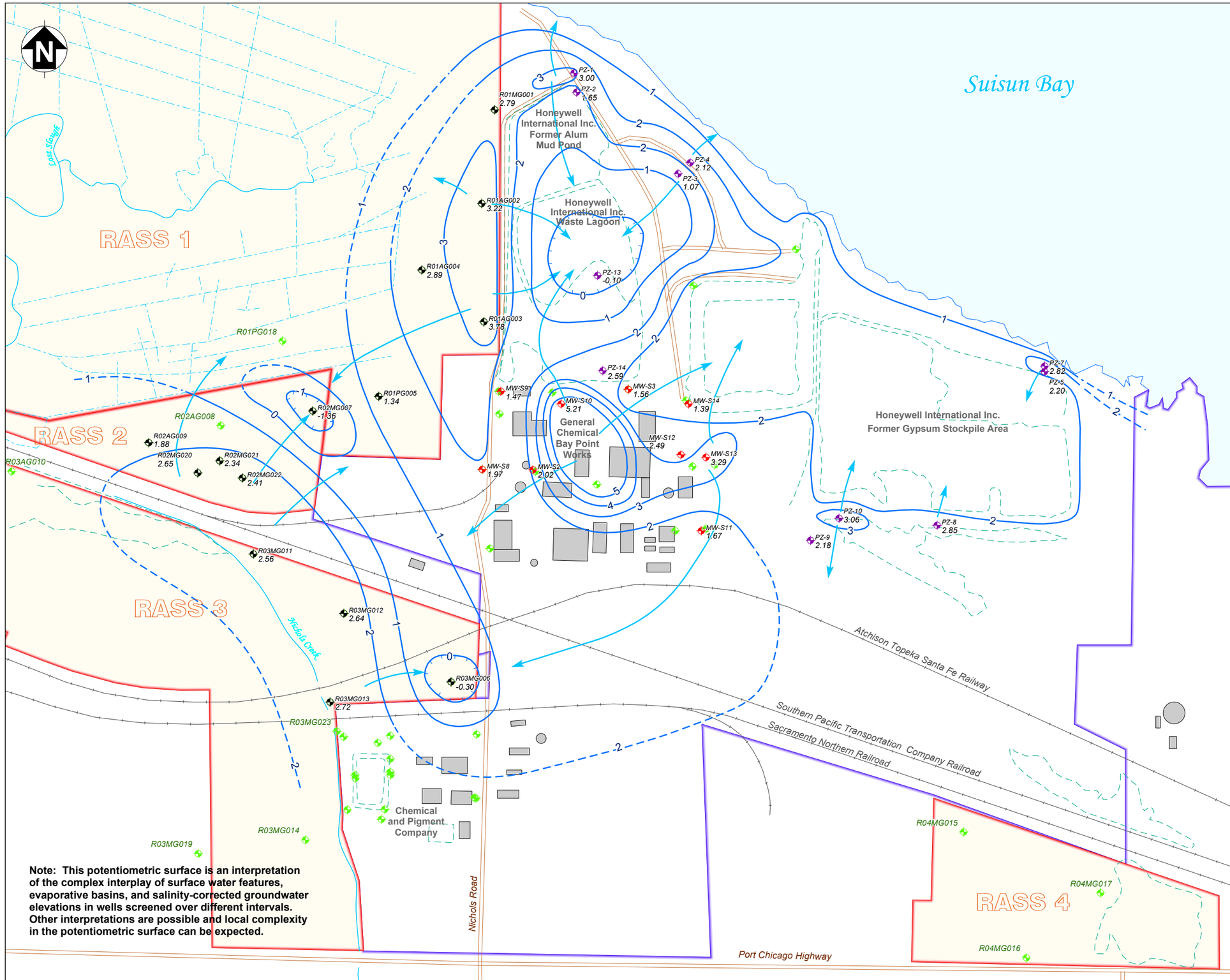
Engineering Field Activity West, Daly City

FIGURE C-5
GROUNDWATER CONTOUR MAP
WET SEASON (FEBRUARY 2002)
LITIGATION AREA

Monitoring Plan

2004-10-08 V:\Concord\Projects\Data_Gap_Invest\GW_Wells_Litig_Feb'02alt.mxd TtEMI-SF Aleksandr Zhuk



Notes:
1. Groundwater elevations shown in feet msl.
2. Groundwater elevations were measured and corrected for salinity by Montgomery Watson Harza.
3. msl - Mean sea level.
4. NWS SBD - Naval Weapons Station Seal Beach Detachment.
5. RASS - Remedial action subsite.

Note: This potentiometric surface is an interpretation of the complex interplay of surface water features, evaporative basins, and salinity-corrected groundwater elevations in wells screened over different intervals. Other interpretations are possible and local complexity in the potentiometric surface can be expected.

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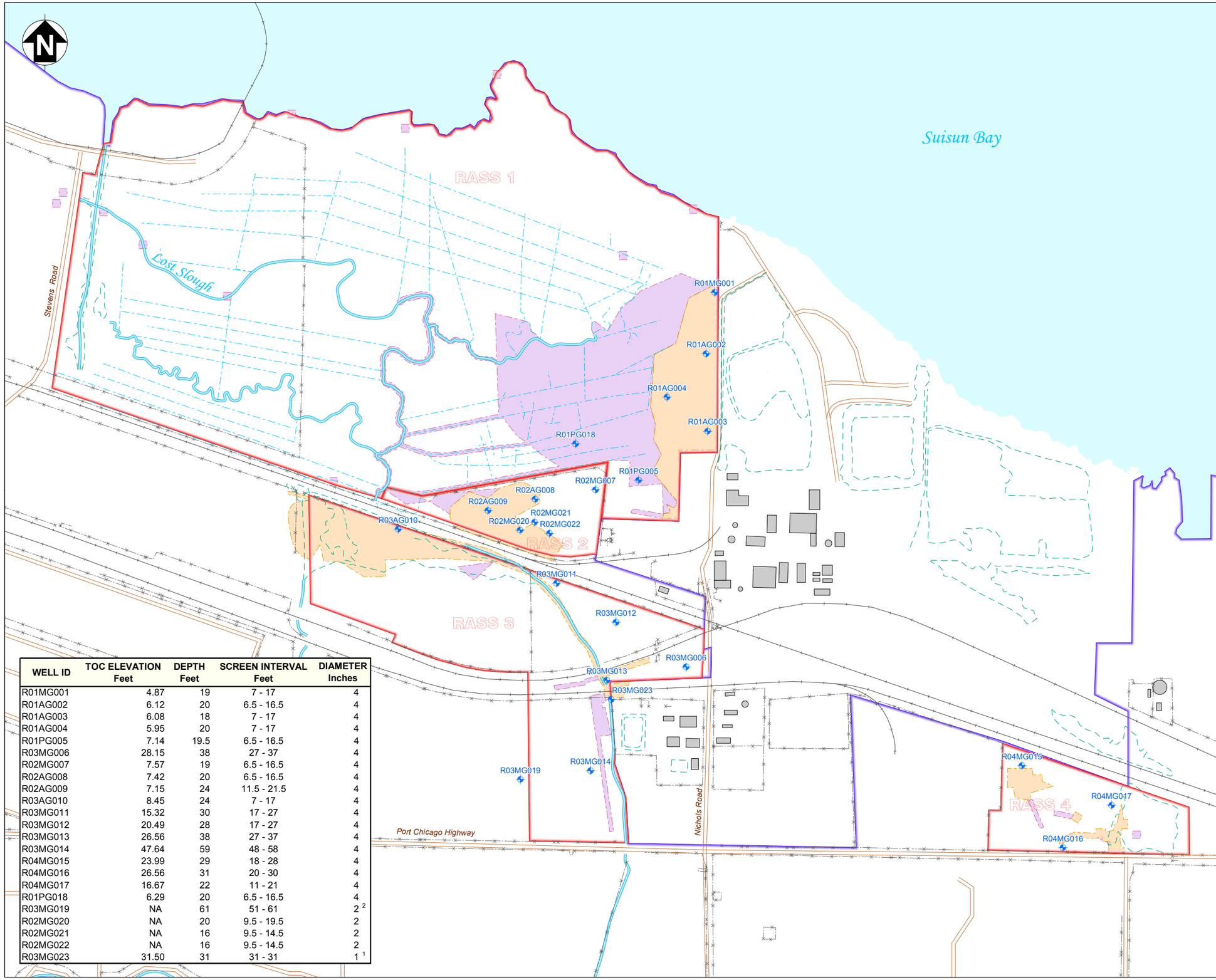
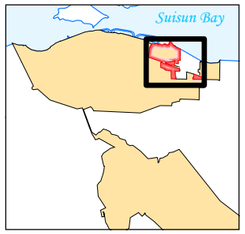
FIGURE C-6
GROUNDWATER CONTOUR MAP
DRY SEASON (NOVEMBER 2003)
LITIGATION AREA

Monitoring Plan

2004-10-08 V:\Concord\Projects\Data_Gap_Invest\GW_Wells_Litig_Nov'03alt.mxd TtEMI-SF Aleksandr Zhuk



WELL ID	TOC ELEVATION Feet	DEPTH Feet	SCREEN INTERVAL Feet	DIAMETER Inches
R01MG001	4.87	19	7 - 17	4
R01AG002	6.12	20	6.5 - 16.5	4
R01AG003	6.08	18	7 - 17	4
R01AG004	5.95	20	7 - 17	4
R01PG005	7.14	19.5	6.5 - 16.5	4
R03MG006	28.15	38	27 - 37	4
R02MG007	7.57	19	6.5 - 16.5	4
R02AG008	7.42	20	6.5 - 16.5	4
R02AG009	7.15	24	11.5 - 21.5	4
R03AG010	8.45	24	7 - 17	4
R03MG011	15.32	30	17 - 27	4
R03MG012	20.49	28	17 - 27	4
R03MG013	26.56	38	27 - 37	4
R03MG014	47.64	59	48 - 58	4
R04MG015	23.99	29	18 - 28	4
R04MG016	26.56	31	20 - 30	4
R04MG017	16.67	22	11 - 21	4
R01PG018	6.29	20	6.5 - 16.5	4
R03MG019	NA	61	51 - 61	2 [2]
R02MG020	NA	20	9.5 - 19.5	2
R02MG021	NA	16	9.5 - 14.5	2
R02MG022	NA	16	9.5 - 14.5	2
R03MG023	31.50	31	31 - 31	1 [1]



Existing Groundwater Monitoring Wells Proposed for Sampling

Building

Active Remediation Area

Passive Remediation Area

Naval Weapons Station Boundary

Road

Railroad

RASS Boundary

Mosquito Ditch

Fence

Other Surface Features

Notes:
1. Unless otherwise indicated, data in the table comes from IT Corporation, 1993.
2. [1] - Tetra Tech, 2004.
3. [2] - PRC, 1994.
4. NA - Not available.
5. RASS - Remedial action subsite.
6. TOC - Top of casing.

600 0 600
Feet

Tetra Tech EM Inc.

Naval Weapons Station Seal Beach Detachment
Concord, California
Engineering Field Activity West, Daly City

FIGURE C-7
GROUNDWATER MONITORING
WELL SPECIFICATIONS
LITIGATION AREA

Monitoring Plan

2004-10-08 V:\Concord\Projects\LA_long_term_monit_plan\GW_MW_Specifications.mxd TtEMI-SF Aleksandr Zhuk

TABLES

TABLE C-2: PROPOSED IMPLEMENTATION SCHEDULE FOR SAMPLING, ANALYSIS, AND REPORTING

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Milestone	Due Date	Anticipated Date
Final SAP to regulatory agencies	12 calendar days after Navy comments are received or October 14, 2004	October 14, 2004
Year 1 sampling events (groundwater, surface water – wet season, marsh soil, vegetation surveys, invertebrate and seed sampling)	Surface water – 3 events 1 week apart starting 15 November, 2004 (wet); 3 events 1 week apart, starting May 2, 2005 (dry) Groundwater – deep well installation and all wells sampled 1x in March 2004 Marsh soil – sample 1x in March 2004 Aerial photo of marsh surface and ground truthing – May 2004 Invertebrate/seed sampling – March 2004	July 15, 2005
Draft Year 1 TM submitted to agencies	21 days after receipt of Navy comments	September 12, 2005
Agency review of Draft Year 1 TM	60 days after submittal	November 11, 2005
Submit RTC and Draft Final Year 1 TM to agencies	19 days after Navy review completed	January 10, 2006
Year 2 sampling events (surface water – dry and wet season, groundwater sentinel wells)	Surface water – 3 events 1 week apart starting February 1, 2006 (wet); 3 events 1 week apart, starting May 1, 2006 (dry) Groundwater – 1x sentinel well sampling in February 2006 Aerial photo of marsh surface – May 2006	May 26, 2006
Draft Year 2 TM submitted to agencies	21 days after receipt of Navy comments	September 7, 2006
Agency review of Draft Year 2 TM	60 days after submittal	November 6, 2006
Submit RTC and Draft Final Year 2 TM to agencies	18 days after Navy review completed	January 5, 2007
Year 3 sampling events (surface water – dry and wet seasons, groundwater sentinel wells)	Surface water – 3 events 1 week apart starting February 1, 2007 (wet); 3 events 1 week apart, starting May 1, 2007 (dry) Groundwater – 1x sentinel well sampling in February 2007 Aerial photo of marsh surface – May 2007	May 25, 2007
Draft Year 3 TM submitted to agencies	21 days after receipt of Navy comments	September 3, 2007
Agency review of Draft Year 3 TM	60 days after submittal	November 2, 2007

TABLE C-2: PROPOSED IMPLEMENTATION SCHEDULE FOR SAMPLING, ANALYSIS, AND REPORTING (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Milestone	Due Date	Anticipated Date
Submit RTC and Draft Final Year 3 TM to agencies	18 days after Navy review completed	January 1, 2008
Year 4 sampling events (surface water – dry and wet seasons, groundwater sentinel wells)	Surface water – 3 events 1 week apart starting February 1, 2008 (wet); 3 events 1 week apart, starting May 1, 2008 (dry) Groundwater – 1x all wells sampling in February 2008 Aerial photo of marsh surface – May 2008	May 26, 2008
Draft Year 4 TM submitted to agencies	21 days after receipt of Navy comments	August 29, 2008
Agency review of Draft Year 4 TM	60 days after submittal	October 28, 2008
Submit RTC and Draft Final Year 4 TM to agencies	20 days after Navy review completed	December 29, 2008
Year 5 sampling events (surface water – dry and wet seasons, groundwater sentinel wells)	Surface water – 3 events 1 week apart starting February 1, 2009 (wet); 3 events 1 week apart, starting May 1, 2009 (dry) Groundwater – 1x sentinel wells sampling in February 2009 Marsh soil – sample 1x in March 2009 Aerial photo of marsh surface – May 2009	May 25, 2009
Draft 5-Year Periodic Review Assessment #2 submitted to agencies	21 days after receipt of Navy comments	January 1, 2010
Agency review of Draft 5-Year Periodic Review Assessment #2	60 days after submittal	March 3, 2010
Draft RTC for 5-Year Periodic Review Assessment #2 submitted to agencies	30 days after receipt of comments	April 2, 2010
Draft Final 5-Year Periodic Review Assessment #2 submitted to agencies	30 days after Draft RTC submitted to agencies	May 3, 2010

Notes:

RTC Response to comments
SAP Sampling and analysis plan
TM Technical memorandum

TABLE C-3: DATA QUALITY OBJECTIVES

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Step 1: State the Problem

The Navy completed four remedial actions between 1992 and 1995 at the Litigation Area, a 307-acre site located within the Tidal Area of the Naval Weapons Station Seal Beach Detachment Concord in north-central Contra Costa County, California. Six metal chemicals of concern (COC) (arsenic, cadmium, copper, lead, selenium, and zinc) identified in soil, sediment, and surface and groundwater have been the focus of 5 years of post-remediation monitoring conducted at four remedial action subsites (RASS). A baseline ecological risk assessment (BERA) was completed in 2003 as part of the first 5-year assessment review under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and identified selected locations across the site where concentrations of COCs remain at levels posing an unacceptable risk to ecological receptors. A long-term monitoring program is being proposed to continue to assess portions of the site where elevated concentrations of metals remain, as well as to address data gaps identified in the BERA and concerns raised by the regulatory agencies in their comments on the Draft Monitoring Plan. The broad objectives of the monitoring program include assessing compliance with regulatory requirements (primarily surface and groundwater components), evaluating the effectiveness of prior remedial actions (primarily for selected locations on the marsh surface), and assessing site conditions and ongoing risk to ecological receptors.

The following problems have been identified that require additional data collection as part of the monitoring program:

- Concentrations of several COCs in surface water have consistently exceeded the ambient water quality criteria (AWQC) during the 5 years of post-remediation monitoring. Continued monitoring of dissolved and total metals in the main reach of Lost Slough is needed to assess the AWQC that were exceeded, detect potentially significant increases in the magnitude of risk to aquatic receptors and wildlife, and assess the potential for off site transport of metals to Suisun Bay.
- Concentrations of several COCs in groundwater have consistently exceeded the AWQC during the 5 years of post-remediation monitoring. Continued periodic monitoring of concentrations of total metals in the existing network of 23 monitoring wells is needed to assess the AWQC that were exceeded as well as the potential for unacceptable risk to ecological receptors posed by contaminated groundwater. More frequent monitoring of a subgroup of wells along the border of the Navy property is needed to detect potential migration of contamination from off-site sources. More frequent monitoring is also indicated for wells that consistently exceed the AWQC or show increasing trends in concentrations of metals over time. The installation of several new, deeper wells is needed along the eastern border of the property adjacent to off-site industrial operations to detect potential migration of contaminants from these potential sources via the deep aquifer.
- Elevated concentrations of several COCs have consistently been detected in marsh surface soil in RASS 1 and 2 during the 5 years of post-remediation monitoring. Continued monitoring of total metals in surface soil is needed at locations where the highest concentrations of metals remain to detect potentially significant increases in the magnitude of risk to plants and wildlife on the marsh surface.
- The BERA conducted as part of the 5-year assessment review for the Litigation Area, as well as comments received from the regulatory agencies, identified characterization of exposure to contaminated soil and prey on the marsh surface as a data gap for the assessment of risk to the California Black Rail. Data on tissue burdens of metals in prey of the Black Rail are needed to fill this data gap and refine the results of the food chain modeling conducted in the BERA.
- The Navy requires an efficient means of monitoring landscape-scale changes in site conditions that could have negative impacts on plants and wildlife. Factors associated with habitat suitability, including both plant cover and forage quality, are believed to be key to explaining observed trends for several populations of special status species, such as the California Black Rail and the salt marsh harvest mouse. The Navy needs to be able to detect significant large-scale changes in vegetation and other surface features at the site that could provide early warning that habitat conditions are deteriorating for these species.

TABLE C-3: DATA QUALITY OBJECTIVES (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

STEP 2: Identify the Decisions

The following decisions will be addressed for each of the proposed monitoring components:

Surface Water:

(1) Do total or dissolved concentrations of one or more COCs in surface water exceed the AWQC at selected locations in the main reach (Units 9 and 10) of Lost Slough, and is there evidence that risk to ecological receptors is increasing and that elevated levels of COCs are being transported offsite to Suisun Bay? Alternative actions based on comparison of surface water metal concentrations to the AWQC include: evaluate remedial alternatives via the feasibility study process (based, in part, on evaluations being conducted as part of the current feasibility study), continue monitoring (with or without modifications to the monitoring design), and no further action.

Groundwater:

(2) Do total concentrations of one or more COCs exceed the AWQC in groundwater monitoring wells? Alternative actions based on comparison of groundwater metal concentrations to the AWQC include: evaluation of remedial alternatives via the feasibility study process, continue monitoring (with or without modifications to the monitoring design), and no further action.

(3) Is there evidence that COCs in groundwater are migrating from off-site sources on to Navy property? Alternative actions based on an examination of evidence of potential migration of COCs from offsite sources onto Navy property include: pursuing appropriate action against one or more potentially responsible parties (PRP), continue monitoring (with or without modifications to the monitoring design), and no further action.

Marsh Surface Soil:

(4) Do concentrations of one or more COCs in marsh surface soil exceed ecological benchmarks? Alternative actions based on comparison of soil concentrations of metals to ecological benchmarks include: evaluation of remedial alternatives via the feasibility study process, continue monitoring (with or without modifications to the monitoring design), and no further action.

Supplemental Evaluation of Risk to the California Black Rail:

(5) Are concentrations of COCs in marsh surface soil or prey of the California Black Rail at sufficient levels to pose an unacceptable risk to this species? Alternative actions based on refinement of the risk assessment for the Black Rail include: evaluation of remedial alternatives via the feasibility study process, continued monitoring (with or without modifications to the monitoring design), and no further action.

Detection of Landscape-Scale Changes in Site Conditions:

(6) Are significant large-scale changes in vegetation or other site factors occurring that could signal the potential for negative impacts to plants and wildlife? Alternative actions based on an examination of evidence that significant changes in site conditions are occurring will depend on the specific nature of the changes. The Navy will review all evidence of changes in site conditions and prepare technical recommendations for any modifications to the monitoring plan or a proposal to implement other alternative actions as needed.

STEP 3: Identify Inputs to the Decisions

- Validated analytical chemistry data for total and dissolved metals, temperature, pH, conductivity, and suspended solids in surface water samples from the main reach of Lost Slough (Units 9 and 10).
- Validated analytical chemistry data for total metals, temperature, pH, conductivity, and suspended solids from all groundwater-monitoring wells at the site.
- Validated analytical chemistry data for total metals in marsh surface soil.
- Validated analytical chemistry data for total whole-body concentrations of metals in selected prey of the California Black Rail.

TABLE C-3: DATA QUALITY OBJECTIVES (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

STEP 3: Identify Inputs to the Decisions (Continued)

- Benchmark values or promulgated criteria for assessing the potential risk posed by concentrations of COCs in soil, surface water, and groundwater. For surface water and groundwater, the criteria will be the AWQC. No promulgated criteria currently exist for soil. The Navy will prepare a technical memorandum outlining a proposed approach for deriving soil criteria, and will submit this for agency review prior to analyzing the next round of monitoring data. The Navy will review options for deriving food-chain modeling data via back calculation or adopting a set of ecological benchmarks for evaluating soil.
- Analysis of metals in marsh surface soil, surface water, and groundwater will follow U.S. Environmental Protection Agency (EPA) 6010B/7000 and EPA 6020/7000 (water), SW-846. Analysis for mercury will follow EPA 1631 and 7000 (soil) and for hexavalent chromium will follow EPA 7196A, SW-846.

STEP 4: Define Study Boundaries

Except for groundwater monitoring, sampling activities will be restricted to the marsh surface in RASS 1 and 2.

Soil samples will be collected from 0 to 0.50 feet below ground surface (bgs) within selected portions of RASS 1 and 2. Surface water sampling will be conducted in the main reach (spatial units 9 and 10) of Lost Slough in RASS 1. Groundwater samples will be collected from the existing network of monitoring wells located in RASSs 1, 2, and 3, as well as from three new deep wells that will be established in RASS 1 (2 wells) and RASS 2 (1 well).

Temporal boundaries for the design are defined by the sampling schedule for individual monitoring components and ultimately by the expected duration of the long-term monitoring program. Sampling frequency for individual monitoring components (see Table 1) include: a one-time event during the next round of sampling (tissue concentrations for prey of the Black Rail), six sampling events per year (surface water), one event per year (subset of groundwater wells), one event every 3 years (assessment of landscape-scale changes in site conditions, full network of groundwater monitoring wells), and one event every 5 years (marsh surface soil). The long-term duration of the monitoring program is unknown. Changes to the monitoring plan and schedule will undergo periodic evaluation over the life of the program.

STEP 5: Develop Decision Rules

The following decision rules will be applied to select an appropriate action based on the results obtained for each component of the monitoring program:

Surface Water:

(1) If one or more COCs in surface water exceed the chronic AWQC at any sampling location, then the Navy will use a weight-of-evidence (WOE) process (see discussion for item 1 in Step 6) to select one of the following alternative actions: evaluation of remedial alternatives via the feasibility study process and continued monitoring (with or without modification to the sampling design).

If all COCs in surface water are below the chronic AWQC for six consecutive events at all locations, then monitoring of surface water will be discontinued.

These decision rules are based on the most protective trigger level wherein additional evaluation is required in cases where even a single COC exceeds the AWQC at a point location during any sampling event. The final selection of an alternative action will use a WOE process to evaluate the following lines of evidence (LOE): (a) number of COCs that exceed the AWQC, (b) number of locations where the AWQC are exceeded, (c) frequency that AWQC are exceeded, (d) relative magnitude that they are exceeded, and (e) estimated risk to aquatic ecological receptors and/or plants and wildlife that consume or come into contact with surface water.

Assessment of risk to ecological receptors will include calculation of exposure point concentrations for metals in surface water based on estimates of the one-sided upper confidence limit of the average concentrations. It will be assumed that elevated concentrations of COCs are being transported off site to Suisun Bay if concentrations of any COCs near the mouth of Lost Slough exceed the AWQC.

Groundwater:

(2) If one or more COCs exceed the chronic AWQC in any groundwater monitoring well, then the Navy will use a WOE process (see discussion for item 2 in Step 6) to select one of the following alternative actions: evaluation of remedial alternatives via the feasibility study process, and continued monitoring (with or without modification to the sampling design).

STEP 5: Develop Decision Rules (Continued)

Groundwater (continued):

If all COCs are below the chronic AWQC for three consecutive sampling events, then monitoring of groundwater will be discontinued for that well. The exception to this rule will be "upgradient" wells located on the eastern border of the Navy's property, which are part of the subset of sentinel wells being used to detect ongoing and any new releases from offsite sources.

(3) If there is evidence of migration of COCs in groundwater from offsite sources on to Navy property, then the Navy will use a WOE process (see discussion for item 3 in Step 6) to select one or both of the following alternative actions: pursue appropriate action against one or more PRPs, and continued monitoring (with or without modifications to the monitoring design). If there is no evidence that offsite sources of COCs in groundwater are migrating onto Navy property, then the Navy will reevaluate the frequency of monitoring for individual wells based on the magnitude of COC concentrations relative to the AWQC.

Marsh Surface Soil:

(4) If concentrations of one or more COCs in marsh surface soil exceed ecological benchmarks at any sampling location, then the Navy will use a WOE process (see discussion for item 4 in Step 6) to select one of the following alternative actions: evaluation of remedial alternatives via the feasibility study process, and continued monitoring (with or without modifications to the monitoring design).

If all COCs in marsh surface soil are below the ecological benchmarks at all sampling locations for two successive sampling events, then monitoring of marsh surface soil will be discontinued. If all COCs are below the ecological benchmarks for only a subset of sampling locations for two successive sampling events, then the Navy will evaluate discontinuation of monitoring for the subset of locations only.

Supplemental Evaluation of Risk to the California Black Rail:

(5) If concentrations of one or more COCs in marsh surface soil or prey of the California Black Rail are at sufficient levels to pose an unacceptable risk to this species (that is, hazard quotients based on the high toxicity reference value exceed unity), then the Navy will select one of the following alternative actions: evaluation of remedial alternatives via the feasibility study process, and continued monitoring (with or without modifications to the monitoring design).

If all concentrations of COCs in marsh surface soil and prey are below levels that pose an unacceptable risk to the California Black Rail, then no additional monitoring will be conducted to evaluate risk to this species. That is, focused monitoring specifically conducted to evaluate risk to rails on the marsh surface, such as measurement of concentrations of COCs in prey tissue, will be discontinued. Decisions to continue monitoring of marsh surface soil will be based on ecological benchmarks for soil that have been exceeded.

Detection of Landscape-Scale Changes in Site Conditions:

(6) If monitoring results indicate that landscape-scale changes in site conditions are occurring that could signal the potential for negative impacts to plants and wildlife, then the Navy will further evaluate the extent of any potential impacts and prepare technical recommendations for any proposed actions. The proposed actions could include modifying the monitoring plan to include a focused investigation of the causal factors underlying any observed changes in site conditions, or an evaluation of remedial alternatives through the FS process.

Because this monitoring component is designed to provide early warning of a significant change in site conditions that could signal the potential for significant degradation of habitat for plants and wildlife, the Navy is not proposing any exit criteria for suspending monitoring activities at this time.

STEP 6: Specify Tolerable Limits on Decision Errors

Surface Water:

(1) The surface water sampling design uses professional judgment to select the number of samples, sampling locations, and sampling frequency. Sampling locations within individual areas (bottom, middle, and top) of each reach (that is, Unit 9 and Unit 10) of the slough will be selected at random. The decision rules for this monitoring component are based on comparing individual measurements at selected point locations to the AWQC. Limits on decision errors cannot be specified for comparisons between individual measurements and fixed threshold criteria.

STEP 6: Specify Tolerable Limits on Decision Errors

Surface Water (Continued)

Decision rules for the surface water DQOs are conservative in that they are based on assuring that all measurements from each location are below threshold criteria. However, surface water data will also be evaluated to monitor exposure conditions for aquatic receptors and wildlife and to determine whether elevated concentrations of COCs are being transported offsite to Suisun Bay. Per EPA guidance, an upper confidence limit of the average concentration is used to estimate exposure point concentrations within the context of a risk assessment. Appendix A in the Monitoring Plan discusses decision errors in cases where interest is in comparing average water column concentrations of COCs with the AWQC. The errors associated with comparison of average surface water concentrations to the AWQC include: falsely rejecting the null hypothesis (H_0) that average concentrations exceed the AWQC and, therefore, incorrectly concluding that no unacceptable risk exists (Type I error); and failing to reject H_0 when it is true and falsely concluding that unacceptable risk exists when average concentrations are below the AWQC (Type II error). Average concentrations will be calculated for several scenarios, including: a) individual seasons (wet and dry) for each sampling round (annual period), and b) both seasons combined within a sampling round. Averages will be calculated for individual reaches as well as both reaches combined for each scenario.

Calculation of average concentrations for each of the scenarios described above will be used as an additional line of evidence (LOE) in making decisions when criteria based on individual measurements are exceeded. That is, if one or more COCs exceed the AWQC at one or more locations, then several additional factors will be evaluated before selecting an appropriate action, including: comparison of average concentrations to the AWQC; consideration of the number of measurements, locations, and COCs that exceed the AWQC; and consideration of the relative magnitude that each measurement is exceeded, location, and COC.

Groundwater:

(2) The groundwater sampling design will use the existing network of 23 wells in addition to three new wells that will be installed in RASS 1 (2 new wells) and RASS 2 (1 new well). The decision rules for this monitoring component are based on comparing individual measurements within each well and sampling round to the AWQC, therefore, limits on decision errors cannot be specified.

Decision rules for the groundwater DQOs are conservative in that they are based on assuring that all measurements from each well are below threshold criteria. In the case of pesticides, detection limits for some constituents exceed threshold criteria. Cases where measured concentrations of pesticides exceed threshold criteria will be evaluated on a chemical by chemical basis. Because pesticides are not expected to occur in groundwater, the Navy does not feel the additional analytical costs required to achieve lower detection limits can be justified at the present time. Decisions concerning the appropriate action to take following each round of sampling will also consider additional LOEs, including an examination of temporal trends (see discussion below) and the spatial pattern of COC concentrations for closely spaced wells with similar hydrogeology. Decision errors can be specified in cases where closely spaced wells are grouped (or measurements over time are pooled for an individual well) and average concentrations of COCs are compared with the AWQC. In these cases, H_0 is that an average concentration of at least one COC exceeds its respective AWQC. The decision errors for these cases are rejecting H_0 when it is true and incorrectly concluding that average concentrations of all COCs are below the AWQC (Type I error), and failure to reject H_0 when it is false and incorrectly concluding that at least one average concentration exceeds its respective AWQC (Type II error). Because the potential for grouping wells (or measurements) during data analysis will be evaluated only after each round of sampling is completed and the results are reviewed, it is not possible to specify fixed thresholds for decision errors beforehand. Appendix A in the Monitoring Plan includes additional discussion on evaluating decision errors in cases where wells (or measurements) are grouped and estimation of average concentrations is needed to calculate exposure point concentrations.

Temporal trends in concentrations of COCs will be calculated for individual wells in the existing network of 23 wells plus the three new wells that will be established in RASS 1 and RASS 2. Short-term trends (that is, three or fewer rounds of sampling) will be evaluated qualitatively using graphical methods and professional judgment. For four or more rounds of sampling, monotonic trends will be evaluated using statistical as well as graphical methods. The H_0 for this design is that concentrations of one or more COCs in a well are increasing over time. Decision errors for trend testing include rejecting H_0 when it is true and incorrectly concluding that concentrations of COCs are not increasing (Type I error), and failing to reject H_0 when it is false and incorrectly concluding that an increasing trend exists (Type II error). Limits will not be established for decision errors in these cases, but rather professional judgment and a WOE process will be used to evaluate the trend test results (that is, tests against the H_0 of zero slope) for individual COCs, and calculation of the slope (that is, rate of change in chemical concentration) using parametric and nonparametric methods.

STEP 6: Specify Tolerable Limits on Decision Errors (Continued)

Groundwater: (Continued)

(3) Evidence of migration of COCs from offsite sources will be evaluated using professional judgment and examination of the following LOEs: (a) detection of elevated concentrations of one or more COCs in sentinel wells established along the border of the Navy's property, (b) observation of an increasing temporal trend in the concentration of one or more COCs in the sentinel wells, (c) observation of a decreasing spatial trend in the concentration of COCs extending from the sentinel wells along the property border toward the interior of Navy property (that is, downgradient), and (d) evaluation of groundwater elevation data. Professional judgment and a WOE process will be used to make a determination as to whether there is evidence of migration from offsite sources and what action the Navy should take.

Marsh Surface Soil:

(4) The selection of soil sampling locations on the marsh surface were selected based on an evaluation of data collected during the first 5 years of post-remediation monitoring. All locations exceeding at least one of two criteria (based on comparison of concentrations to the effects range- median [ER-M] benchmark for arsenic and the mean ER-M quotient calculated for all COCs) were selected for inclusion in the monitoring program (see item 4 under Step 7). The decision rules for evaluating the marsh soil monitoring component are based on comparison of individual surface soil measurements to ecological benchmarks that will be established for each COC. Limits on decision errors cannot be specified for comparisons between individual measurements and fixed threshold criteria.

Decision rules for the marsh surface soil DQOs are conservative in that they are based on assuring that all measurements from each location are below threshold criteria. Decisions concerning the appropriate action to take following each round of sampling will also consider additional LOEs, such as temporal trends and an examination of the spatial pattern of COC concentrations for closely spaced sampling locations. Decision errors can be specified in cases where closely spaced locations are grouped (or measurements over time are pooled for an individual location) and average concentrations of COCs are compared to ecological benchmarks. In these cases, H_0 is that an average concentration of at least one COC exceeds its ecological benchmark. The decision errors for these cases are rejecting H_0 when it is true and incorrectly concluding that average concentrations of all COCs are below benchmark values (Type I error), and failure to reject H_0 when it is false and incorrectly concluding that at least one average concentration exceeds its benchmark (Type II error). Because the decision to group sampling locations (or measurements) will be made as part of the data analysis (that is, after each new round of results is reviewed and different options for evaluating the data are assessed), it is not possible to specify fixed thresholds for decision errors beforehand. Appendix A in the Monitoring Plan includes additional discussion on evaluating decision errors in cases where individual locations (or measurements) are grouped and estimation of average concentrations is performed to calculate exposure point concentrations.

Supplemental Evaluation of Risk to the California Black Rail:

(5) Risk will be calculated for the California Black Rail using a food-chain modeling approach and collocated soil and prey (terrestrial invertebrates and seeds) samples collected from three areas on the marsh surface. Directed or judgmental sampling will be used to assure that soil and prey samples are collected from areas where the highest concentrations of arsenic and other COCs have been measured. To the extent practicable, prey selection will focus on food items that have the highest bioaccumulation potential for arsenic and other COCs based on literature reviews. The purpose of sample collection is to fill a data gap and will address the hypothesis that concentrations of COCs in marsh surface soil and prey items pose an unacceptable risk to the Black Rail. Limits on decision errors are not specified for this component because only judgmental samples will be collected. The relative magnitude of the hazard quotients obtained for this new set of samples will be compared qualitatively with results previously reported in the BERA, and the Navy will discuss the implications of these results with the regulatory agencies.

TABLE C-3: DATA QUALITY OBJECTIVES (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

STEP 6: Specify Tolerable Limits on Decision Errors (Continued)

Detection of Landscape-Scale Changes in Site Conditions:

(6) Parameters of the sampling design for this component will be developed through a pilot study conducted as part of the next sampling event (see item 6 under Step 7). The ultimate goal of the design is to provide an efficient means to detect significant landscape-scale changes in site conditions that could signal the potential for negative impacts to plants and wildlife. Of particular interest are major changes in dominant vegetation communities, especially those plant species known to be favored for cover and forage by special status species such as the California Black Rail and the salt marsh harvest mouse. The pilot study will investigate whether it is technically feasible to specify quantitative decision errors for different elements of the design. If technically feasible, the design would establish a fixed probability of being able to detect a particular magnitude of change in one or more elements (for example, a 40 to 50 percent change in pickleweed cover in selected habitats preferred by the salt marsh harvest mouse). The H_0 for the design will be that significant changes in site conditions are occurring that could potentially impact plants and wildlife. The decision errors in this case would include rejecting H_0 when it is true and incorrectly concluding that site conditions are acceptable (Type I error), and failure to reject H_0 when it is false, and incorrectly concluding that site conditions are unacceptable (Type II error).

STEP 7: Optimize the Sampling Design

Surface Water:

(1) Surface water samples will be collected from three locations in Unit 9 and three locations in Unit 10 during three sampling events (approximately 1 to 2 weeks between events) in both the wet and dry seasons (that is, 2 Units times 3 locations times 3 events times 2 season, for a total of 36 samples per year from the main channel of Lost Slough). Sampling will be conducted annually. Sample locations will be distributed evenly within each reach (that is, one sample from the first third of each reach, one sample from the middle of each reach, and one sample from the last third of each reach). Samples will be collected at mid depth from the center of the channel in each reach during an outgoing tide Samples will be analyzed for total and dissolved metals (full suite of contract laboratory program [CLP] metals), temperature (field measurement), pH, conductivity, and total suspended solids.

Groundwater:

(2-3) A single sample will be collected from each of the existing 23 groundwater monitoring wells, plus three new wells that will be installed before the next round of sampling, during a single sampling event in the wet season every 3 years (Figure C-3). The three additional groundwater-monitoring wells will extend into the deep aquifer. Two of these wells will be located in RASS 1 along the berm separating the Navy and off site industrial properties to the east (Honeywell), and one well will be located southwest of the berm in RASS 2, near existing well R02AG009. A subset of wells, including the three new wells, will be identified as “sentinel” wells and will be sampled once per year during the wet season. The sentinel wells will be made up of wells located near the border of the property (that is, those wells that have the potential to measure ongoing migration from off site sources), and any wells that show an increasing trend in concentrations based on the previous two rounds of sampling (that is, data collected in 2003 and data collected during the next round of sampling) or wells where metal concentrations are reported that are consistently in excess of the AWQC. The full set of sentinel wells will be identified following the next round of sampling, and annual sampling of this subset of wells will commence the following year (that is, the year following the next round of sampling). Samples will be analyzed for total metals (full suite contract laboratory program (CLP) metals), temperature (field measurement), pH, conductivity, total dissolved solids, and total suspended solids.

Marsh Surface Soil:

(4) Marsh surface soil will be sampled every 5 years and will use the existing network of locations (that is, each location is defined by a 100 by 100 foot grid) established as part of the existing post-remediation monitoring design. Sampling locations were selected based on meeting either of two criteria applied to the existing 5 years of post-remediation monitoring data: at least one sample with an ER-M for arsenic greater than 1.0, or at least one sample with a mean ER-M quotient greater than 1.5 for all six COCs. A total of 32 marsh surface sampling locations met at least one of the selection criteria (Table C-8, Figure C-3).

A single random sample will be collected at a depth of 0 to 0.5 feet below ground surface from each of the four grid quadrants at each sampling location. One new 100 by 100 foot grid will also be established east of grid 078 (location R01SS308) to fill a spatial data gap. Therefore, a total of 128 surface soil samples (32 locations X 4 samples per location) will be collected every 5 years. Samples will be analyzed for total metals (full suite of CLP metals), pH, and total organic carbon.

TABLE C-3: DATA QUALITY OBJECTIVES (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

STEP 7: Optimize the Sampling Design (Continued)

Supplemental Evaluation of Risk to the California Black Rail:

(5) Sampling to measure whole-body concentrations of COCs in prey items of the California Black Rail and concentrations in collocated soil samples will be conducted within three areas on the marsh surface during the next round of sampling. This will be a one-time sampling event, but may need to be conducted over a period of several months to account for the temporal variability of target prey items. Sampling will focus on areas of the site where the highest concentrations of arsenic and other COCs have been measured during the first five years of post-remediation monitoring. Black Rails are known to be opportunistic feeders and consume a variety of invertebrates (snails, amphipods, and spiders), insects, and seeds (including cattails and bulrush). Since both the diet of rails on the marsh surface and the seasonal availability of potential prey items is not known, it is not possible to identify all of the parameters of the sampling design before the field work is conducted. The design will be based on collecting a minimum of three samples for at least two food categories: terrestrial invertebrates and seeds. Each sample will consist of a composite of individual invertebrates or seeds collected within a 100-foot X 100-foot grid from representative rail habitats on the marsh surface. It may be necessary to pool more than one invertebrate species or the seeds from more than one plant species to collect a sufficient sample for chemical analysis. Different orders of invertebrates and species of seeds will be maintained in separate sample containers during the field collection, and a decision on the need for pooling will be made after sampling is completed and an assessment is made as to the relative mass of each food type collected within each of the sampling grids. If sufficient biomass is collected for multiple invertebrate species and seeds of multiple plant species, selection will be based on the prey or food items that have the greatest bioaccumulation potential for arsenic and other COCs (subject to the availability of information on bioaccumulation in the technical literature for the prey or food items collected).

Detection of Landscape-Scale Changes in Site Conditions:

(6) A pilot study will be conducted to evaluate alternative designs and data collection methods for assessing landscape-scale changes in site conditions. The pilot study will be conducted as part of the next sampling event and will be used to determine the design parameters for subsequent monitoring events. The Navy will evaluate the feasibility of using aerial photographs as a means to provide coarse or landscape-scale resolution of dominant vegetation types across the site (as well as changes in other surface features). Ground surveys will be used to evaluate the accuracy with which selected vegetation types can be determined based on features identified in the photographs. If deemed to be technically feasible and cost effective, this approach will create a permanent record of the relative cover of different vegetation communities (and other surface features at the site) and allow the Navy to assess whether significant changes are occurring over time.

The Navy will also evaluate the utility of establishing a network of permanent photo points in selected areas of the site to provide better resolution of changes in vegetation and other surface features at a finer spatial scale. Existing vegetation maps, analysis of aerial photographs, and results of previous wildlife studies will be used to define candidate areas for establishing permanent photo points.

An assessment of landscape-scale changes in site conditions will be conducted every 3 years.

Notes:

AWQC	Ambient water quality criteria
BERA	Baseline ecological risk assessment
CLP	Contract laboratory program
COC	Chemical of concern
DQO	Data quality objective
EPA	U.S. Environmental Protection Agency
ER-M	Effects range-median
FS	Feasibility study
FCM	Food-chain modeling
GW	Groundwater
H_0	Null hypothesis
Navy	U.S. Department of the Navy
PRP	potentially responsible parties
RASS	Remedial action sub-site
SW	Surface water

TABLE C-4: QUALITY CONTROL SAMPLES FOR PRECISION AND ACCURACY

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

QC Type	Precision	Accuracy	Frequency
Field QC	Field Duplicate	None	Field Duplicate = 10 percent of samples (water)
		Equipment Rinsate	Equipment Rinsate = 1/day/piece of equipment used for sampling
		Source Water Blank	Source Water Blank = 1/source of water used for the final decontamination rinse
		Trip Blank	One per transport container with samples for analysis of VOCs and TPH purgeable
		Temperature Blank	One per transport container with samples for analysis of VOCs and TPH purgeable
Laboratory QC	MS/MSD RPD	MS/MSD %R	MS/MSD = 1/20 samples (soil, water, and prey*)
		Method Blanks	Method Blank = 1/20 samples (all samples)
		LCS or Blank Spikes	LCS or Blank Spikes = 1/20 samples (soil, water, and SRM)
		Surrogate Standards %R	Every sample for organic analysis by GC (deep aquifer groundwater)
		Internal Standards %R	Every sample for organic analysis by GC/MS (deep aquifer groundwater)

Notes:

*	If tissue mass collected allows for this.
%R	Percent recovery
GC	Gas chromatography
GC/MS	Gas chromatography and mass spectroscopy
LCS	Laboratory control sample
MS/MSD	Matrix spike/matrix spike duplicate
QC	Quality control
RPD	Relative percent difference
SRM	Standard Reference Material
TPH-p	Total petroleum hydrocarbons (purgeable)
VOC	Volatile organic compound

TABLE C-5: KEY PERSONNEL

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Name	Organization	Role	Responsibilities	Contact Information
Stephen Tyahla	Navy	Remedial Project Manager (Acting)	Responsible for overall project execution and for coordination with base representatives, regulatory agencies, and Navy management Actively participates in DQO process Provides management and technical oversight during data collection	Naval Facilities Engineering Command, Engineering Field Activity West EFA West), Daly City, CA stephen.f.tyahla@navy.mil (650) 746-7451
Narciso A. Ancog	Navy	QA Officer	Responsible for QA issues for all SWDIV environmental work Provides government oversight of Tetra Tech's QA program Reviews and approves SAP and any significant modifications Has authority to suspend project activities if Navy quality requirements are not met	Naval Facilities Engineering Command, SWDIV, San Diego, CA narciso.ancog@navy.mil (619) 532-2540
Joanna Canepa	Tetra Tech	Installation Coordinator	Responsible for ensuring that all Tetra Tech activities at this installation are carried out in accordance with current Navy requirements and Tetra Tech program guidance	Tetra Tech EMI, San Francisco, CA Joanna.Canepa@ttemi.com (415) 222-8362
Cindi Rose	Tetra Tech	Project Manager	Responsible for implementing all activities called out in DO Prepares or supervises preparation of SAP Monitors and directs field activities to ensure compliance with SAP requirements Oversees data analysis, interpretation, and report preparation	Tetra Tech EMI, San Francisco, CA Cindi.Rose@ttemi.com (415) 222-8286
Greg Swanson	Tetra Tech	Program QA Manager	Responsible for regular discussion and resolution of QA issues with Navy QA officer Provides program-level QA guidance to installation coordinator, project manager, and project teams Reviews and approves SAPs Identifies nonconformances through audits and other QA review activities and recommends corrective action	Tetra Tech EMI, San Diego, CA Greg.Swanson@ttemi.com (619) 525-7188

TABLE C-5: KEY PERSONNEL (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Name	Organization	Role	Responsibilities	Contact Information
Ron Ohta	Tetra Tech	Project QA Officer	Responsible for providing guidance to project teams that are preparing SAPs Verifies that data collection methods specified in SAP comply with Navy and Tetra Tech requirements May conduct laboratory evaluations and audits	Tetra Tech EMI, Sacramento, CA Ron.Ohta@ttemi.com (916) 853-4506
Richard Vernimen	Tetra Tech	Field Team Leader	Responsible for directing day-to-day field activities conducted by Tetra Tech and subcontractor personnel Verifies that field sampling and measurement procedures follow SAP Provides project manager with regular reports on status of field activities	Tetra Tech EMI, San Francisco, CA Richard.Vernimen@ttemi.com (415) 222-8226
To Be Determined	Tetra Tech	On-site Safety Officer	Responsible for implementing health and safety plan and for determining appropriate site control measures and personal protection levels Conducts safety briefings for Tetra Tech and subcontractor personnel and site visitors Can suspend operations that threaten health and safety	To Be Determined
Kevin Hoch	Tetra Tech	Chemist	Responsible for working with project team to define analytical requirements Assists in selecting a pre-qualified laboratory to complete required analyses (see Section 2.4 of SAP) Coordinates with laboratory project manager on analytical requirements, delivery schedules, and logistics Reviews laboratory data before they are released to project team	Tetra Tech EMI, San Francisco, CA Kevin.Hoch@ttemi.com (415) 222-8304
Wing Tse	Tetra Tech	Database Manager	Responsible for developing, monitoring, and maintaining project database under guidance of project manager Works with analytical coordinator during preparation of SAP to resolve sample identification issues	Tetra Tech EMI, San Francisco, CA Wing.Tse@ttemi.com (415) 222-8326

TABLE C-5: KEY PERSONNEL (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Name	Organization	Role	Responsibilities	Contact Information
To Be Determined	Laboratory	Project Manager	Responsible for delivering analytical services that meet requirements of SAP	To Be Determined
			Reviews SAP to understand analytical requirements	
			Works with Tetra Tech analytical coordinator to confirm sample delivery schedules	
			Reviews laboratory data package before it is delivered to Tetra Tech	
To Be Determined	Subcontractor	Project Manager	Responsible for ensuring that subcontractor activities are conducted in accordance with requirements of SAP	To Be Determined
			Coordinates subcontractor activities with Tetra Tech project manager or field team leader	

Notes:

DO	Delivery order
DQO	Data quality objective
Navy	U.S. Department of the Navy
QA	Quality assurance
SAP	Sampling and analysis plan
SWDIV	Naval Facilities Engineering Command, Southwest Division
Tetra Tech	Tetra Tech EM Inc.

TABLE C-6: REQUIREMENTS FOR SUMMARY AND FULL DATA PACKAGES

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Requirements for Summary Data Packages – Organic Analysis	Requirements for Summary Data Packages – Inorganic Analysis
Section I Case Narrative	**Section I Case Narrative**
1. Case narrative	1. Case narrative
2. Copies of nonconformance and corrective action forms	2. Copies of nonconformance and corrective action forms
3. Chain-of-custody forms	3. Chain-of-custody forms
4. Copies of sample receipt notices	4. Copies of sample receipt notices
5. Internal tracking documents, as applicable	5. Internal tracking documents, as applicable
Section II Sample Results - Form I for the following:	**Section II Sample Results - Form I for the following:**
1. Environmental samples, including dilutions and re-analysis	1. Environmental sample including dilutions and re-analysis
2. Tentatively identified compounds (TIC) (SVOC only)	
	Section III QA/QC Summaries - Forms II through XIV for the following:
Section III QA/QC Summaries - Forms II through XI for the following:	1. Initial and continuing calibration verifications (Form II)
1. System monitoring compound and surrogate recoveries (Form II)	2. PRRL standard (Form II)
2. MS and MSD recoveries and RPDs (Forms I and III)	3. Detection limit standard (Form II-Z)
3. Blank spike or LCS recoveries (Forms I and III-Z)	4. Method blanks, continuing calibration blanks, and preparation blanks (Form III)
4. Method blanks (Forms I and IV)	5. Inductively coupled plasma (ICP) interference-check samples (Form IV)
5. Performance check (Form V)	6. MS and post-digestion spikes (Forms V and V-Z)
6. Initial calibrations with retention time information (Form VI)	7. Sample duplicates (Form VI)
7. Continuing calibrations with retention time information (Form VII)	8. LCSs (Form VII)
8. Quantitation limit standard (Form VII-Z)	9. Method of standard additions (Form VIII)
9. Internal standard areas and retention times (Form VIII)	10. ICP serial dilution (Form IX)
10. Analytical sequence (Forms VIII-D and VIII-Z)	11. IDL (Form X)
11. Gel permeation chromatography (GPC) calibration (Form IX)	12. ICP interelement correction factors (Form XI)
12. Single component analyte identification (Form X)	13. ICP linear working range (Form XII)
13. Multicomponent analyte identification (Form X-Z)	
14. Matrix-specific MDL (Form XI-Z)	

TABLE C-6: REQUIREMENTS FOR SUMMARY AND FULL DATA PACKAGAES (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Requirements for Full Data Packages – Organic Analysis	Requirements for Full Data Packages – Inorganic Analysis
Section IV Sample Raw Data - indicated form, plus all raw data	**Section IV Instrument Raw Data - Sequential measurement readout records for ICP, graphite furnace atomic absorption (GFAA), flame atomic absorption (AA), cold vapor mercury, cyanide, and other inorganic analyses, which will contain the following information:**
1. Analytical results, including dilutions and re-analysis (Forms I and X)	1. Environmental samples, including dilutions and re-analysis
2. TICs (Form I — VOC and SVOC only)	2. Initial calibration
	3. Initial and continuing calibration verifications
Section V QC Raw Data - indicated form, plus all raw data	4. Detection limit standards
1. Method blanks (Form I)	5. Method blanks, continuing calibration blanks, and preparation blanks
2. MS and MSD samples (Form I)	6. ICP interference check samples
3. Blank spikes or LCSs (Form I)	7. MS and post-digestion spikes
	8. Sample duplicates
Section VI Standard Raw Data - indicated form, plus all raw data	9. LCSs
1. Performance check (Form V)	10. Method of standard additions
2. Initial calibrations, with retention-time information (Form VI)	11. ICP serial dilution
3. Continuing calibrations, with retention-time information (Form VII)	
4. Quantitation-limit standard (Form VII-Z)	**Section V Other Raw Data**
5. GPC calibration (Form IX)	1. Percent moisture for soil samples
	2. Sample digestion, distillation, and preparation logs, as necessary
Section VII Other Raw Data	3. Instrument analysis log for each instrument used
1. Percent moisture for soil samples	4. Standard preparation logs, including initial and final concentrations for each standard used
2. Sample extraction and cleanup logs	
3. Instrument analysis log for each instrument used (Form VIII-Z)	5. Formula and a sample calculation for the initial calibration
4. Standard preparation logs, including initial and final concentrations for each standard used	6. Formula and a sample calculation for soil sample results
5. Formula and a sample calculation for the initial calibration	
6. Formula and a sample calculation for soil sample results	

Notes:

GPC	Gel permeation chromatography	MSD	Matrix spike duplicate	SAP	Sampling and analysis plan
ICP	Inductively coupled plasma	PRRL	Project-required reporting limits	SVOC	Semivolatile organic compound
IDL	Instrument detection limit	QA/QC	Quality assurance/quality control	TIC	Tentatively identified compound
LCS	Laboratory control sample	RPD	Relative percent difference	VOC	Volatile organic compound
MS	Matrix spike				

TABLE C-7: SUMMARY OF PROPOSED SAMPLES, ANALYSES, AND RATIONALE

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Type of Samples	Analytes	Matrix	Number of Sampling Locations	Field Duplicate Samples	Other QC Samples	Total Number of Samples	Rationale
Initial RASS 1 and 2, Units 6 and 12, respectively, Soil Samples	Metals pH TOC	Soil	32 (times 4 quadrants sampled per location) (128 samples)	0	Equipment Rinsate (4)	132	Metals and pH need to be characterized in areas where reference values are exceeded
Surface water samples in the main channel of Lost Slough (Units 9 and 10)	Total metals Dissolved metals pH Conductivity TSS Temperature	Water	6 (Sampled 3 times in wet and 3 times in dry seasons during outgoing tides) (36 samples per annum)	6 (one per sampling event)	Equipment Rinsate (6) Source Water Blank (6)	54	Assess metal concentrations in water in the slough and entering Suisun Bay
Initial RASS 1-4 Groundwater Samples	Total Metals pH Temperature Conductivity TSS TDS	Water	23	2	Equipment Rinsate (2)	27	Monitor wells still exceed AWQC and to establish sentinel wells for annual monitoring.

TABLE C-7: SUMMARY OF PROPOSED SAMPLES, ANALYSES, AND RATIONALE (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Type of Samples	Analytes	Matrix	Number of Sampling Locations	Field Duplicate Samples	Other QC Samples	Total Number of Samples	Rationale
Initial RASS 1 and 2 Deep Aquifer Groundwater Samples	Total Metals (including hexavalent chromium) TSS TDS pH Temperature Conductivity VOC's SVOC's Pesticides Herbicides TPH's PCBs	Water	3	1	Equipment Rinsate (1) Trip Blank (1) Temperature Blank (1) Source Water Blank (1)	8	Determine if contaminated water is migrating into the deep aquifer from off-site sources.
Prey Monitoring	Total metals % Moisture Content	Tissue	3 (If possible, 1 terrestrial invertebrate and 1 seed sample per location)	NA	NA	6	Fill a data gap in California Black Rail food chain modeling

Notes:

NA	Not applicable	TDS	Total Dissolved Solids
pH	Hydrogen	TOC	Total organic carbon
TSS	Total suspended solids	AWQC	Ambient Water Quality Criteria
%	Percent	CA	California
VOC	Volatile Organic Compound	SVOC	Semi-Volatile Organic Compound
RASS	Restoration Area Sub-site	PCB	Polychlorinated bi-phenyl
TPH	Total Petroleum Hydrocarbons		

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	**ID**	**Location**	**ID**	**Location**	**ID**	**Location**	**ID**
First Wet Season Event		R01MG001	105R01GW010	R01SS037	105R01SS130A 105R01SS131B 105R01SS132C 105R01SS133D	R01SS083	105R01IS001
R01SH309	105R01SW001	R01AG002	105R01GW011	R01SS095	105R01SS134A 105R01SS135B 105R01SS136C 105R01SS137D	R01SS083	105R01PL001
R01SH310	105R01SW002	R01AG003	105R01GW012	R01SS102	105R01SS138A 105R01SS139B 105R01SS140C 105R01SS141D	R01SS253	105R01IS002
R01SH311	105R01SW003	R01AG004	105R01GW013	R01SS103	105R01SS013A 105R01SS014B 105R01SS015C 105R01SS016D	R01SS253	105R01PL002
R01SH312	105R01SW004	R01PG005	105R01GW014	R01SS104	105R01SS017A 105R01SS018B 105R01SS019C 105R01SS020D	R01SS264	105R01IS003
R01SH313	105R01SW005	R01PG018	105R01GW015	R01SS062	105R01SS021A 105R01SS022B 105R01SS023C 105R01SS024D	R01SS264	105R01PL003

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	**ID**	**Location**	**ID**	**Location**	**ID**	**Location**	**ID**
R01SH314	105R01SW006	R01MD024[a]	105R01GW016	R01SS076	105R01SS025A 105R01SS026B 105R01SS027C 105R01SS028D		
R01SH314	105R01SW007[b]	R01MD025[a]	105R01GW017	R01SS078	105R01SS029A 105R01SS030B 105R01SS031C 105R01SS032D		
Equipment Rinsate	105R00SW008	R02MG007	105R02MG018	R01SS083	105R01SS033A 105R01SS034B 105R01SS035C 105R01SS036D		
Source Water Blank	105R00SW009	R02MG007	105R02GW019[b]	R01SS084	105R01SS037A 105R01SS038B 105R01SS039C 105R01SS040D		
Second Wet Season Event		R02AG008	105R02GW020	R01SS109	105R01SS041A 105R01SS042B 105R01SS043C 105R01SS044D		
R01SH309	105R01SW010	R02AG009	105R02GW021	R01SS088	105R01SS045A 105R01SS046B 105R01SS047C 105R01SS048D		
R01SH310	105R01SW011	R02MG020	105R02GW022	R01SS089	105R01SS049A 105R01SS050B 105R01SS051C 105R01SS052D		

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	ID	Location	ID	Location	ID	Location	ID
R01SH311	105R01SW012	R02MG021	105R02GW023	R01SS091	105R01SS053A 105R01SS054B 105R01SS055C 105R01SS056D		
R01SH312	105R01SW013	R02MG022	105R02GW024	R01SS106	105R01SS057A 105R01SS058B 105R01SS059C 105R01SS060D		
R01SH313	105R01SW014	R02MD026	105R02GW025	R01SS264	105R01SS061A 105R01SS062B 105R01SS063C 105R01SS064D		
R01SH314	105R01SW015	R02MD026[a]	105R02GW026[b]	R01SS107	105R01SS065A 105R01SS066B 105R01SS067C 105R01SS068D		
R01SH314	105R01SW016[b]	R03MG006	105R03GW027	R01SS108	105R01SS069A 105R01SS070B 105R01SS071C 105R01SS072D		
Equipment Rinsate	105R00SW017	R03AG010	105R03GW028	R01SS119	105R01SS073A 105R01SS074B 105R01SS075C 105R01SS076D		
Source Water Blank	105R00SW018	R03MG011	105R03GW029	R01SS125	105R01SS077A 105R01SS078B 105R01SS079C 105R01SS080D		

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	ID	Location	ID	Location	ID	Location	ID
Third Wet Season Event		R03MG012	105R03GW030	R01SS128	105R01SS081A 105R01SS082B 105R01SS083C 105R01SS084D		
R01SH309	105R01SW019	R03MG013	105R03GW031	R01SS135	105R01SS085A 105R01SS086B 105R01SS087C 105R01SS088D		
R01SH310	105R01SW020	R03MG014	105R03GW032	R01SS138	105R01SS089A 105R01SS090B 105R01SS091C 105R01SS092D		
R01SH311	105R01SW021	R03MG019	105R03GW033	R01SS253	105R01SS093A 105R01SS094B 105R01SS095C 105R01SS096D		
R01SH312	105R01SW022	R03MG023	105R03GW034	R01SS258	105R01SS097A 105R01SS098B 105R01SS099C 105R01SS100D		
R01SH313	105R01SW023	R03MG023	105R03GW035[b]	R01SS308[c]	105R01SS101A 105R01SS102B 105R01SS103C 105R01SS104D		

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	**ID**	**Location**	**ID**	**Location**	**ID**	**Location**	**ID**
R01SH314	105R01SW024	R04MG015	105R04GW036	R02SS271	105R01SS105A 105R01SS106B 105R01SS107C 105R01SS108D		
R01SH314	105R01SW025[b]	R04MG016	105R04GW037	R02SS267	105R01SS109A 105R01SS110B 105R01SS111C 105R01SS112D		
Equipment Rinsate	105R00SW026	R04MG017	105R04GW038	R02SS137	105R01SS113A 105R01SS114B 105R01SS115C 105R01SS116D		
Source Water Blank	105R00SW027	Equipment Rinsate	105R00GW039	R02SS148	105R01SS117A 105R01SS118B 105R01SS119C 105R01SS120D		
First Dry Season Event		Equipment Rinsate	105R00GW040	R02SS149	105R01SS121A 105R01SS122B 105R01SS123C 105R01SS124D		
R01SH309	105R01SW028	Equipment Rinsate	105R00GW041	R02SS150	105R01SS125A 105R01SS126B 105R01SS127C 105R01SS128D		
R01SH310	105R01SW029	Source Water Blank	105R00GW042	Equipment Rinsate	105R00SW055		

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	**ID**	**Location**	**ID**	**Location**	**ID**	**Location**	**ID**
R01SH311	105R01SW030	Trip Blank	105R00GW043	Equipment Rinsate	105R00SW056		
R01SH312	105R01SW031	Temperature Blank	105R00GW044	Equipment Rinsate	105R00SW057		
R01SH313	105R01SW032			Equipment Rinsate	105R00SW056		
R01SH314	105R01SW033						
R01SH314	105R01SW034[b]						
Equipment Rinsate	105R00SW035						
Source Water Blank	105R00SW036						
Second Dry Season Event							
R01SH309	105R01SW037						
R01SH310	105R01SW038						
R01SH311	105R01SW039						
R01SH312	105R01SW040						
R01SH313	105R01SW041						
R01SH314	105R01SW042						
R01SH314	105R01SW043[b]						
Equipment Rinsate	105R00SW044						
Source Water Blank	105R00SW045						

TABLE C-8: SUMMARY OF PROPOSED SAMPLE LOCATIONS AND IDENTIFICATION (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Surface Water		Groundwater		Soil		Prey	
Location	**ID**	**Location**	**ID**	**Location**	**ID**	**Location**	**ID**
Third Dry Season Event							
R01SH309	105R01SW046						
R01SH310	105R01SW047						
R01SH311	105R01SW048						
R01SH312	105R01SW049						
R01SH313	105R01SW050						
R01SH314	105R01SW051						
R01SH314	105R01SW052[b]						
Equipment Rinsate	105R00SW053						
Source Water Blank	105R00SW054						

Notes:

a New deep aquifer monitoring well at a proposed depth of 60 feet.
b QC field duplicate to assess precision of field sampling.
c New soil sampling location.
d Trip blank will be analyzed for VOCs and TPH-purgeables only.
e Temperature blank will be analyzed for temperature only.

ID Identification
QC Quality control
TPH Total petroleum hydrocarbon
VOC Volatile organic compound

TABLE C-9: SAMPLE CONTAINER, HOLDING TIME, AND PRESERVATIVE REQUIREMENTS

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Parameter	Method Number	Sample Volume	Sample Container	Preservative	Holding/Extraction Time[a]
Soil					
Metals (except Mercury)	EPA 6010B/ SW-846	2.5 grams	Two 8-ounce glass jars with Teflon-lined caps	Cool 4 ± 2ºC	180 days
Mercury	EPA 7471A/ SW-846	0.2 gram	A subsample from the container for metals analysis	Cool 4 ± 2ºC	28 days
pH	EPA 9040/9045A, SW-846	50 grams	A subsample from the container for metals analysis	Cool 4 ± 2ºC	2 days
TOC	EPA 415.2	25 grams	A subsample from the container for metals analysis	Cool 4 ± 2ºC	28 days
Surface Water					
Metals (except Mercury)	EPA 6010B/ SW-846	1 L	Polyethylene	pH < 2 with HNO_3; Cool 4 ± 2ºC	180 days
Mercury	EPA 7470A/ SW-846	100 mL	Polyethylene	pH < 2 with HNO_3; Cool 4 ± 2ºC	28 days
Dissolved metals (except Mercury)	EPA 6010B/ SW-846	1 L	Polyethylene	pH < 2 with HNO_3; Cool 4 ± 2ºC	180 days
Dissolved Mercury	EPA 7470A/ SW-846	100 mL	Polyethylene	pH < 2 with HNO_3; Cool 4 ± 2ºC	28 days
TSS	EPA 160.2	1 L	Polyethylene	Cool 4 ± 2ºC	7 days
Ground Water (All wells, including new deep aquifer wells)					
Metals (except Mercury)	EPA 6010B/ SW-846	1 L	Polyethylene	pH < 2 with HNO_3; Cool 4 ± 2ºC	6 months
Mercury	EPA 7470A/ SW-846	100 mL	A subsample from the container for metals analysis	pH < 2 with HNO_3; Cool 4 ± 2ºC	28 days
TSS	EPA 160.2	1 L	Polyethylene	Cool 4 ± 2ºC	7 days
TDS	EPA 160.1	One 1-L	Glass or polyethylene	Cool 4 ± 2ºC	7 days

TABLE C-9: SAMPLE CONTAINER, HOLDING TIME, AND PRESERVATIVE REQUIREMENTS (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Parameter	Method Number	Sample Volume	Sample Container	Preservative	Holding/Extraction Time[a]
Ground Water (New deep aquifer wells only)					
TPH-Extractables	EPA 8015B, SW-846	Two 1-L	Amber glass with Teflon-lined lid	Cool 4 ± 2ºC	7 days/40 days
TPH-Purgeables	EPA 8015B, SW-846	Three 40-mL	Amber glass vials with Teflon-lined lid	pH < 2 with HNO_3; Cool 4 ± 2ºC	14 days
Hexavalent Chromium	EPA 7196A, SW-846	500-mL	Polyethylene	Cool 4 ± 2ºC	24 hours
VOCs	EPA 8260B, SW-846	Three 40-mL	Amber glass vials with Teflon-lined lid	pH < 2 with HCL; Cool 4 ± 2ºC	14 days
SVOCs	EPA 8270C, SW-846	Two 1-L	Amber glass with Teflon-lined lid	Cool 4 ± 2ºC	7 days/40 days
PCBs	EPA 8082, SW-846	Four 1-L	Amber glass with Teflon-lined lid	Cool 4 ± 2ºC	7 days
Pesticides	EPA 8081A, SW846	Two 1-L	Amber glass with Teflon-lined lid	Cool 4 ± 2ºC	7 days/40 days
Herbicides	EPA 8151A, SW846	Two 1-L	Amber glass with Teflon-lined lid	Cool 4 ± 2ºC	7 days/40 days
Prey Tissue (Plant and Insect)					
Metals (except Mercury)	EPA 6010B/ SW-846	10 grams plant 70 grams insects	Zip-lock bag	None	180 days
Mercury	EPA 7470A/ SW-846	5 grams plant 10 grams insects	Zip-lock bag	None	28 days
% Moisture Content	CLP-SOW	5 grams	Zip-lock bag	None	None

TABLE C-9: SAMPLE CONTAINER, HOLDING TIME, AND PRESERVATIVE REQUIREMENTS (Continued)

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Notes: More than one analysis can be performed from the same sample container. The sample quantities listed in the table are the quantities necessary if only the specific analysis is requested. The laboratory will indicate which of the analyses can be performed from the same container so that a smaller quantity of sample can be collected at each depth.

Additional sample volume will be collected at 5 percent of the groundwater sampling locations for matrix spike / matrix spike duplicate analysis.

Analyses for characterization of investigation-derived waste (IDW) samples are included in the table.

a "x" days/"y" days refers to the maximum number of days from sampling to extraction/the maximum number of days from extraction to analysis.

EPA	U.S. Environmental Protection Agency
HNO_3	Nitric acid
L	Liter
mL	Milliliter
TDS	Total dissolved solids
SVOC	Semivolatile organic compound
PCB	Polychlorinated biphenyl
SOW	Statement of Work
TSS	Total suspended solids
TOC	Total organic carbon
CLP	Contract Laboratory Program
VOC	Volatile organic compound

TABLE C-10: FIELD QC SAMPLES

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Sample Type	Frequency of Analysis	Matrix
Source Water Blank	1 per source of water used for the final decontamination rinse	Water
Field Duplicate	10 percent	Water
Equipment Rinsate	1 per day of soil sampling[a]	Soil
Trip Blank	1 per container used to ship deep aquifer groundwater samples	Water
Temperature Blank	1 per container used to ship deep aquifer groundwater samples	Water

Note:

a Tetra Tech anticipates one soil sampling event, occurring over the course of two days, per year.

TABLE C-11: DATA VALIDATION CRITERIA

Monitoring Plan, Litigation Area, Naval Weapons Station Seal Beach Detachment Concord

Analytical Parameter Group	Cursory Data Validation Criteria	Full Data Validation Criteria
CLP Inorganic Analyses	Holding times Calibration Blanks Matrix spike recovery Matrix duplicate sample analysis Laboratory control sample or blank spike Field duplicate sample analysis Inductively Coupled Plasma (ICP) serial dilution Overall assessment of data for an SDG	Holding times Calibration Blanks ICP interference check sample Matrix spike recovery Matrix duplicate sample analysis Laboratory control sample Field duplicate sample analysis Graphite furnace atomic absorption QC Sample result verification ICP serial dilution Detection limits Overall assessment of data for an SDG
Non-CLP Inorganic and Physical Analyses	Method compliance Holding times Calibration Blanks Matrix spike and matrix spike duplicate recovery Laboratory control sample or blank spike Field duplicate sample analysis Other laboratory QC specified by the method Overall assessment of data for an SDG	Method compliance Holding times Calibration Blanks Matrix spike and matrix spike duplicate recovery Laboratory control sample Field duplicate sample analysis Other laboratory QC specified by the method Detection limits Analyte identification Analyte quantitation Sample results verification Overall assessment of data for an SDG

Notes:

CLP Contract laboratory program
QC Quality control
SDG Sample delivery group

ATTACHMENT A
METHOD PRECISION AND ACCURACY GOALS

TABLE A-1: METHOD PRECISION AND ACCURACY GOALS

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment, Concord

Compound	QC Type	Analytical Method	Precision (RPD)(a)	Accuracy (% Rec)(b)
			Water	Water
Total petroleum hydrocarbons-extractable				
Diesel	MS/MSD	EPA 8015B/CA LUFT Manual	50	50-150
Diesel	LCS	EPA 8015B/CA LUFT Manual	NA	60–140
Hexacosane	Surrogate	EPA 8015B/CA LUFT Manual	NA	60-140
Total petroleum hydrocarbons-purgeable				
Gasoline	MS/MSD	EPA 8015B/CA LUFT Manual	30	70-130
Gasoline	LCS	EPA 8015B/CA LUFT Manual	NA	75–125
Bromofluorobenzene	Surrogate	EPA 8015B/CA LUFT Manual	NA	75-125
Metals				
All metals	Matrix Spike	EPA 6010B/7000A/1631	NA	75-125
Metals	LCS	EPA 6010B/7000A	NA	80-120
Mercury	LCS	EPA 1631	NA	75-125
All metals	Duplicate	EPA 6010B/7000A	20	NA
Hexavalent Chromium				
Hexavalent chromium	MS, LCS	EPA 7196A	NA	85-115
Hexavalent chromium	Duplicate	EPA 7196A	20	NA
Volatile Organic Compounds				
1,1-Dichloroethene	MS/MSD, LCS	EPA 8260B	14	61-145
Trichloroethene	MS/MSD, LCS	EPA 8260B	14	71-120
Benzene	MS/MSD, LCS	EPA 8260B	11	76-127
Toluene	MS/MSD, LCS	EPA 8260B	13	76-125
Chlorobenenze	MS/MSD, LCS	EPA 8260B	13	75-130
Toluene-d8	Surrogate	EPA 8260B	NA	88-110
Bromofluorobenzene	Surrogate	EPA 8260B	NA	86-115
1,2-Dichloroethane-d4	Surrogate	EPA 8260B	NA	76-114

TABLE A-1: METHOD PRECISION AND ACCURACY GOALS (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment, Concord

Compound	QC Type	Analytical Method	Precision (RPD)(a)	Accuracy (% Rec)(b)
			Water	Water
Semivolatile Organic Compounds				
Acenaphthene	MS/MSD, LCS	EPA 8270C	31	46-118
2,4-Dinitrotoluene	MS/MSD, LCS	EPA 8270C	38	24-96
Pyrene	MS/MSD, LCS	EPA 8270C	31	26-127
N-Nitroso-di-n-propylamine	MS/MSD, LCS	EPA 8270C	38	41-116
Pentachlorophenol	MS/MSD, LCS	EPA 8270C	50	9-103
Phenol	MS/MSD, LCS	EPA 8270C	42	12-110
2-Chlorophenol	MS/MSD, LCS	EPA 8270C	40	27-123
4-Chloro-3-methylphenol	MS/MSD, LCS	EPA 8270C	42	23-97
4-Nitrophenol	MS/MSD, LCS	EPA 8270C	50	10-80
Nitrobenzene-d5	Surrogate	EPA 8270C	NA	35-114
2-Fluorobiphenyl	Surrogate	EPA 8270C	NA	43-116
p-Terphenyl-d14	Surrogate	EPA 8270C	NA	33-141
Phenol-d5	Surrogate	EPA 8270C	NA	10-110
2-Fluorophenol	Surrogate	EPA 8270C	NA	21-110
2,4,6-Tribromophenol	Surrogate	EPA 8270C	NA	10-123
Pesticides				
gamma-BHC	MS/MSD, LCS	EPA 8081A	15	56-123
Heptachlor	MS/MSD, LCS	EPA 8081A	20	40-131
Aldrin	MS/MSD, LCS	EPA 8081A	22	40-120
Dieldrin	MS/MSD, LCS	EPA 8081A	18	52-126
Endrin	MS/MSD, LCS	EPA 8081A	21	56-121
4,4-DDT	MS/MSD, LCS	EPA 8081A	27	38-127
Tetra-m-xylene	Surrogate	EPA 8081A	NA	30-150
Decachlorobiphenyl	Surrogate	EPA 8081A	NA	30-150

TABLE A-1: METHOD PRECISION AND ACCURACY GOALS (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment, Concord

Compound	QC Type	Analytical Method	Precision (RPD)(a)	Accuracy (% Rec)(b)
			Water	Water
Herbicides				
2, 4-D	MS/MSD, LCS	EPA 8151A	20	55-140
2, 4, 5-TP (Silvex)	MS/MSD, LCS	EPA 8151A	20	50-120
2, 4, 5-T	MS/MSD, LCS	EPA 8151A	20	65-120
2, 4-D	Surrogate	EPA 8151A	NA	47-154
Miscellaneous Analytes				
Total dissolved solids	Duplicate	EPA 160.1	20	NA
Total suspended solids	Duplicate	EPA 160.2	20	NA

Notes:

a Precision as relative percent difference (RPD)

b Accuracy as percent recovery (% Rec)

CA LUFT State of California. 1989. "LUFT Field Manual: Guidelines for Site Assessment, Cleanup, and Underground Storage Tank Closure." Leaking Underground Fuel Tank Task Force. October.

EPA U.S. Environmental Protection Agency

LCS Laboratory control spike (blank spike)

MS/MSD Matrix spike and matrix spike duplicate

NA Not applicable

%Rec Percent recovery

QC Quality control

RPD Relative percent difference

ATTACHMENT B
STANDARD OPERATING PROCEDURES

SOP No. 002	General Equipment Decontamination
SOP No. 005	Soil Sampling
SOP No. 009	Surface Water Sampling
SOP No. 010	Groundwater Sampling
SOP No. 011	Field Measurement of Water Temperature
SOP No. 012	Field Measurement of pH
SOP No. 013	Field Measurement of Specific Conductance
SOP No. 014	Static Water Level, Total Well Depth, and Immiscible Layer Measurement
SOP No. 019	Packaging and Shipping Samples
SOP No. 020	Monitoring Well Installation
SOP No. 021	Monitoring Well Development
SOP No. 024	Recording of Notes in Field Logbook
SOP No. 026	Borehole Logging
SOP No. 061	Field Measurement of Groundwater pH, Specific Conductance, and Temperature Using the YSI Model 3560

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

GENERAL EQUIPMENT DECONTAMINATION

SOP NO. 002

REVISION NO. 2

Last Reviewed: December 1999

Quality Assurance Approved	*February 2, 1993* Date

1.0 BACKGROUND

All nondisposable field equipment must be decontaminated before and after each use at each sampling location to obtain representative samples and to reduce the possibility of cross-contamination.

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for decontaminating equipment in the field.

1.2 SCOPE

This SOP applies to decontaminating general nondisposable field equipment. To prevent contamination of samples, all sampling equipment must be thoroughly cleaned prior to each use.

1.3 DEFINITIONS

Alconox: Nonphosphate soap

1.4 REFERENCES

U.S. Environmental Protection Agency (EPA). 1992. "RCRA Ground-Water Monitoring: Draft Technical Guidance. Office of Solid Waste. Washington, DC. EPA/530-R-93-001. November.

EPA. 1994. "Sampling Equipment Decontamination." Environmental Response Team SOP #2006 (Rev. #0.0, 08/11/94). On-Line Address: http://204.46.140.12/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

The equipment required to conduct decontamination is as follows:

- Scrub brushes
- Large wash tubs or buckets
- Squirt bottles

- Alconox
- Tap water
- Distilled water
- Plastic sheeting
- Aluminum foil
- Methanol or hexane
- Dilute (0.1 N) nitric acid

2.0 PROCEDURE

The procedures below discuss decontamination of personal protective equipment (PPE), drilling and monitoring well installation equipment, borehole soil sampling equipment, water level measurement equipment, and general sampling equipment.

2.1 PERSONAL PROTECTIVE EQUIPMENT DECONTAMINATION

Personnel working in the field are required to follow specific procedures for decontamination prior to leaving the work area so that contamination is not spread off-site or to clean areas. All used disposable protective clothing, such as Tyvek coveralls, gloves, and booties, will be containerized for later disposal. Decontamination water will be containerized in 55-gallon drums.

Personnel decontamination procedures will be as follows:

1. Wash neoprene boots (or neoprene boots with disposable booties) with Liquinox or Alconox solution and rinse with clean water. Remove booties and retain boots for subsequent reuse.

2. Wash outer gloves in Liquinox or Alconox solution and rinse in clean water. Remove outer gloves and place into plastic bag for disposal.

3. Remove Tyvek or coveralls. Containerize Tyvek for disposal and place coveralls in plastic bag for reuse.

4. Remove air purifying respirator (APR), if used, and place the spent filters into a plastic bag for disposal. Filters should be changed daily or sooner depending on use and application. Place respirator into a separate plastic bag after cleaning and disinfecting.

5. Remove disposable gloves and place them in plastic bag for disposal.

6. Thoroughly wash hands and face in clean water and soap.

2.2 DRILLING AND MONITORING WELL INSTALLATION EQUIPMENT DECONTAMINATION

All drilling equipment should be decontaminated at a designated location on-site before drilling operations begin, between borings, and at completion of the project.

Monitoring well casing, screens, and fittings are assumed to be delivered to the site in a clean condition. However, they should be steam cleaned on-site prior to placement downhole. The drilling subcontractor will typically furnish the steam cleaner and water.

After cleaning the drilling equipment, field personnel should place the drilling equipment, well casing and screens, and any other equipment that will go into the hole on clean polyethylene sheeting.

The drilling auger, bits, drill pipe, temporary casing, surface casing, and other equipment should be decontaminated by the drilling subcontractor by hosing down with a steam cleaner until thoroughly clean. Drill bits and tools that still exhibit particles of soil after the first washing should be scrubbed with a wire brush and then rinsed again with a high-pressure steam rinse.

All wastewater from decontamination procedures should be containerized.

2.3 BOREHOLE SOIL SAMPLING EQUIPMENT DECONTAMINATION

The soil sampling equipment should be decontaminated after each sample as follows:

1. Prior to sampling, scrub the split-barrel sampler and sampling tools in a bucket using a stiff, long bristle brush and Liquinox or Alconox solution.
2. Steam clean the sampling equipment over the rinsate tub and allow to air dry.
3. Place cleaned equipment in a clean area on plastic sheeting and wrap with aluminum foil.
4. Containerize all water and rinsate.

5. Decontaminate all pipe placed down the hole as described for drilling equipment.

2.4 WATER LEVEL MEASUREMENT EQUIPMENT DECONTAMINATION

Field personnel should decontaminate the well sounder and interface probe before inserting and after removing them from each well. The following decontamination procedures should be used:

1. Wipe the sounding cable with a disposable soap-impregnated cloth or paper towel.
2. Rinse with deionized organic-free water.

2.5 GENERAL SAMPLING EQUIPMENT DECONTAMINATION

All nondisposable sampling equipment should be decontaminated using the following procedures:

1. Select an area removed from sampling locations that is both downwind and downgradient. Decontamination must not cause cross-contamination between sampling points.
2. Maintain the same level of protection as was used for sampling.
3. To decontaminate a piece of equipment, use an Alconox wash; a tap water wash; a solvent (methanol or hexane) rinse, if applicable or dilute (0.1 N) nitric acid rinse, if applicable; a distilled water rinse; and air drying. Use a solvent (methanol or hexane) rinse for grossly contaminated equipment (for example, equipment that is not readily cleaned by the Alconox wash). The dilute nitric acid rinse may be used if metals are the analyte of concern.
4. Place cleaned equipment in a clean area on plastic sheeting and wrap with aluminum foil.
5. Containerize all water and rinsate.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

SOIL SAMPLING

SOP NO. 005

REVISION NO. 1

Last Reviewed: December 1999

	March 23, 1992
Quality Assurance Approved	Date

1.0 BACKGROUND

Soil sampling is conducted for three main reasons. First, samples can be obtained for laboratory chemical analysis. Second, samples can be obtained for laboratory physical analysis. Third, samples can be obtained for visual classification and field screening. These three sampling objectives can be achieved separately or in combination with each other. Sampling locations are typically chosen to provide chemical, physical, or visual information in both the horizontal and vertical directions. A sampling and analysis plan is used to outline sampling methods and provide preliminary rationale for sampling locations. Sampling locations may be adjusted in the field based on the screening methods being used and the physical features of the area.

1.1 PURPOSE

Soil sampling is conducted to determine the chemical, physical, and visual characteristics of surface and subsurface soils.

1.2 SCOPE

This standard operating procedure (SOP) describes procedures for soil sampling in different areas using various implements. It includes procedures for test pit, surface soil, and subsurface soil sampling, and describes eight devices.

1.3 DEFINITIONS

Hand auger: Instrument attached to the bottom of a length of pipe that has a crossarm or “T” handle at the top. The auger can be closed-spiral or open-spiral.

Bucket auger: A type of auger that consists of a cylindrical bucket 10 to 72 inches in diameter with teeth arranged at the bottom.

Core sampler: Thin-wall cylindrical metal tube with diameter of 0.5 to 3 inches, a tapered nosepiece, a "T" handle to facilitate sampler deployment and retrieval, and a check valve (flutter valve) in the headpiece.

Spatulas or Spoons: Stainless steel instruments for collecting loose unconsolidated material.

Trier: Tube cut in half lengthwise with a sharpened tip that allows for collection of sticky solids or loosening of cohesive soils.

Trowel: Tool with a scooped blade 4 to 8 inches long and 2 to 3 inches wide with a handle.

Split-Spoon (or Split-Barrel) Sampler: Thick-walled steel tube that is split lengthwise. A cutting shoe is attached to the lower end; the upper end contains a check valve and is connected to drill rods.

Thin-Wall Tube Sampler: Steel tube (1 to 3 millimeters thick) with tapered bottom edge for cutting. The upper end is fastened to a check valve that is attached to drill rods.

1.4 REFERENCES

Barth, D.S., and B.J. Mason. 1984. "Soil Sampling Quality Assurance Users Guide." EPA 600/4-84-043.

DeVara, E.R., B.P. Simmons, R.D. Stephens, and D.L. Storm. 1980. "Samplers and Sampling Procedures for Hazardous Waste Streams." EPA 600/2-80-018. January.

Mason, B.J. 1983. "Preparation of Soil Sampling Protocol: Techniques and Strategies." EPA 600/4-83-020.

U.S. Environmental Protection Agency (EPA). 1987. "A Compendium of Superfund Field Operations Methods." OSWER Directive 9355.0-14 (EPA/540/P-87/001).

EPA. 1991. "Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells." March. EPA/600/4-89/034.

EPA. 1994. "Soil Sampling." Environmental Response Team SOP #2012 (Rev. #0.0, 11/16/94). On-Line Address: http://204.46.140.12/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

Soil sampling requires that one or more of the following types of equipment be used:

Sampling Equipment	Other Required Equipment
Spoons and spatulas	Sample containers, labels, and chain-of-custody forms
Trowel	Logbook
Shovel or spade	Tape for measuring recovery
Trier	Soil classification information
Core sampler	Wax for sealing ends of thin-wall tube
Hand auger	Plastic sheeting
Bucket auger	Decontamination equipment
Split-spoon	Drilling equipment
Thin-wall tube	Backhoe
	Health and safety equipment

2.0 PROCEDURES

This SOP presents procedures for conducting test pit, surface soil, and subsurface soil sampling. The site sampling plan will specify which of the following procedures will be used.

Soil samples for chemical analysis should be collected in the following order: (1) volatile organics, (2) semivolatile organics, and (3) metals. Once the chemical samples have been containerized, samples for physical analyses can be containerized. Typical physical analyses conducted include (1) grain size distribution, (2) moisture content, (3) saturated permeability, (4) unsaturated permeability, and (5) Atterberg limits. Additionally, visual descriptions of samples, using the Unified Soil Classification System (USCS), should be recorded. Field tests such as head space analyses can also be conducted.

Soil samples for chemical analyses can be collected either as grab samples or composite samples. A grab sample is collected from a discrete location or depth. A composite sample consists of soil combined from more than one discrete location. Typically, composite samples consist of soil obtained from several locations and homogenized in a stainless steel or Teflon® pan or tray. Samples for volatile organic analysis (VOA) should not be composited.

2.1 TEST PIT SOIL SAMPLING

Test pit soil sampling is conducted when a complete soil profile is required or as a means of locating visually detectable contamination. This type of sampling provides a detailed description of the soil profile and allows for multiple samples to be collected from specific soil horizons. Prior to conducting any test pit or trench excavation with a backhoe, the sampling team should ensure that the sampling area is clear of utility lines, subsurface pipes, and poles.

A test pit or trench is excavated by incrementally removing soil material with a backhoe bucket. The excavated soil is placed on plastic sheeting well away from the edge of the test pit. A test pit should not be excavated to depths greater than 4 feet unless its walls are properly stabilized.

Personnel entering the test pit may be exposed to toxic or explosive gases and oxygen deficient environments. Air monitoring is required before entering the test pit and the use of appropriate respiratory gear and protective clothing is mandatory. At least two persons must be present at the test pit before sampling personnel enter the excavation and begin soil sampling.

Test pits are not practical for depths greater than 15 feet. If soil samples are required from depths greater than 15 feet, samples should be obtained using test borings instead of test pits. Test pits are also usually limited to a few feet below the water table. In some cases, a pumping system may be required to control the water level within the pits.

Access to open test pits should be restricted by use of flagging, tape, or fencing. If a fence is used, it should be erected at least 6 feet from the perimeter of the test pit. The test pit should be backfilled as soon as possible after sampling is completed.

Soil samples can be collected from the walls or bottom of a test pit using various equipment. A hand auger, bucket auger, or core sampler can be used to obtain samples from various depths. A trier, trowel, or spoons can be used to obtain samples from the walls or pit bottom surface.

2.2 SURFACE SOIL SAMPLING

The surface soil sampling equipment presented in this SOP is best suited for sampling to depths of 0 to 6 feet below ground surface (bgs). The sample depth, sample analyses, soil type, and soil moisture will also dictate the best suited sampling equipment. Prior to sample collection, the sampling locations should be cleared of any surface debris such as twigs, rocks, and litter. The following table presents various surface soil sampling equipment and their effective depth ranges, operating means (manual or power), and sample types collected (disturbed or undisturbed).

Sampling Equipment	Effective Depth Range (feet bgs)	Operating Means	Sample Type
Hand Auger	0 to 6	Manual	Disturbed
Bucket Auger	0 to 4	Power	Disturbed
Core Sampler	0 to 4	Manual or Power	Undisturbed
Shovel	0 to 6	Manual	Disturbed
Trier	0 to 1	Manual	Disturbed
Trowel	0 to 1	Manual	Disturbed
Spoon/Spatula	0 to 0.5	Manual	Disturbed

The procedures for using these various types of sampling equipment are discussed below.

2.2.1 Hand Auger

A hand auger equipped with extensions and a “T” handle is used to obtain samples from a depth of up to 6 feet. If necessary, a shovel may be used to excavate the topsoil to reach the desired subsoil level. If topsoil is removed, its thickness should be recorded. Samples obtained using a hand auger are disturbed in their collection; determining the exact depth at which samples are obtained is difficult.

The hand auger is screwed into the soil at an angle of 45 to 90 degrees from horizontal. When the entire auger blade has penetrated soil, the auger is removed from the soil by lifting it straight up without turning it, if possible. If the desired sampling depth has not been reached, the soil is removed from the auger and

deposited onto plastic sheeting. This procedure is repeated until the desired depth is reached and the soil sample is obtained. The auger is then removed from the boring and the soil sample is collected directly from the auger into an appropriate sample container.

2.2.2 Bucket Auger

A bucket auger, equipped similarly as the hand auger, is used to obtain disturbed samples from a depth of up to 4 feet. A bucket auger should be used when sampling stony or dense soil that prohibits the use of a hand-operated core or screw auger. A bucket auger with closed blades is used in soil that cannot generally be penetrated or retrieved by a core sampler.

The bucket auger is rotated while downward pressure is exerted until the bucket is full. The bucket is then removed from the boring, the collected soil is placed on plastic sheeting, and this procedure is repeated until the appropriate depth is reached and a sample is obtained. The bucket is then removed from the boring and the soil sample is transferred from the bucket to an appropriate sample container.

2.2.3 Core Sampler

A hand-operated core sampler (Figure 1), similarly equipped as the hand auger, is used to obtain samples from a depth of up to 4 feet in uncompacted soil. The core sampler is capable of retrieving undisturbed soil samples and is appropriate when low concentrations of metals or organics are of concern. The core sampler should be constructed of stainless steel. A polypropylene core sampler is generally not suitable for sampling dense soils or sampling at an appreciable depth.

The core sampler is pressed into the soil at an angle of 45 to 90 degrees from horizontal and is rotated when the desired depth is reached. The core is then removed, and the sample is placed into an appropriate sample container.

2.2.4 Shovel

A shovel may be used to obtain large quantities of soil that are not readily obtained with a trowel. A shovel is used when soil samples from a depth of up to 6 feet are to be collected by hand excavation; a tiling spade (sharpshooter) is recommended for excavation and sampling. A standard steel shovel may be used for excavation; either a stainless steel or polypropylene shovel may be used for sampling. Soil excavated from above the desired sampling depth should be stockpiled on plastic sheeting. Soil samples should be collected from the shovel and placed into the sample container using a stainless-steel scoop, plastic spoon, or other appropriate tool.

2.2.5 Trier

A trier (Figure 2) is used to sample soil from a depth of up to 1 foot. A trier should be made of stainless steel or polypropylene. A chrome-plated steel trier may be suitable when samples are to be analyzed for organics and heavy metal content is not a concern.

Samples are obtained by inserting the trier into soil at an angle of up to 45 degrees from horizontal. The trier is rotated to cut a core and is then pulled from the soil being sampled. The sample is then transferred to an appropriate sample container.

2.2.6 Trowel

A trowel is used to obtain surface soil samples that do not require excavation beyond a depth of 1 foot. A trowel may also be used to collect soil subsamples from profiles exposed in test pits. Use of a trowel is practical when sample volumes of approximately 1 pint (0.5 liter) or less are to be obtained. Excess soil should be placed on plastic sheeting until sampling is completed. A trowel should be made of stainless steel or galvanized steel. It can be purchased from a hardware or garden store. Soil samples to be analyzed for organics should be collected using a stainless steel trowel. Samples may be placed directly from the trowel into sample containers.

2.3 SUBSURFACE SOIL SAMPLING

Subsurface soil sampling, in conjunction with borehole drilling, is required for soil sampling from depths greater than approximately 6 feet. Subsurface soil sampling is frequently coupled with exploratory boreholes or monitoring well installation. Refer to SOP Nos. 045, 046, and 047 (borehole drilling SOPs) and SOP No. 020 (Monitoring Well Installation).

Subsurface soil sampling may be conducted using a drilling rig or power auger. Selection of sampling equipment depends upon geologic conditions and the scope of the sampling program. Two types of samplers used with machine-driven augers— the split-spoon sampler and the thin-wall tube sampler— are discussed below. All sampling tools should be cleaned before and after each use in accordance with SOP No. 002 (General Equipment Decontamination). Both the split-spoon sampler and the thin-wall tube sampler can be used to collect undisturbed samples from unconsolidated soils. The procedures for using the split-spoon and thin-wall tube samplers are presented below.

2.3.1 Split-Spoon Sampler

Split-spoon samplers are available in a variety of types and sizes. Site conditions and project needs such as large sample volume for multiple analyses determine the specific type of split-spoon sampler to be used. Figure 3 shows a generic split-spoon sampler.

The split-spoon sampler is advanced into the undisturbed soil beneath the bottom of the casing or borehole using a weighted hammer and a drill rod. The relationship between hammer weight, hammer drop, and number of blows required to advance the split-spoon sampler in 6-inch increments indicates the density or consistency of the subsurface soil. After the split-spoon sampler has been driven to its intended depth, it should be removed carefully to avoid loss of sample material. In noncohesive or saturated soil, a catcher or basket should be used to help retain the sample.

After the split-spoon sampler is removed from the casing, it is detached from the drill rod and opened. If VOA samples are to be collected, VOA vials should be filled with soil taken directly from the split-spoon sampler. Samples for other specific chemical analyses should be taken as soon as the VOA sample has

been collected. The remainder of the recovered soil can then be used for visual classification of the sample and containerized for physical analysis. The entire sample (except for the top several inches of possibly disturbed material) is retained for analysis or disposal.

2.3.2 Thin-Wall Tube Sampler

A thin-wall tube sampler, sometimes called the Shelby tube (Figure 4), may be pressed or driven into soil inside a hollow-stem auger flight, wash bore casing, or uncased borehole. The tube sampler is pressed into the soil without rotation to the desired depth or until refusal. If the tube cannot be advanced by pushing, it may be necessary to drive it into the soil without rotation using a hammer and drill rod. The tube sampler is then rotated to collect the sample from the soil and removed from the borehole.

After removal of the tube sampler from the drilling equipment, the tube sampler should be inspected for adequate sample recovery. The sampling procedure should be repeated until an adequate soil core is obtained (if sample material can be retained by the tube sampler). The soil core obtained should be documented in the logbook. Any disturbed soil is removed from each end of the tube sampler. If chemical analysis is required, VOA samples must be collected immediately after the tube sampler is withdrawn. Before use, and during storage and transport, the tube sampler should be capped with a nonreactive material. For physical sampling parameters, the tube sampler should be sealed by pouring three 0.25-inch layers of sealing liquid (such as wax) in each end, allowing each layer to solidify before applying the next. The remaining space at each end of the tube is filled with Ottawa sand or other, similar sand, which is allowed to settle and compact. Plastic caps are then taped over the ends of the tube. The top and bottom of the tube sampler should be labeled and the tube sampler should be stored accordingly.

FIGURE 1

HAND-OPERATED CORE SAMPLER

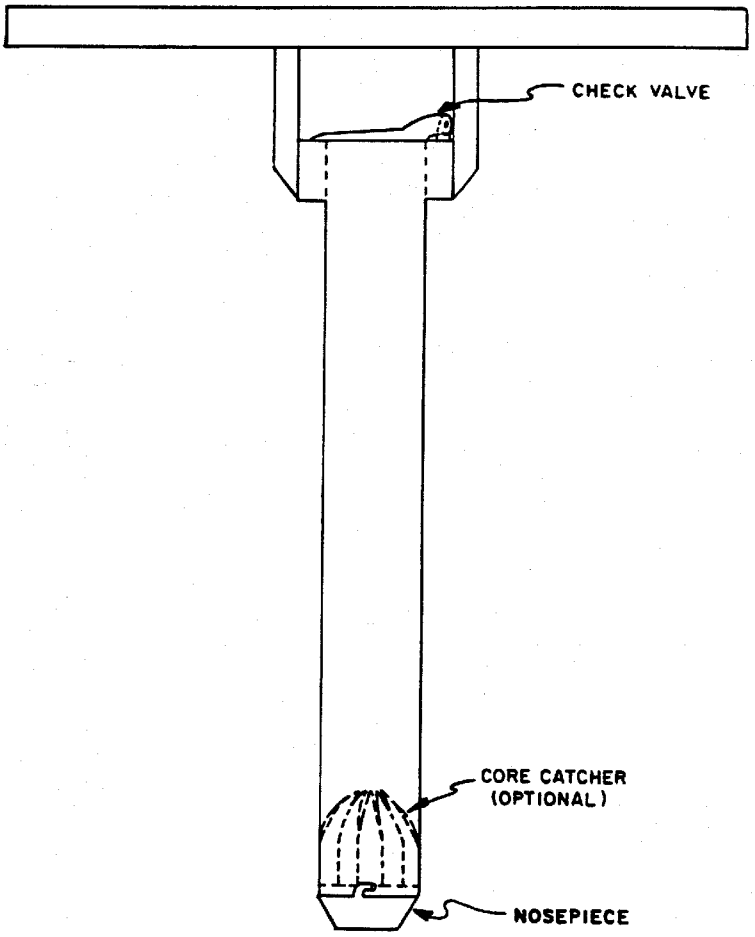


FIGURE 2

TRIER

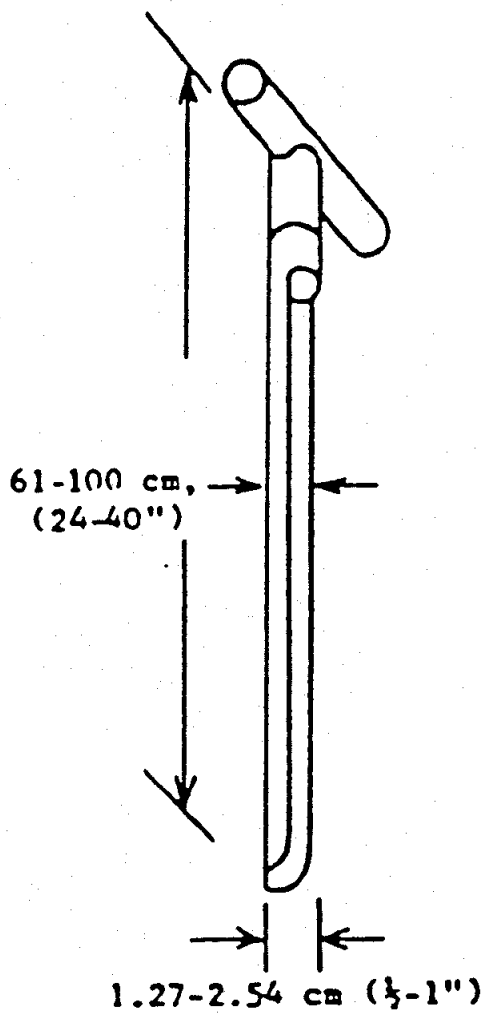


FIGURE 3

GENERIC SPLIT-SPOON SAMPLER

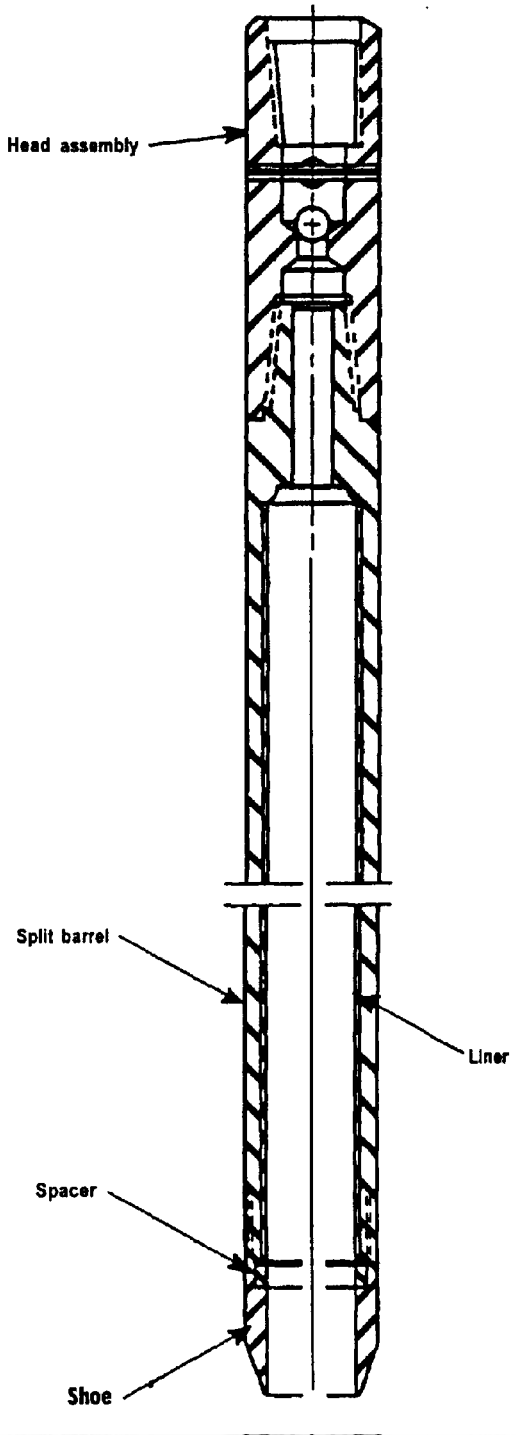
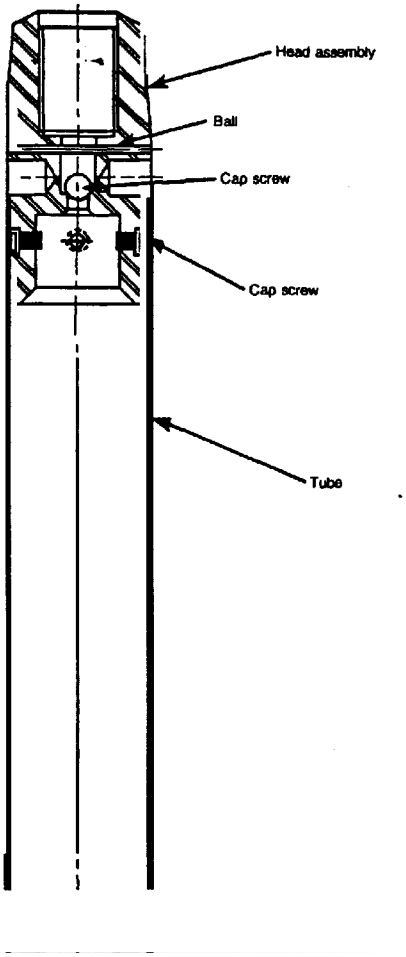


FIGURE 4

THIN-WALL TUBE SAMPLER



SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

SURFACE WATER SAMPLING

SOP NO. 009

REVISION NO. 3

Last Reviewed: December 1999

Quality Assurance Approved	*May 19, 1993* Date

1.0 BACKGROUND

Surface water sampling is conducted to determine the quality of surface water entering, leaving, or affected by a site. Surface water bodies that can be sampled include streams, rivers, lakes, ponds, lagoons, and surface impoundments. This standard operating procedure (SOP) discusses common methods of collecting grab samples that represent water quality in a water body at a particular point in time.

A series of grab samples also can be composited to represent water quality over a longer period of time. Composite samples can be flow proportional or time proportional. The details of compositing water samples are not included in this SOP.

1.1 PURPOSE

This SOP establishes the requirements and procedures for surface water sampling.

1.2 SCOPE

This SOP applies to surface water sampling and the instruments and methods used to collect the samples.

1.3 DEFINITIONS

Kemmerer Sampler: A messenger-activated water sampling device. Water flows through the device until the release mechanism is triggered to close the container.

Peristaltic Pump: A rotary, positive-displacement pumping device characterized by its low suction and rhythmic nature, and by the fact that the pump does not come into direct contact with the water being sampled.

Pond Sampler: A sampling device fabricated by using an adjustable beaker clamp to attach a beaker to a telescoping, heavy-duty aluminum pole.

1.4 REFERENCES

deVera, E.R., and others. 1980. "Samplers and Sampling Procedures for Hazardous Waste Streams." EPA-600/2-80-018. January.

U.S. Environmental Protection Agency (EPA). 1977. "Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities." EPA-530/SW-611. August.

EPA. 1984. "Characterization of Hazardous Waste Sites — A Methods Manual, Volume II. Available Sampling Methods." Second Edition. EPA-600/4-84-076. December.

EPA. 1994. "Surface Water Sampling." Environmental Response Team SOP #2013 (Rev. #0.0, 11/17/94). On-Line Address: http://204.46.140.12/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

Surface water sampling requires a variety of procedures and instruments. The choice of procedure should be determined by site-specific conditions, such as the type of surface water body, the sampling depth, and the sample location's distance from shore.

Samples can be collected from shallow depths by submerging the sample container. An intermediary disposable collection container or one constructed of a nonreactive material also may be used. A pond sampler, a peristaltic pump, or a Kemmerer sampler may be used to provide extended reach. The following equipment may be required to sample surface water:

- Decontamination materials
- Sample containers and labels
- Point-source bailer
- Dipper
- Boat
- Pond sampler
- Peristaltic pump with batteries or power source
- Silicone tubing
- Heavy-wall Teflon® tubing
- Kemmerer sampler
- Logbook or field sheets

- Chain-of-custody documentation
- Shipping materials

2.0 PROCEDURES

Safe access, handling, and other physical limitations should be influential factors during surface water sampling. A site-specific sampling plan should delineate which of the procedures described below will be used. Any deviations from the sampling plan should be recorded in the site-specific field logbook.

The following subsections provide detailed procedures for surface water sampling using specific instruments and methods. In all cases, select a sampling location where the water quality will best represent the water chemistry of the water body. Avoid stagnant or fast-moving areas. Do not sample immediately downstream of incoming tributaries, because of the likelihood of incomplete mixing.

2.1 SURFACE WATER SAMPLING BY SUBMERGING SAMPLE CONTAINER

Samples from shallow depths should be collected by submerging the sample container. This method is advantageous when the sample might be significantly altered during transfer from a collection vessel into another container. This method should not be used for sampling lagoons or surface impoundments where contact with contaminants is a potential concern.

The following procedure can be used for sampling surface water by submerging the sample container:

1. Place all equipment on plastic sheeting next to the sampling location. Sample containers should be selected in accordance with the requirements in SOP No. 017 (Sample Collection Container Requirements).

2. If required by the project, measure the temperature, pH, and specific conductance of the surface water body before collecting the sample using procedures in SOPs No. 11 (Field Measurement of Water Temperature), No. 12 (Field Measurement of pH in Water), and No. 13 (Field Measurement of Specific Conductance), respectively. Record this information on the field sheet or in the logbook.

3. For stream sampling, sample the location farthest downstream first. Orient the mouth of the sample container upstream while standing downstream so as not to stir up any sediment that would contaminate the sample.

4. For a larger body of surface water, such as a lake, collect samples near the shore, unless boats are feasible and permitted. Collect samples from shallow depths by submerging the sample container.

5. Collect surface water samples at each location before collecting sediment samples to avoid contaminating the water samples with excess suspended particles generated during sediment sampling.

6. Continue delivery of the sample until the container is almost full. If sampling for volatile organic compounds (VOC), the container must be completely filled leaving no head space.

7. Preserve the sample in accordance with requirements in SOP No. 16 (Sample Preservation and Maximum Holding Times). Ensure that a Teflon® liner is present in the cap of the sample container if required. Secure the cap tightly and affix a completed sample label to the container.

8. Complete all chain-of-custody documentation, field logbook entries, and sample packaging requirements.

2.2 SURFACE WATER SAMPLING WITH TRANSFER DEVICE

A dipper, bailer, or other device made of inert material, such as stainless steel or Teflon®, can be used to transfer liquid samples from their source to a sample container. This prevents contamination of the outside of the sample container as a result of direct immersion in surface water. Depending on the sampling application, the transfer device may be either disposed of or reused. If reused, the device should be thoroughly rinsed and decontaminated prior to sampling a different source.

A transfer device can be used in most sampling situations. However, direct collection by submerging the sample container is the preferred method when (1) aeration of the sample must be avoided (as in sampling surface water for VOCs) or (2) a significant amount of the sample may be lost due to adhesion to the transfer device.

The following procedure can be used for sampling surface water with a dipper, bailer, or other transfer device:

1. Place all equipment on plastic sheeting next to the sampling location. Sample containers should be selected in accordance with the requirements in SOP No. 017 (Sample Collection Container Requirements).

2. If required by the project, measure the temperature, pH, and specific conductance of the surface water body before collecting the sample using procedures in SOPs No. 11 (Field Measurement of Water Temperature), No. 12 (Field Measurement of pH in Water), and No. 13 (Field Measurement of Specific Conductance), respectively. Record this information on the field sheet or in the logbook.

3. With minimal surface water disturbance, submerge a precleaned dipper, bailer, or other transfer device.

4. Allow the device to fill slowly and continuously.

5. Retrieve the device from the surface water with minimal disturbance.

6. Remove the cap from the sample container. Slightly tilt the mouth of the container below the edge of the transfer device.

7. Empty the device slowly, allowing the sample to flow gently down the inside of the container with minimal entry turbulence. Continue delivery of the sample until the container is almost full. If sampling for VOCs, the container must be completely filled leaving no head space.

8. Preserve the sample in accordance with requirements in SOP No. 16 (Sample Preservation and Maximum Holding Times). Ensure that a Teflon® liner is present in the cap of the sample container if required. Secure the cap tightly and affix a completed sample label to the container.

9. Complete all chain-of-custody documentation, field logbook entries, and sample packaging requirements.

10. Decontaminate the transfer device prior to reuse or storage using the procedures in SOP No. 002, General Equipment Decontamination.

2.3 SURFACE WATER SAMPLING WITH POND SAMPLER

A pond sampler may be used to collect liquid samples from ponds, pits, and lagoons (see Figure 1). A pond sampler is easily and inexpensively fabricated. To construct a pond sampler, use an adjustable clamp to attach a sampling beaker to the end of a two- or three-piece telescoping aluminum tube. The telescoping tube serves as the handle. Nondisposable equipment should be cleaned before and after each use.

The following procedure can be used for sampling surface water with a pond sampler:

1. Place all equipment on plastic sheeting next to the sampling location. Sample containers should be selected in accordance with the requirements in SOP No. 017 (Sample Collection Container Requirements).

2. If required by the project, measure the temperature, pH, and specific conductance of the surface water body before collecting the sample using procedures in SOPs No. 11 (Field Measurement of Water Temperature), No. 12 (Field Measurement of pH in Water), and No. 13 (Field Measurement of Specific Conductance), respectively. Record this information on the field sheet or in the logbook.

3. Assemble the pond sampler. Ensure that the sampling beaker, bolts, and nuts securing the clamp to the pole are tightened properly.

4. Collect the sample by slowly submerging the precleaned beaker with minimal surface water disturbance.

5. Retrieve the pond sampler from the surface water with minimal disturbance.

6. Remove the cap from the sample container. Slightly tilt the mouth of the container below the edge of the beaker.

7. Empty the beaker slowly, allowing the sample to flow gently down the inside of the container with minimal entry turbulence. Continue delivery until the container is almost full. If sampling for VOCs, the container must be completely filled leaving no head space.

8. Preserve the sample in accordance with requirements in SOP No. 16 (Sample Preservation and Maximum Holding Times). Ensure that a Teflon® liner is present in the cap of the sample container if required. Secure the cap tightly and affix a completed sample label to the container.

9. Complete all chain-of-custody documentation, field logbook entries, and sample packaging requirements.

10. Decontaminate the pond sampler prior to reuse or storage using the procedures in SOP No. 002, General Equipment Decontamination.

2.4 SURFACE WATER SAMPLING WITH PERISTALTIC PUMP

To extend reach in sampling efforts, a small peristaltic pump can be used (see Figure 2). A peristaltic pump draws the sample through heavy-wall Teflon® tubing and pumps it directly into the sample container. Use of a peristaltic pump allows the operator to reach out into a liquid body, to sample from a depth or to sweep the width of a narrow stream. A battery-powered pump is preferable because it eliminates the need for a direct current generator or an alternating current inverter.

If medical-grade silicone tubing is used in the peristaltic pump, it is suitable for sampling almost any parameter, including most organics. However, some VOC stripping may occur and some sample material

may adhere to the tubing. Teflon® tubing may be used in place of silicon tubing on the intake side of the pump to minimize the amount of sample adherence to the tubing. If tubing is to be reused, it should be cleaned before and after each use. Depending on project requirements, it may be necessary to replace the Teflon® intake tubing and the pump silicon tubing between sampling locations to prevent cross contamination.

Procedures for sampling surface water with a peristaltic pump are summarized below:

1. Place all equipment on plastic sheeting next to the sampling location. Sample containers should be selected in accordance with the requirements in SOP No. 017 (Sample Collection Container Requirements).

2. If required by the project, measure the temperature, pH, and specific conductance of the surface water body before collecting the sample using procedures in SOPs No. 11 (Field Measurement of Water Temperature), No. 12 (Field Measurement of pH in Water), and No. 13 (Field Measurement of Specific Conductance), respectively. Record this information on the field sheet or in the logbook.

3. Install clean, medical-grade silicone tubing in the pump head according to the manufacturer's instructions. Allow enough tubing on the discharge side to facilitate delivery of liquid into the sample container. Allow only enough tubing on the suction end for attachment to the intake line. This will minimize sample contact with the tubing.

4. Select the length of intake tubing needed to reach the required sample location. Attach it to the intake side of the pump tubing. Heavy-wall Teflon® tubing of a diameter equal to that of the required pump tubing suits most applications. A heavier tubing wall will allow slightly greater lateral reach.

5. If possible, allow several liters of surface water to pass through the pump before collecting the sample. Collect this purge volume. Return it to the source after the samples have been withdrawn.

6. Fill the sample container by allowing the pump discharge to flow gently down the inside of the bottle with minimal entry turbulence. Continue delivery of the sample until the container is almost full. If sampling for VOCs, the container must be completely filled leaving no head space.

7. Preserve the sample in accordance with requirements in SOP No. 16 (Sample Preservation and Maximum Holding Times). Ensure that a Teflon® liner is present in the cap of the sample container if required. Secure the cap tightly and affix a completed sample label to the container.

8. Complete all chain-of-custody documentation, field logbook entries, and sample packaging requirements.

9. Allow the pump to drain, and then disassemble it. Decontaminate the tubing before reuse using the procedures in SOP No. 002 (General Equipment Decontamination) or dispose of it.

2.5 SURFACE WATER SAMPLING WITH KEMMERER SAMPLER

The Kemmerer sampler (see Figure 3) is used to collect surface water samples when the required sample depth is greater than that which can be sampled with a pump. A Kemmerer sampler may be constructed of various materials to be compatible with the required analytical technique. The sampler should be cleaned before and after each use.

Procedures for sampling surface water with a Kemmerer sampler are summarized below:

1. Place all equipment on plastic sheeting next to the sampling location. Sample containers should be selected in accordance with the requirements in SOP No. 017 (Sample Collection Container Requirements).

2. If required by the project, measure the temperature, pH, and specific conductance of the surface water body before collecting the sample using procedures in SOPs No. 11 (Field Measurement of Water Temperature), No. 12 (Field Measurement of pH in Water), and No. 13 (Field Measurement of Specific Conductance), respectively. Record this information on the field sheet or in the logbook.

3. Inspect the body of the Kemmerer sampler to ensure that the drain line valve is closed, as appropriate. Measure and mark the sample line (cable) at the desired sampling depth.

4. Open the sampler by lifting the upper stopper-trip head assembly.

5. Gradually lower the sampler into the surface water until the sample liquid reaches the sample line.

6. Place a messenger on the sample line and release it, closing the sampler.

7. Retrieve the sampler. Prevent accidental opening of the lower stopper by holding the center rod of the sampler.

8. Rinse or wipe off the exterior of the sampler. Recover the sample by grasping the lower stopper and sampler body with one hand. Transfer the sample by lifting the upper stopper with the other hand and carefully pouring the contents into the sample container. If a drain line valve is present, hold the valve over the sample container, and open the valve slowly to release the sample.

9. Transfer the sample slowly, allowing it to flow gently down the inside of the container with minimal entry turbulence. Continue delivery until the container is almost full. If sampling for VOCs, the container must be completely filled leaving no head space.

10. Preserve the sample in accordance with requirements in SOP No. 16 (Sample Preservation and Maximum Holding Times). Ensure that a Teflon® liner is present in the cap of the sample container if required. Secure the cap tightly and affix a completed sample label to the container.

11. Complete all chain-of-custody documentation, field logbook entries, and sample packaging requirements.

12. Decontaminate the Kemmerer sampler prior to reuse or storage using the procedures in SOP No. 002, General Equipment Decontamination.

FIGURE 1

POND SAMPLER

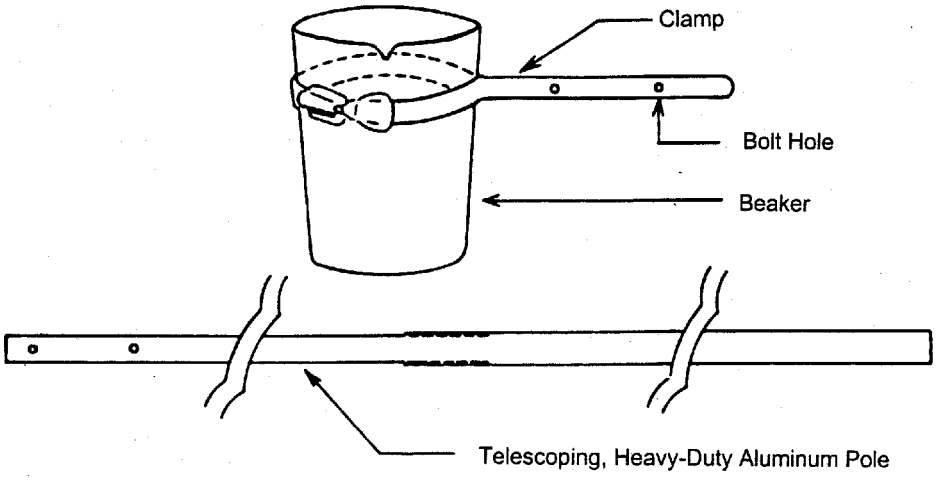


FIGURE 2

PERISTALTIC PUMP FOR LIQUID SAMPLING

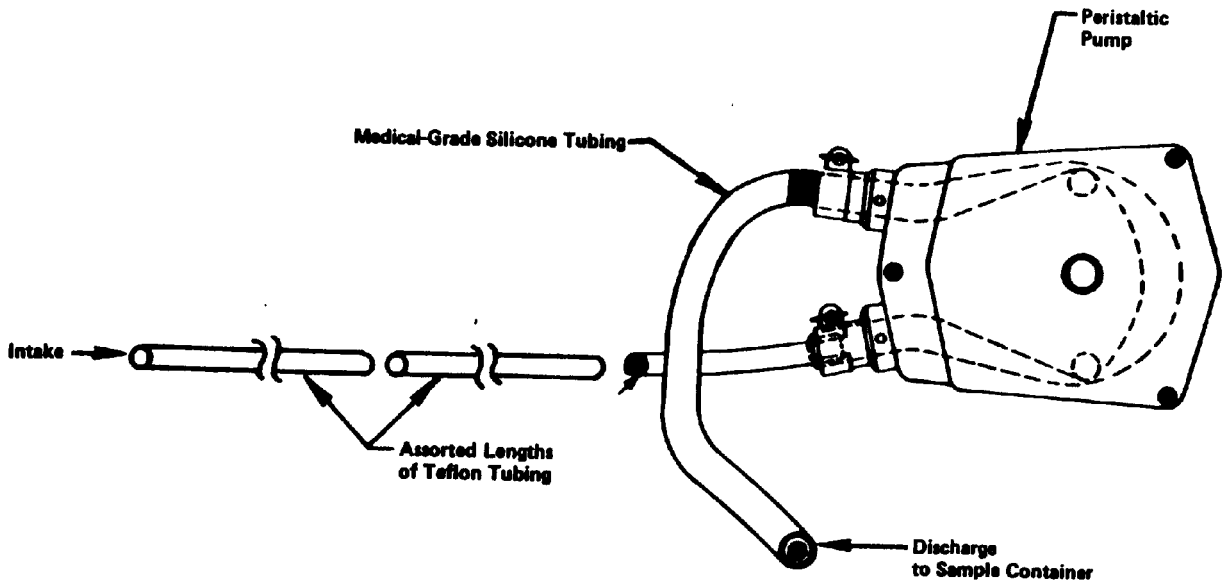
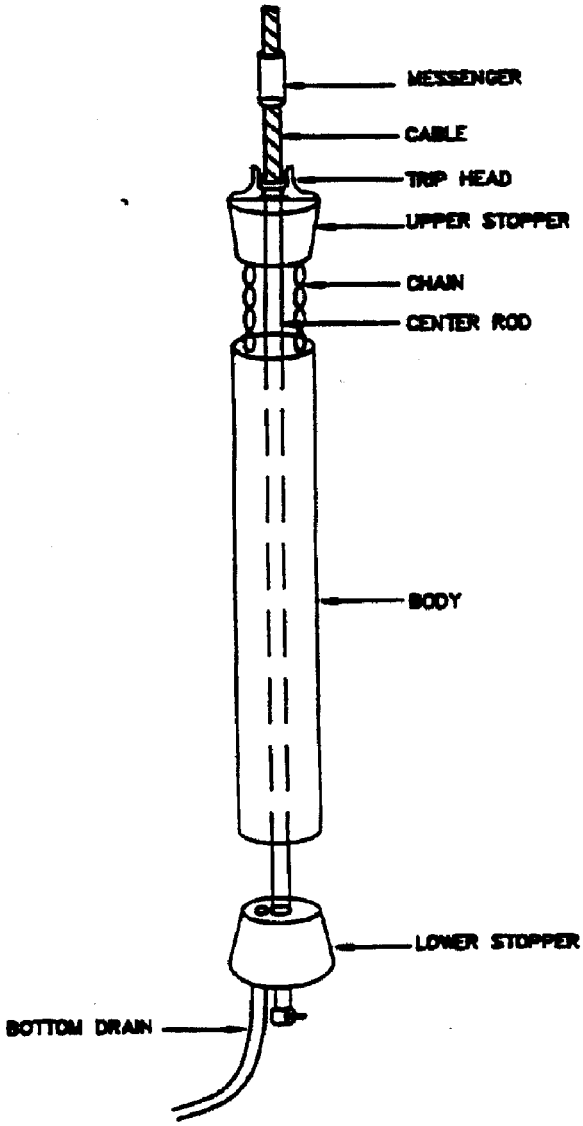


FIGURE 3

KEMMERER SAMPLER



SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

GROUNDWATER SAMPLING

SOP NO. 010

REVISION NO. 3

Last Reviewed: March 2000

Quality Assurance Approved	*February 19, 1993* Date

1.0 BACKGROUND

Groundwater sampling may be required for a variety of reasons, such as examining potable or industrial water supplies, checking for and tracking contaminant plume movement in the vicinity of a land disposal or spill site, Resource Conservation and Recovery Act (RCRA) compliance monitoring, or examining a site where historical information is minimal or non-existent, but where groundwater may be contaminated.

Groundwater is usually sampled through an in-place well, either temporarily or permanently installed. However, it can also be sampled anywhere groundwater is present, such as a pit or a dug or drilled hole.

Occasionally, a well will not be in the preferred location to obtain the sample needed (for example, to track a contaminant plume). In such a case, a temporary or permanent well will have to be installed. An experienced and knowledgeable person, preferably a hydrogeologist, will need to locate the well and supervise its installation so that the samples ultimately collected will be representative of the groundwater. SOP No. 020 (Monitoring Well Installation) provides guidance for installing new monitoring wells.

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for determining the quality of groundwater entering, leaving, or affected by site activities through groundwater sampling. The samples are obtained by retrieving water from a well screened in the aquifer(s) underlying a site.

1.2 SCOPE

This SOP provides general guidance for groundwater sampling activities conducted in the field. SOP No. 015 (Groundwater Sample Collection Using Micropurge Technology) provides additional specific guidance for using low flow methods to collect groundwater samples.

1.3 DEFINITIONS

Bailer: A cylindrical sampling device with valves on either end used to extract water from a well. Bailers are usually constructed of an inert material such as stainless steel or polytetrafluoroethylene (Teflon). The bailer is lowered and raised by means of a cable that may be cleaned and reused, or by disposable rope.

Electrical Water Level Indicator: An electrical device that has a light or sound alarm connected to an open circuit used to determine the depth to liquid. The circuit is closed when the probe intersects a conducting liquid. The wire used to raise and lower the probe is usually graduated.

Immiscible Phase: Liquid phases that cannot be uniformly mixed or blended with water. Heavy immiscible phases sink, and light immiscible phases float on water.

Interface Probe: An electrical probe that determines the distance from the surface to air/water, air/immiscible, or immiscible/water interfaces.

Purge Volume: The volume of water that needs to be removed from the well prior to sampling to ensure that the sample collected is representative of the groundwater.

Riser Pipe: The length of well casing above the ground surface.

Total Well Depth: The distance from the ground surface to the bottom of the well.

Water Level: The level of water in a well, measured as depth to water or as elevation of water, relative to a reference mark or datum.

1.4 REFERENCES

U.S. Department of Energy. 1985. "Procedures for the Collection and Preservation of Groundwater and Surface Water Samples and for the Installation of Monitoring Wells: Second Edition." Edited by N. Korte and P. Kearl. Technical Measurements Center, Grand Junction Projects Office. GJ/TMC-08.

U.S. Environmental Protection Agency (EPA). 1977. "Procedures Manual for Ground Water Monitoring at Solid Waste Disposal Facilities." EPA-530/SW-611. August.

EPA. 1984. "Sampling at Hazardous Materials Incidents." EPA Hazardous Response Support Division, Cincinnati, 1984.

EPA. 1995. "Groundwater Well Sampling." Environmental Response Team SOP #2007 (Rev. #0.0, 01/26/95). On-Line Address: http://204.46.140.12/media_resrcs/media_resrcs.asp?Child1=

U.S. Geological Survey. 1984. "National Handbook of Recommended Methods for Water-Data Acquisition" Reston, Virginia.

1.5 REQUIREMENTS AND RESOURCES

There are various options available to obtain groundwater samples. The procedures are outlined in the following section. The equipment needed to accomplish these procedures includes the following:

- Organic vapor detector with a flame ionization detector (FID) or a photoionization detector (PID)
- Pipe wrench
- Electrical water level indicator or interface probe
- Steel tape with heavy weight
- Purging device (type needed depends on well depth, casing diameter, and type of sample desired; see sampling devices below)
- Sampling device (type needed depends upon depth to water and type of sample desired)
    - Teflon bailer
    - Stainless steel bailer
    - Teflon bladder pump
    - Stainless steel submersible (nonoil-bearing) pump
    - Existing dedicated equipment
    - Peristaltic pump
- Sample containers
- Wastewater containers
- Field logbook
- Stopwatch

Additional equipment is required to complete measurement of field parameters (for example, pH, specific conductance, and temperature) of the groundwater in the well.

2.0 PROCEDURE

Prior to sampling, a site-specific sampling plan should be developed. The plan should take into consideration the site characteristics and should include:

- Specific repeatable well measurement techniques and reference points for determining the depth to water and the depth to the bottom of the well
- Specific method of purging and selection of purging equipment
- Specific methods and equipment for measurements of field parameters
- Specific method of sample collection and the sampling equipment that will be used
- Specific parameters for which samples will be analyzed
- Order in which sample bottles will be filled, based on the analytical parameters

The following sections discuss procedures for approaching the well, establishing a sample preparation area, making preliminary well measurements, purging the well, and collecting samples.

2.1 APPROACHING THE WELL

In general, all wells should be assumed to pose a health and safety risk until field measurements indicate otherwise. Approach wells from the upwind side. Record well appearance and general condition of the protective casing, surface seal, and surrounding area in the logbook.

Once at the well, the lead person should systematically use the organic vapor detector to survey the immediate area around the well (from the breathing zone to the top of the casing to the ground). If elevated FID and PID meter readings are encountered, retreat to a safe area and instruct the sampling team to put on the appropriate level of personal protective equipment (PPE). See SOP No. 003 (Organic Vapor Air Monitoring) for additional guidance.

Upon opening the well casing, the lead person should systematically survey inside the well casing, above the well casing in the breathing zone and the immediate area around the well. If elevated FID or PID meter readings in the breathing zone are encountered (see health and safety plan for action levels), retreat and put on appropriate PPE. It is important to remember that action levels are based on readings in the breathing zone, not within the well casing. Representative organic vapor detector readings should be recorded in the logbook.

2.2 ESTABLISHING A SAMPLE PREPARATION AREA

The sample preparation area is generally located upwind or to either side of the well. If elevated readings are encountered using an organic vapor detector, this area should be taped off and the sample preparation area should be located upwind where ambient readings are found.

2.3 MAKING PRELIMINARY WELL MEASUREMENTS

Several preliminary well measurements should be made prior to initiating sampling of the well. These include determining water level and total well depth measurements, determining the presence of immiscible phases, and calculating purge volumes. All preliminary measurements will be recorded in the logbook as they are determined. SOP No. 014 (Static Water Level, Total Well Depth, and Immiscible Layer Measurement) provides additional information concerning these preliminary measurements.

2.3.1 Water Level and Total Well Depth Measurements

Tetra Tech typically uses an electric water level indicator for water level measurements. This device sounds an alarm or illuminates a light when the measuring probe touches the water surface, thus closing an electrical circuit. The electric cable supporting the probe is usually graduated in feet and can be read at the well site directly. The remaining fraction is measured with a steel tape graduated to 0.01 foot. The distance between the static water level and the marked or notched location at the top of the riser pipe is measured. The height of the riser pipe above ground surface, as obtained from well location survey data, is then subtracted from the total reading to give the depth to static water. To improve accuracy, three separate readings should be made, and the values averaged. This helps to eliminate any errors due to kinks or bends in the cables, which may change in length when the water level indicator is raised and lowered.

The total well depth can be measured by using a steel tape with a heavy weight attached to the end. The tape is lowered into the well until resistance is met, indicating that the weight has reached the bottom of the well. The total well depth is then read directly from the steel tape to the 0.01-foot fraction. The distance between the bottom of the well and the marked or notched location on the riser pipe is measured. The height of the riser pipe above the ground surface, as obtained from well survey data, is then subtracted from the total reading to give the depth to the bottom of the well. To improve accuracy, three separate readings should be made, and the readings averaged.

2.3.2 Determining If Immiscible Phases Are Present

If immiscible phases (organic floaters or sinkers) are present, the following measurement activities should be undertaken. Organic liquids are measured by lowering an interface probe slowly to the surface of the liquid in the well. When the audible alarm sounds, record the depth. If the alarm is continuous, a floating immiscible layer has been detected. To determine the thickness of this layer, continue lowering the probe until the alarm changes to an oscillating signal. The oscillating signal indicates that the probe has detected an aqueous layer. Record this depth as the depth to water and determine the thickness and the volume of the immiscible layer.

Continue lowering the probe into the well to determine if dense immiscible phases (sinkers) are present. If the alarm signal changes from oscillating to a continuous sound, a heavier immiscible layer has been detected; record this depth.

Continue lowering the probe to the bottom of the well and record the total depth. Separate total depth measurements with a steel tape are not necessary when using an interface probe. Calculate and record the sinker phase volume and total water volume in the well. A chart is provided in Table 1 to assist in these calculations. If immiscible phases are present, immediately refer to Section 2.5.3 or 2.5.4 of this SOP.

2.3.3 Determination of Purging Volume

If the presence of floaters or sinkers does not need to be determined, determine the depth to water and the total depth of the well as described in Section 2.3.1. Once these measurements have been made and recorded, use Table 1 to calculate the total volume of water in the well. Multiply this volume by the purging factor to determine purging volume. The minimum purging factor is typically three casing

volumes but may be superseded by site-specific program requirements, individual well yield characteristics, or stabilization of field parameters measured during purging. Field parameters (for example, pH, specific conductance, and temperature) should be measured prior to purging and after each well volume. All field parameter data should be recorded in the field logbook. SOPs No. 011 (Field Measurement of Water Temperature), 012 (Field Measurement of pH), and 013 (Field Measurement of Specific Conductance) include more detailed procedures for determining these field parameters.

In Table 1, the volume of water in a 1-foot section of a 2-inch-diameter well is 0.163 gallon. This chart can easily be used for any water depth by multiplying all the values in Table 1 by the L value (depth, in feet, of water in the well). The volume of water in the well is based on the following formula:

$$V = \frac{\pi \times D^2}{4} \times L$$

where

V = volume of water in the well (cubic feet)
D = inside diameter of the well (feet)
L = depth of water in the well (feet)

2.4 PURGING THE WELL

Currently, Tetra Tech standards allow for six options for purging wells:

1. Teflon bailers
2. Stainless steel bailers
3. Teflon bladder pumps
4. Stainless steel submersible (nonoil-bearing) pumps
5. Existing dedicated equipment
6. Peristaltic pumps (these devices are for shallow wells only)

As previously stated, the minimum purging volume is typically three casing volumes. Exceptions to this standard may be made in the case of low-yield wells. When purging low-yield wells, purge the well once

to dryness. Samples should be collected as soon as the well recovers. When the time required for full recovery exceeds 3 hours, samples should be collected as soon as sufficient groundwater volume is available.

The well should be purged until measured field parameters have stabilized. If any field parameter has not stabilized, additional purging should be performed. To be considered stable, field parameters should change by no more than the tolerance levels listed on Table 2 between each well volume purged.

At no time should the purging rate be high enough to cause the groundwater to cascade back into the well, resulting in excessive aeration and potential stripping of volatile constituents.

The actual volume of purged water can be measured using several acceptable methods:

- When bailers are used, the actual volume of each bailer's contents can be measured using a calibrated bucket.
- If a pump is used for purging, the pump rate can be determined by using a bucket of known volume, stopwatch, and the duration of pumping time necessary to purge the known volume.

2.5 SAMPLE COLLECTION

This section first describes general groundwater sample collection procedures. This section also describes procedures for collecting groundwater samples for volatile organic analysis (VOA) and for collecting samples when light or heavy immiscible layers are present in a monitoring well. Samples of light and heavy immiscible layers should be collected before the well is purged.

2.5.1 General Groundwater Sampling Procedures

The technique used to withdraw a groundwater sample from a well should be selected based on the parameters for which the sample will be analyzed. To ensure that the groundwater samples are representative, it is important to avoid physically altering or chemically contaminating the sample during collection, withdrawal, or containerization. If the samples are to be analyzed for volatile organic compounds, it is critical that air does not become entrained in the water column.

Acceptable sampling devices for all parameters are double check valve stainless steel or Teflon bailers, bladder pumps, low-flow positive displacement pumps, or for shallow wells, peristaltic pumps. Additional measurements of field parameters should be performed at the time of sampling.

In some cases, it may become necessary to use dedicated equipment already in the well to collect samples. This is particularly true of high volume, deep wells (>150 feet) where bladder pumps are ineffective and bailing is impractical. If existing equipment must be used, however, determine the make and model of the pump and obtain information on component construction materials from the manufacturer or facility representatives. If an existing pump is to be used for sampling, make sure the flow volume can be reduced so that a reliable VOA sample can be taken. Record the specific port, tap, or valve from which the sample is collected.

General sampling procedures include the following:

- Clean sampling equipment should not be placed directly on the ground. Use a plastic drop cloth or feed line from clean reels. Never place contaminated lines back on reels.
- Check the operation of the bailer check valve assemblies to confirm free operation.
- If the bailer cable is to be decontaminated and reused, it must be made of Teflon-coated stainless steel.
- Lower sampling equipment slowly into the well to avoid degassing the water and damaging the equipment.
- Pump flow rates should be adjusted to eliminate intermittent or pulsed flow. The settings should be determined during the purging operations.
- A separate sample volume should be collected to measure necessary field parameters. Samples should be collected and containerized in the order of the parameters' volatilization sensitivity. Table 3 lists the preferred collection order for common groundwater parameters.

Intermediate containers should never be used to prepare VOA samples and should be avoided for all parameters in general. All VOA containers should be filled at a single sampling point or from a single bailer volume.

2.5.2 Collection of Volatile Organics Samples

This section discusses the collection of samples for VOA using either a bailer or bladder pump in detail. Other pumps (such as positive displacement or peristaltic) can be used. The following factors are critical to the collection of representative samples for VOA: ensuring that no air has become entrained in the water column, low pump flow rates (less than 100 milliliter [mL] per minute, if possible), and avoiding flow surges.

2.5.2.1 Collection with Bailers

Samples for VOA should be collected from the first bailer removed from the well after purging. The most effective means requires two people. One person should retrieve the bailer from the well and pour its contents into the appropriate number of 40-mL VOA vials held by the second person. Cap each vial and invert it. If a bubble exists, unscrew the cap and add more water, or discard and repeat. The sample should be transferred from the bailer to the sample container in a manner that will limit the amount of agitation in order to reduce the loss of volatile organics from the sample.

Always fill VOA vials from a single bailer volume. If the bailer is refilled, samples cannot be considered duplicates or splits.

2.5.2.2 Collection with a Bladder Pump (Well Wizard)

To successfully perform VOA sampling with a Well Wizard bladder pump, the following steps must be completed:

1. Following manufacturer's directions, activate the pump. Full water flow from the discharge tubing will begin after 5 to 15 pumping cycles. These initial pumping cycles are required to purge air from the pump and discharge tubing. The discharge and recharge settings must be manually set and adjusted to pump at optimum flow rates. To activate the bladder, it is best to set the initial cycle at long discharge and recharge rates.

2. Reduce water flow rate for VOA sample collection. To reduce the water flow rate, turn the throttle control valve (located on the left side of the Well Wizard pump control panel) counterclockwise.

3. Collect VOA sample from discharge tubing. VOA vials must be placed beneath the discharge tubing while avoiding direct contact between the vials and the tubing. Never place tubing past the mouth of the VOA vial. The pump throttle control must be turned as necessary to maintain a trickle of water in order to obtain a meniscus in the vial.

4. Continue with non-VOA sampling. Increase pump flow rate by turning the throttle control knob clockwise.

2.5.3 Collection of Light Immiscible Floaters

The approach used when collecting floaters depends on the depth to the floating layer and the thickness of that layer. If the thickness of the floater is 2 feet or greater, a bottom-filling valve bailer should be used. Slowly lower the bailer until contact is made with the floater surface, and lower the bailer to a depth less than that of the floater/water interface depth as determined by preliminary measurements with the interface probe.

When the thickness of the floating layer is less than 2 feet, and the depth to the surface of the floating layer is less than 15 feet, a peristaltic pump can be used to extract a sample.

When the thickness of the floating layer, however, is less than 2 feet and the depth to the surface of the floating layer is beyond the effective "lift" of a peristaltic pump (greater than 25 feet), a bailer can be modified to allow filling from the top only (an acceptable alternative is to use a top- loading Teflon or stainless-steel bailer). Disassemble the bailer's bottom check valve and insert a piece of 2-inch diameter Teflon sheet between the ball and ball seat. This will seal off the bottom valve. Remove the ball from the top check valve, thus allowing the sample to enter from the top. To overcome buoyancy when the bailer is lowered into the floater, place a length of one-inch stainless steel pipe on the retrieval line above the bailer (this pipe may have to be notched to allow sample entry if the pipe remains within the top of the bailer). As an alternative, use a top-loading stainless-steel bailer. Lower the device, carefully measuring the depth to the surface of the floating layer, until the top of the bailer is level with the top of the floating layer. Lower the bailer an additional one-half thickness of the floating layer and collect the sample. This technique is the most effective method of collection if the floating layer is only a few inches thick.

2.5.4 Collection of Heavy Immiscible Sinkers

The best method for collection of sinkers is use of a double check valve bailer. The key to collection is controlled, slow lowering and raising of the bailer to and from the bottom of the well. Collection methods are equivalent to those described in Section 2.5.3 above.

TABLE 1

LIQUID VOLUME IN A 1-FOOT SECTION OF WELL CASING

Well Casing Inside Diameter (D) (inches)	Volume of Liquid in 1-Foot Well Section (gallons) $V= 0.0408 (D^2)$
1	0.041
1.5	0.092
2	0.163
3	0.367
4	0.653

TABLE 2

FIELD MEASUREMENT TOLERANCE LEVELS

Field Parameter	Tolerance Level
pH	0.1 pH unit
Specific Conductance	10 percent relative percent difference (RPD)[a]
Temperature	1 °C

Note:

[a] RPD can be determined as follows:

$$RPD = \frac{(\text{Measurement 1} - \text{Measurement 2}) \times 100}{(\text{Measurement 1} + \text{Measurement 2}) / 2}$$

TABLE 3

ORDER OF PREFERRED SAMPLE COLLECTION

1. VOA
2. Purgeable organic halogens (POX)
3. Total organic halogens (TOX)
4. Cyanide
5. Extractable organics
6. Purgeable organic carbon (POC)
7. Total metals
8. Dissolved metals
9. Total organic carbon (TOC)
10. Phenols
11. Sulfate and chloride
12. Nitrate and ammonia
13. Radionuclides

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF WATER TEMPERATURE

SOP NO. 011

REVISION NO. 2

Last Reviewed: November 1999

Quality Assurance Approved	*May 11, 1993* Date

1.0 BACKGROUND

Water temperature readings are used in the calculation of various forms of alkalinity, in studies of saturation and stability with respect to calcium carbonate, in the calculation of salinity, and in general laboratory operations. Properly measuring water temperature, therefore, is important to a wide variety of field measurements.

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for measuring water temperature in the field.

1.2 SCOPE

This SOP applies to measuring the temperature of surface water and groundwater while in the field.

1.3 DEFINITION

National Institute of Standards and Technology Certified Thermometer: A thermometer that carries certification of its temperature-reading precision.

1.4 REFERENCE

U.S. Environmental Protection Agency. 1986. "Resource Conservation and Recovery Act (RCRA) Ground-Water Monitoring Technical Enforcement Guidance Document." September.

1.5 REQUIREMENTS AND RESOURCES

The following equipment may be required for the measurement of water temperature in the field:

- Mercury-filled thermometer with metal case
- Electronic thermistor with accuracy of 0.1EC and with an extension probe

- National Institute of Standards and Technology certified thermometer
- Sample container
- Decontamination materials
- Field logbook

2.0 PROCEDURES

Under normal conditions, temperature measurements may be made with any reliable, glass, mercury-filled thermometer. At a minimum, the thermometer should have a scale etched on the capillary glass every 0.1 or 0.2 EC. The thermometer should have a minimal thermal capacity to permit rapid equilibration. The thermometer should be calibrated at least annually using a precision thermometer certified by the National Institute of Standards and Technology. Thermometers should be housed in a metal case to prevent breakage.

In some situations, temperature measurements may be made with a digital electronic thermistor with an accuracy of 0.1 EC. The thermistor must be maintained as described in the manufacturer's operation and maintenance manual. In particular, always check the energy level of the thermistor's battery before each use. If the standard probe is not sufficient for taking temperature readings, then an extension probe may be used. Follow the manufacturer's directions to ensure that unbalanced resistance in the extension probe does not distort temperature readings.

Temperature measurements should be taken at the water source. If it is not possible to measure the temperature at the source, collect a sample of the water to be measured and place the sample in an intermediate container. When an intermediate container is used, fill the container with the sample and allow the temperature of the container to equilibrate with that of the sample and record the temperature. Dispose of the sample and collect a new sample. Place the new sample in an intermediate container and repeat the process just described.

Take temperature readings using the thermometer or probe while it is immersed in water long enough to allow complete equilibration. Depending on the type of thermometer, immerse it to mark or immerse totally. Report results to the nearest 0.1 or 1.0 EC, depending on the project specifications.

Record measurements in the field logbook. After taking the measurements, decontaminate the thermometer or probe.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT of pH

SOP NO. 012

REVISION NO. 3

Last Reviewed: November 1999

Quality Assurance Approved	*May 18, 1993* Date

1.0 BACKGROUND

Determining pH is critical for predicting and interpreting the reactions and migration of dissolved chemical constituents in groundwater or surface water. The pH of groundwater or surface water must be determined when a sample is collected in the field.

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for measuring the pH of water samples in the field.

1.2 SCOPE

This SOP applies to the use of pH meters in the field.

1.3 DEFINITIONS

pH Electrode: An electrode that measures the hydrogen ion potential of a solution by comparing it to a standard solution with a known hydrogen ion potential. A thin glass membrane functions as a cation exchange surface. When the electric potential of the interior of the glass membrane is compared to the electric potential of a standard solution kept isolated from the environment, a quantitative determination of the change in the internal solution's electric potential, induced by the external solution, can be made.

Nernst Potential: Nernst Potential is the voltage observed when the glass membrane separates the external solution from the internal solution. Nernst Potential varies depending on the hydrogen ion potential between the external and internal solutions and, therefore, correlates with the pH of the solution. Because the hydrogen ion content of the internal solution is constant, the changes in Nernst Potential are due to the changes in the external solution.

Buffer Solution: A buffer solution is capable of maintaining the relative concentrations of acids and bases by neutralizing, within limits, added acids or bases. It has a known pH for a specific temperature range.

1.4 REFERENCES

None

1.5 REQUIREMENTS AND RESOURCES

The pH meters used by personnel in the field should have temperature and slope adjustments and a repeatability of plus or minus 0.01 standard pH unit. Meters used for pH field measurement should be of rugged construction. A foam-lined carrying case is convenient both for transport and for use as a work table. Battery-operated meters with easily replaceable or rechargeable batteries are required. Also, a spare pH electrode should be available in the field. Both the spare and working electrodes should be immersed in a pH 4 or pH 7 buffer solution when not in use.

The following are recommended for field measurement of pH:

- pH meter with repeatability of ±0.01 standard pH unit
- Buffer solutions of pH 4, 7, and 10
- pH electrode (probe)
- Electrode filling solution
- Electrode holder
- Calibrated thermometer
- Deionized water and wash bottle
- Disposable beakers
- Logbook or field sheets

2.0 PROCEDURES

Meter calibration and field measurement procedures are outlined in the following subsections.

2.1 CALIBRATION

Commercially prepared buffer solutions should be used for calibration. Solutions traceable to the National Institute of Standards and Technology can be purchased inexpensively from any major laboratory supply company. These solutions are certified with an accuracy of plus or minus 0.01 pH unit at a specific temperature, usually 25 EC. Theoretically, buffer solutions are stable indefinitely. However, they are susceptible to contamination, and old, partially full bottles should be replaced.

Because various terms are used to describe the pH meter calibration process, providing a detailed set of instructions for each type of instrument is not practical. Always refer to the manufacturer's instructions when using a particular instrument. The general procedure below can be used to calibrate any pH meter.

1. Calibrate the meter with two buffer solutions to determine if the electrodes are in working order. The slope cannot be adjusted with a one-point calibration.

2. To calibrate the meter, use one buffer solution with a pH greater than and one buffer solution with a pH less than the anticipated pH of the sample. For example, for an anticipated pH of 6, calibrate with pH 4 and pH 7 buffers; for an anticipated pH of 8, calibrate with pH 7 and pH 10 buffers.

3. Ensure that the buffers are at the same temperature as the sample (within 2EC). Pour aliquots into small containers; never put the electrode into the buffer storage bottles.

4. Adjust the instrument to read the pH 7 buffer accurately. Adjust the temperature compensator according to the manufacturer's instructions. Be sure to rinse the probe with deionized water after taking the calibration measurement.

5. Adjust the instrument to read the pH of the second buffer accurately. If it is not possible to adjust the instrument to read the pH of buffer solutions accurately, check for a defective electrode or contaminated buffer solution. Be sure to rinse the probe with deionized water after taking the calibration measurement.

6. The meter must be calibrated before the start of each work day. Check the calibration periodically and recalibrate if necessary.

2.2 FIELD MEASUREMENT

Do not filter field samples prior to analysis. When measuring the pH of groundwater samples, use a submersible pump or bladder pump to obtain the sample to minimize the release of gas from the sample.

The procedure below should be used for field measurement of pH.

1. Calibrate the instrument and set the temperature compensation in accordance with the manufacturer's instructions.
2. Collect the sample to be measured in a prerinsed jar or beaker or a flow-through cell.
3. Measure the temperature of the sample to the nearest 0.1EC.
4. Set the temperature compensation on the pH meter to the temperature of the sample, following the manufacturer's instructions.
5. Rinse the probe with deionized water.
6. Immerse the probe in the sample. Record the pH value indicated. If the sample is being pumped through a closed container, wait for the temperature and pH to stabilize. Stop sample flow to eliminate streaming potential. Record the pH value indicated.
7. Record measurements in a logbook, on field sheets, or as specified in the project work plan.

3.0 POTENTIAL PROBLEMS

Temperature, atmospheric contamination, and ionic strength are factors that may affect pH measurements. Each of these three factors is discussed below. Color, turbidity, and colloids will not affect pH measurements.

Temperature: As indicated in Table 1, pH is affected by temperature. To prevent this from causing incorrect pH readings, the temperature compensator on the pH meter must be set to the temperature of the sample. Also, the meter must be calibrated at approximately this same temperature. The temperatures of the buffer and the unknown liquid should both be recorded at the time of measurement. Ideally, their temperatures should be within 2EC of each other.

Atmospheric Contamination: Atmospheric contamination can be a significant problem when sampling the pH of groundwater. When the sample is exposed to air, dissolved oxygen and carbon dioxide can change a sample's pH. To ensure that this problem does not affect the pH measurement, a groundwater sample should ideally be pumped through a closed container in which pH and temperature probes are immersed. The measurements should not be recorded until both temperature and pH have stabilized. The sampling pump should be stopped before recording the data because a streaming potential will affect the measurement in a flowing sample.

Ionic Strength: Because of the potential for errors due to ionic strength, pH measurement should always be accompanied by a measurement of specific conductance.

In general terms, pH is a measure of hydrogen ion activity. Normally, water samples are assumed to be ideal solutions in which other ions do not affect hydrogen ion activity. However, if the ionic strength is too high, this assumption does not hold true. Some site investigations include sampling of waste ponds or other highly contaminated water that has very high ionic strength. Because buffer solutions used in the field are not made with a similarly high concentration of dissolved ions, pH measurement of highly contaminated water will be inaccurate. Similarly, pH measurement of samples with very low ionic strength will be inaccurate because the low ionic strength of the sample approaches the level of resistance in the glass electrode. To reduce this problem, samples with very low ionic strength should be stirred for a few seconds before taking a reading. Even then, several minutes may be required for the reading to stabilize.

High sodium concentration also may produce errors in pH measurement because of the high ionic strength of these solutions. To measure the pH of such solutions, a special electrode is needed. Such an electrode can be purchased from any of several electrode manufacturers.

TABLE 1

pH OF BUFFER SOLUTIONS AS A FUNCTION OF TEMPERATURE

	Buffer Solution pH		
Standard	4.0	7.0	10.0
Temperature (EC)			
0	4.01	7.13	10.34
5	3.99	7.10	10.26
10	4.00	7.07	10.19
15	3.99	7.05	10.12
20	4.00	7.02	10.06
25	4.00	7.00	10.00
30	4.01	6.99	9.94

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF SPECIFIC CONDUCTANCE

SOP NO. 013

REVISION NO. 2

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	May 18, 1993
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1.0 BACKGROUND

Specific conductance is a widely used parameter for evaluating groundwater and surface water quality. It is a simple indicator of change within a system and provides useful information to laboratory personnel performing other measurements on a water sample.

1.1 PURPOSE

Specific conductance should be determined at the time the sample is collected. This standard operating procedure (SOP) establishes the requirements and procedures for measuring the specific conductance of groundwater or surface water in the field.

1.2 SCOPE

This SOP applies to the use of specific conductance meters in the field.

1.3 DEFINITION

Specific Conductance- Specific conductance is the reciprocal of electrical resistivity. The values of electrical resistivity and specific conductance depend on the number of ions in a solution. Pure water has 100 percent resistivity and no specific conductance. As ions are added to a solution, resistivity drops and specific conductance increases.

1.4 REFERENCES

U.S. Environmental Protection Agency. 1996. "Test Methods for Evaluating Solid Waste, Volume 1C: Laboratory Manual Physical/Chemical Methods, SW-846."

American Society for Testing and Materials Annual Book of Standards. "Standard Test Methods for Electrical Conductivity and Resistivity of Water, Method D-1125."

U.S. Geological Survey. 1977. *National Handbook of Recommended Methods for Water Data Acquisition*.

1.5 REQUIREMENTS AND RESOURCES

Specific conductance meters should measure temperature, have a temperature compensator, and read directly in micromhos per centimeter (µmhos/cm), corrected to 25°C. For field measurements, a probe-type unit is preferred over a pipet-type unit. Specific conductance meters should have a foam-lined carrying case and should be battery-operated with easily rechargeable or replaceable batteries. A relative accuracy of plus or minus 3 percent is adequate.

The following are required for calibrating a specific conductance meter and for the field measurement of specific conductance:

- A probe-type specific conductance meter meeting the requirements given above
- Deionized water and wash bottle
- Disposable beakers
- Reagent-grade potassium chloride (KCl) or a commercially-prepared, standard 0.01 molar (M) KCl solution
- Sampling containers
- Sampling equipment
- 1-liter mixing container
- Calibrated thermometer
- Field logbook

2.0 PROCEDURES

Meter calibration and field measurement procedures are outlined in the following subsections.

2.1 METER CALIBRATION

Reagent-grade KCl is the universal standard for calibrating specific conductance equipment. The electrodes are calibrated by reading the specific conductance of standard KCl solutions. A concentration of 0.01 M KCl should be used because its specific conductance is closest to that of most natural samples.

The measuring circuit of the specific conductance meter is calibrated either by the manufacturer or with a calibrating resistor. The manufacturer's instructions for the particular instrument should be followed for calibrating the specific conductance meter.

Individual manufacturers may use slightly different terminology, but the following general procedure will always apply:

1. Prepare a 0.01 M KCl solution by dissolving 0.745 gram of pure, dry KCl in 1 liter of deionized water. The base conductivity for the prepared solution is 1,408.1F mhos/cm at 25 EC; if the deionized water has any conductance, it must be corrected to 25EC and added to the value of the solution. Alternatively, commercially prepared solutions can be used.

2. Measure the temperatures of the 0.01 M KCl solution and the deionized water used for the dilution. They should be at the same temperature (±0.2EC).

3. Using Table 1, determine the expected specific conductance of the 0.01M KCl solution at the temperature measured.

4. Measure the specific conductance of the 0.01M KCl solution and of the deionized water.

5. Use the following equation to check the cell constant specified by the manufacturer:

$$K = \frac{C_1 - C_2}{10^6 \times C_3}$$

where

K = the cell constant
C_1 = the specific conductance of the deionized water
C_2 = the specific conductance of the 0.01 M KCl solution
C_3 = the expected specific conductance from the Table 1

6. A measured cell constant different from that specified by the manufacturer generally indicates that the electrodes are dirty. If this is the case, replace the electrode with a clean

spare or clean and replatinize the electrode in accordance with instructions in the manufacturer's manual or in the American Society for Testing and Materials Method D-1125, Section 8.3.

7. After verifying that the cell constant is acceptable, measure the specific conductance of samples in accordance with to the procedure given in Section 2.2.

2.2 FIELD MEASUREMENT

Do not filter samples before analysis. To minimize gas releases from groundwater samples, a submersible pump or bladder pump should be used to obtain samples.

The following procedure should be used for field measurement of specific conductance:

1. Calibrate the instrument and check the cell constant in accordance with the manufacturer's instructions and the procedure provided in Section 2.1.

2. Collect the sample in a prerinsed jar or beaker or a flow-through cell.

3. Rinse the specific conductance meter probe with deionized water.

4. Using a thermometer or the specific conductance meter itself, measure and record the temperature of the sample in°C.

5. Immerse the specific conductance meter probe in the sample. Record the reading in µmhos/cm.

6. Record measurements in the field logbook or as specified in the project work plan.

3.0 POTENTIAL PROBLEMS

Principal problem areas for specific conductance measurement are the temperature effect, determination of the cell constant, and allowance for very high ionic strengths. A change in temperature of 1°C can cause a 20 percent change in the measured specific conductance. Reported data should note whether temperature correction has been applied. Some instruments perform temperature correction automatically, but this, too, should be noted for the reported data. All data should be corrected to 25°C.

Field personnel must be aware that a significant change in the cell constant indicates that the electrodes require cleaning or replacement. The constant should be checked at each calibration, as described in Section 2.1.

Specific conductance varies directly with ion concentrations up to a specific conductance of about 5,000 Fmhos/cm. Samples collected at most sites seldom have a specific conductance greater than 5,000 Fmhos/cm. Readings above this level should not be considered accurate. However, such readings can still provide useful information about the relative levels of conductance and should be noted.

TABLE 1

RELATIONSHIP OF TEMPERATURE AND SPECIFIC CONDUCTANCE FOR 0.01 M POTASSIUM CHLORIDE SOLUTION

Temperature (EC)	Expected Specific Conductance of 0.01 M KCl Solution (F mhos/cm)
15	1,141.5
16	1,167.5
17	1,193.6
18	1,219.9
19	1,246.4
20	1,273.0
21	1,299.7
22	1,326.6
23	1,353.6
24	1,380.8
25	1,408.1
26	1,436.5
27	1,463.2
28	1,490.9
29	1,518.7
30	1,546.7

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

STATIC WATER LEVEL, TOTAL WELL DEPTH,
AND IMMISCIBLE LAYER MEASUREMENT

SOP NO. 014

REVISION NO. 0

Last Reviewed: December 1999

	July 20, 1994
Quality Assurance Approved	Date

1.0 BACKGROUND

Measurement of static water level, total well depth, and any immiscible layers is necessary before a well can be sampled and groundwater flow direction can be determined. If an immiscible layer is present, its depth and thickness must be determined. In addition, the static water level and total depth of a monitoring well are needed to determine a purging volume.

1.1 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide guidelines for field personnel measuring static water levels and total water depths of monitoring wells or piezometers. This SOP also provides guidelines for measuring immiscible layers in such wells.

1.2 SCOPE

This SOP describes the methodologies for measuring static water level, total well depth, and immiscible layer depth and thickness.

1.3 DEFINITIONS

To clarify the methodologies presented in this SOP, the following definitions are presented:

Electrical Water Level Indicator: An electrical probe used to determine the depth to fluid. The probe has a light or sound alarm connected to an open circuit. The circuit is closed and the alarm is activated when the probe contacts a conducting fluid such as water.

Immiscible Layer: A liquid phase that cannot be uniformly mixed or blended with water. Heavy immiscible phases sink in water; light immiscible phases float on water.

Interface Probe: An electrical probe used to determine the thicknesses of light or dense immiscible layers in the water column of a monitoring well.

Ionization Detector: A photoionization detector (PID) or a flame ionization detector (FID) is used to measure the level of volatile organic compounds in the gaseous phase. These units are generally not compound-specific and thus measure only total volatile organic compounds. The PID generally cannot detect as complete a range of compounds as the FID. This difference is the result of the relative ionization energies of the two detectors. Most PIDs cannot detect methane, but FIDs can. The HNu and Microtip are examples of PIDs; the Foxboro organic vapor analyzer (OVA) is an example of an FID.

Static Water Level: The level of water in a monitoring well or piezometer. This level can be measured as the depth to water or as the elevation of water relative to a reference mark or datum.

Total Well Depth: The distance from the ground surface to the bottom of a monitoring well or piezometer

1.4 REFERENCES

SOP No. 002, General Equipment Decontamination

U.S. Environmental Protection Agency. 1994. "Water Level Measurement." Environmental Response Team SOP #2043 (Rev. #0.0, 10/03/94). On-Line Address: http://204.46.140.12/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

The equipment required for measuring static water levels, total well depths, and immiscible layers is as follows:

- Electrical water level indicator
- Interface probe
- PID or FID

2.0 PROCEDURES

This section provides general guidance followed by specific procedures for static water level, total well depth, and immiscible layer measurement.

Techniques for measuring depth to water and depth to the bottom of a monitoring well should be identified in the planning stage of field work. Also at this stage, measuring devices should be chosen, and an individual should be assigned to take and record measurements.

All measurement instruments should be decontaminated before and after use and between measurement locations. Refer to SOP No. 002, General Equipment Decontamination.

Before initiating any measuring activities, the ambient air at a monitoring well head should be monitored for possible emissions of volatile organic compounds. To accomplish this monitoring, a PID or an FID should be used. The health and safety plan for on-site activities should provide action levels and the rationale for selection of either detector.

Appropriate respiratory protection equipment should be worn by the sampling team. Wells should be approached from the upwind side. When opening the monitoring well, the sampling team should systematically survey the inside of the well casing, the area from the casing to the ground, the area from above the well casing to the breathing zone, and the area around the well. Readings for comparison to action levels should be taken not within the well casing but in the breathing zone. If PID or FID readings of volatile organic compounds are above action levels, the sampling team should retreat to a safe area and put on appropriate safety gear. The site-specific health and safety plan should be consulted for action levels.

2.1 STATIC WATER LEVEL MEASUREMENT

The procedure described below should be followed to measure the static water level in a monitoring well or piezometer.

An electric water level indicator is typically used for static water level measurement. The electrical probe of the indicator should be lowered into the monitoring well until the light or sound alarm is activated, indicating that the probe has touched the water surface. The static water level should then be read directly from the indicator to the 0.01-foot fraction. If the monitoring well top is not flush with the ground surface, the distance between the static water level and the top of the riser pipe should be measured; the height of the riser pipe above ground surface should then be subtracted from the first measurement to determine the depth to static water below ground surface. If surveyed elevations are available, they should be used to establish the water level elevation. To ensure measurement accuracy, the probe should be left hanging above the water surface in the monitoring well; a series of three readings should be taken, and the values should be averaged. The measurement date and time, individual readings, and the average of the readings should be recorded in a field logbook.

2.2 TOTAL WELL DEPTH MEASUREMENT

The procedure described below should be followed to measure total well depth in a monitoring well or piezometer.

Total well depth measurement can be performed also using an electric water level indicator. The electrical probe of the indicator should be lowered into the monitoring well until resistance is met, indicating that the probe has reached the bottom of the well. The total well depth should then be read directly from the indicator to the 0.01-foot fraction. If the monitoring well top is not flush with the ground surface, the distance between the bottom of the well and the top of the riser pipe should be measured; the height of the riser pipe above ground surface should then be subtracted from the first measurement to determine the depth from ground surface to the bottom of the well. To ensure measurement accuracy, the probe should be left hanging above the water surface in the monitoring well; a series of three readings should be taken, and the values should be averaged. The measurement date and time, individual readings, and the average of the readings should be recorded in a field logbook.

2.3 IMMISCIBLE LAYER DETECTION AND MEASUREMENT

The procedure described below should be followed to detect and measure an immiscible layer in a monitoring well.

A light immiscible layer in a monitoring well can be detected by slowly lowering an interface probe to the surface of the water in the well. When the audible alarm sounds, the depth of the probe should be recorded. If the alarm is continuous, a light immiscible layer has been detected. To measure the thickness of this layer, the probe should then be lowered until the alarm changes to an oscillating signal. The oscillating alarm indicates that the probe has reached a water layer. The probe depth at the time the alarm begins oscillating should be recorded as the depth to water. The thickness of the light immiscible layer should then be determined by subtracting the depth at which a continuous alarm occurred from the depth at which the alarm began to oscillate. To ensure measurement accuracy, the interface probe should be left hanging above the water surface in the monitoring well; a series of three readings should be taken, and the depths and thicknesses measured should be averaged. The measurement date and time, individual readings for depth and thickness, and average values for depth and thickness should be recorded in a field logbook.

To determine whether a dense immiscible layer is present, the interface probe should be lowered further into the monitoring well. If the alarm changes from an oscillating to a continuous signal, a heavier immiscible layer has been detected, and the probe depth should be recorded at that point. Total well depth obtained in Section 2.2 should be used for calculating the thickness of the dense layer. The dense layer should be calculated by subtracting the depth at which the alarm became continuous from the total well depth. This procedure provides an estimate of the thickness of the dense layer in the monitoring well. To ensure measurement accuracy, the interface probe should be left hanging above the water surface in the monitoring well; a series of three readings should be taken, and the depths and thicknesses measured should be averaged. The measurement date and time, individual readings for depth and thickness, and average values for depth and thickness should be recorded in a field logbook.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

PACKAGING AND SHIPPING SAMPLES

SOP NO. 019

REVISION NO. 5

Last Reviewed: January 2000

	January 28, 2000
Quality Assurance Approved	Date

1.0 BACKGROUND

In any sampling program, the integrity of a sample must be ensured from its point of collection to its final disposition. Procedures for classifying, packaging, and shipping samples are described below. Steps in the procedures should be followed to ensure sample integrity and to protect the welfare of persons involved in shipping and receiving samples. When hazardous substances and dangerous goods are sent by common carrier, their packaging, labeling, and shipping are regulated by the U.S. Department of Transportation (DOT) Hazardous Materials Regulations (HMR, *Code of Federal Regulations*, Title 49 [49 CFR] Parts 106 through 180) and the International Air Transportation Association (IATA) Dangerous Goods Regulations (DGR).

1.1 PURPOSE

This standard operating procedure (SOP) establishes the requirements and procedures for packaging and shipping samples. It has been prepared in accordance with the U.S. Environmental Protection Agency (EPA) "Sampler's Guide to the Contract Laboratory Program (CLP)," the DGR, and the HMR. Sample packaging and shipping procedures described in this SOP should be followed for all sample packaging and shipping. Deviations from the procedures in this SOP must be documented in a field logbook. This SOP assumes that samples are already collected in the appropriate sample jars and that the sample jars are labeled and tagged appropriately.

1.2 SCOPE

This SOP applies to sample classification, packaging, and shipping.

1.3 DEFINITIONS

Custody seal: A custody seal is a tape-like seal. Placement of the custody seal is part of the chain-of-custody process and is used to prevent tampering with samples after they have been packaged for shipping.

Dangerous goods: Dangerous goods are articles or substances that can pose a significant risk to health, safety, or property when transported by air; they are classified as defined in Section 3 of the DGR (IATA 1999).

Environmental samples: Environmental samples include drinking water, most groundwater and ambient surface water, soil, sediment, treated municipal and industrial wastewater effluent, and biological specimens. Environmental samples typically contain low concentrations of contaminants and when handled require only limited precautionary procedures.

Hazardous Materials Regulations: The HMR are DOT regulations for the shipment of hazardous materials by air, water, and land; they are located in 49 CFR 106 through 180.

Hazardous samples: Hazardous samples include dangerous goods and hazardous substances. Hazardous samples shipped by air should be packaged and labeled in accordance with procedures specified by the DGR; ground shipments should be packaged and labeled in accordance with the HMR.

Hazardous substance: A hazardous substance is any material, including its mixtures and solutions, that is listed in Appendix A of 49 CFR 172.101 and its quantity, in one package, equals or exceeds the reportable quantity (RQ) listed in the appendix.

IATA Dangerous Goods Regulations: The DGR are regulations that govern the international transport of dangerous goods by air. The DGR are based on the International Civil Aviation Organization (ICAO) Technical Instructions. The DGR contain all of the requirements of the ICAO Technical Instructions and are more restrictive in some instances.

Nonhazardous samples: Nonhazardous samples are those samples that do not meet the definition of a hazardous sample and **do not** need to be packaged and shipped in accordance with the DGR or HMR.

Overpack: An enclosure used by a single shipper to contain one or more packages and to form one handling unit (IATA 1999). For example, a cardboard box may be used to contain three fiberboard boxes to make handling easier and to save on shipping costs.

1.4 REFERENCES

U.S. Department of Transportation, Transport Canada, and the Secretariat of Communications and Transportation of Mexico (DOT and others). 1996. "1996 North American Emergency Response Guidebook."

International Air Transport Association (IATA). 1997. "Guidelines for Instructors of Dangerous Courses."

IATA. 1999. "Dangerous Goods Regulations." 40th Edition.

U.S. Environmental Protection Agency. 1996. "Sampler's Guide to the Contract Laboratory Program." Office of Solid Waste and Emergency Response. Washington, DC. EPA/540/R-96/032. On-Line Address: http://www.epa.gov/oerrpage/superfund/programs/clp/guidance.htm#sample

1.5 REQUIREMENTS AND RESOURCES

The procedures for packaging and shipping **nonhazardous** samples require the following:

- Coolers
- Ice
- Vermiculite, bubble wrap, or similar cushioning material
- Chain-of-custody forms and seals
- Airbills
- Resealable plastic bags for sample jars and ice
- Tape (strapping and clear)

The procedures for packaging and shipping **hazardous** samples require the following:

- Ice
- Vermiculite or other non-combustible, absorbent packing material
- Chain-of-custody forms and seals
- Appropriate dangerous goods airbills and emergency response information to attach to the airbill

- Resealable plastic bags for sample jars and ice
- Tape (strapping and clear)
- Appropriate shipping containers as specified in the DGR
- Labels that apply to the shipment such as hazard labels, address labels, "Cargo Aircraft Only" labels, and package orientation labels (up arrows)

2.0 PROCEDURES

The following procedures apply to packaging and shipping nonhazardous and hazardous samples.

2.1 SAMPLE CLASSIFICATION

Prior to sample shipment, it must be determined whether the sample is subject to the DGR. Samples subject to these regulations shall be referred to as hazardous samples. If the hazardous sample is to be shipped by air, then the DGR should be followed. Any airline, including FedEx, belonging to IATA must follow the DGR. As a result, FedEx **may not** accept a shipment that is packaged and labeled in accordance with the HMR (although in most cases, the packaging and labeling would be the same for either set of regulations). The HMR states that a hazardous material may be transported by aircraft in accordance with the ICAO Technical Instruction (49 CFR 171.11) upon which the DGR is based. Therefore, the use of the DGR for samples to be shipped by air complies with the HMR, but not vice versa.

Most environmental samples are not hazardous samples and do not need to be packaged in accordance with any regulations. Hazardous samples are those samples that can be classified as specified in Section 3 of the DGR, can be found in the List of Dangerous Goods in the DGR in bold type, are considered a hazardous substance (see definition), or are mentioned in "Section 2 - Limitations" of the DGR for countries of transport or airlines (such as FedEx). The hazard classifications specified in the DGR (and the HMR) are as follows:

Class 1 - Explosives

Division 1.1 - Articles and substances having a mass explosion hazard

Division 1.2 - Articles and substances having a projection hazard but not a mass explosion hazard
Division 1.3 - Articles and substances having a fire hazard, a minor blast hazard and/or a minor projection hazard but not a mass explosion hazard
Division 1.4 - Articles and substances presenting no significant hazard
Division 1.5 - Very sensitive substances mass explosion hazard
Division 1.6 - Extremely insensitive articles which do not have a mass explosion hazard

Class 2 - Gases

Division 2.1 - Flammable gas
Division 2.2 - Non-flammable, non-toxic gas
Division 2.3 - Toxic gas

Class 3 - Flammable Liquids

Class 4 - Flammable Solids; Substances Liable to Spontaneous Combustion; Substances, which, in Contact with Water, Emit Flammable Gases

Division 4.1 - Flammable solids.
Division 4.2 - Substances liable to spontaneous combustion.
Division 4.3 - Substances, which, in contact with water, emit flammable gases.

Class 5 - Oxidizing Substances and Organic Peroxide

Division 5.1 - Oxidizers.
Division 5.2 - Organic peroxides.

Class 6 - Toxic and Infectious Substances

Division 6.1 - Toxic substances.
Division 6.2 - Infectious substances.

Class 7 - Radioactive Material

Class 8 - Corrosives

Class 9 - Miscellaneous Dangerous Goods

The criteria for each of the first eight classes are very specific and are outlined in Section 3 of the DGR and 49 CFR 173 of the HMR. Some classes and divisions are further divided into packing groups based on their level of danger. Packing group I indicates a great danger, packing group II indicates a medium danger, and packing group III indicates a minor danger. Class 2, gases, includes any compressed gas being

shipped and any noncompressed gas that is either flammable or toxic. A compressed gas is defined as having a pressure over 40 pounds per square inch (psi) absolute (25 psi gauge). Most air samples and empty cylinders that did not contain a flammable or toxic gas are exempt from the regulations. An empty hydrogen cylinder, as in a flame ionization detector (FID), is considered a dangerous good unless it is properly purged with nitrogen in accordance with the HMR. A landfill gas sample is usually considered a flammable gas because it may contain a high percentage of methane. Class 3, flammable liquids, are based on the boiling point and flash point of a substance. Most class 3 samples include solvents, oil, gas, or paint-related material collected from drums, tanks, or pits. Division 6.1, toxic substances, is based on oral toxicity (LD_{50} [lethal dose that kills 50 percent of the test animals]), dermal toxicity (LD_{50} values), and inhalation toxicity (LC_{50} [lethal concentration that kills 50 percent of the test animals] values). Division 6.1 substances include pesticides and cyanide. Class 7, radioactive material, is defined as any article or substance with a specific activity greater than 70 kiloBecquerels (kBq/kg) (0.002 [microCuries per gram [µCi/g]). If the specific activity exceeds this level, the sample should be shipped in accordance with Section 10 of the DGR. Class 8, corrosives, are based on the rate at which a substance destroys skin tissue or corrodes steel; they are not based on pH. Class 8 materials include the concentrated acids used to preserve water samples. Preserved water samples are not considered class 8 substances and should be packaged as nonhazardous samples. Class 9, miscellaneous dangerous goods, are substances that present a danger but are not covered by any other hazard class. Examples of class 9 substances include asbestos, polychlorinated biphenyls (PCB), and dry ice.

Unlike the DGR, the HMR includes combustible liquids in hazard class 3. The definition of a combustible liquid is specified in 49 CFR 173.120 of the HMR. The HMR has an additional class, ORM-D, that is not specified in the DGR. "ORM-D material" refers to a material such as a consumer commodity, that although otherwise subject to the HMR, presents a limited hazard during transport due to its form, quantity, and packaging. It must be a material for which exceptions are provided in the table of 49 CFR 172.101. The DGR lists consumer commodities as a class 9 material.

In most instances, the hazard of a material sampled is unknown because no laboratory testing has been conducted. A determination as to the suspected hazard of the sample must be made using knowledge of the site, field observations, field tests, and other available information.

According to 40 CFR 261.4(d) and (e), samples transported to a laboratory for testing or treatability studies, including samples of hazardous wastes, are **not** hazardous wastes. FedEx will not accept a shipment of hazardous waste.

2.2 PACKAGING NONHAZARDOUS SAMPLES

Nonhazardous samples, after being appropriately containerized, labeled, and tagged, should be packaged in the following manner. Note that these are general instructions; samplers should be aware of any client-specific requirements concerning the placement of custody seals or other packaging provisions.

1. Place the sample in a resealable plastic bag.

2. Place the bagged sample in a cooler and pack it to prevent breakage.

3. Prevent breakage of bottles during shipment by either wrapping the sample container in bubble wrap, or lining the cooler with a noncombustible material such as vermiculite. Vermiculite is especially recommended because it will absorb any free liquids inside the cooler. It is recommended that the cooler be lined with a large plastic garbage bag before samples, ice, and absorbent packing material are placed in the cooler.

4. Add a sufficient quantity of ice to the cooler to cool samples to 4 °C. Ice should be double bagged in resealable plastic bags to prevent the melted ice from leaking out. As an option, a temperature blank (a sample bottle filled with distilled water) can be included with the cooler.

5. Seal the completed chain-of-custody forms in a plastic bag and tape the plastic bag to the inside of the cooler lid.

6. Tape any instructions for returning the cooler to the inside of the lid.

7. Close the lid of the cooler and tape it shut by wrapping strapping tape around both ends and hinges of the cooler at least once. Tape shut any drain plugs on the cooler.

8. Place two signed custody seals on the cooler, ensuring that each one covers the cooler lid and side of the cooler. Place clear plastic tape over the custody seals.

9. Place address labels on the outside of the cooler.

10. Ship samples overnight by a commercial carrier such as FedEx.

2.3 PACKAGING HAZARDOUS SAMPLES

The procedures for packaging hazardous samples are summarized below. Note that according to the DGR, all spellings must be exactly as they appear in the List of Dangerous Goods, and only approved abbreviations are acceptable. The corresponding HMR regulations are provided in parentheses following any DGR referrals. The HMR must be followed only if shipping hazardous samples by ground transport.

1. Determine the proper shipping name for the material to be shipped. All proper shipping names are listed in column B of the List of Dangerous Goods table in Section 4 of the DGR (or column 2 of the Hazardous Materials Table in 49 CFR 172.101). In most instances, a generic name based on the hazard class of the material is appropriate. For example, a sample of an oily liquid collected from a drum with a high photoionization detector (PID) reading should be packaged as a flammable liquid. The proper shipping name chosen for this sample would be "flammable liquid, n.o.s." The abbreviation "n.o.s." stands for "not otherwise specified" and is used for generic shipping names. Typically, a specific name, such as acetone, should be inserted in parentheses after most n.o.s. descriptions. However, a technical name is not required when shipping a sample for testing purposes and the components are not known. If shipping a hazardous substance (see definition), then the letters "RQ" must appear in front of the proper shipping name.

2. Determine the United Nations (UN) identification number, class or division, subsidiary risk if any, required hazard labels, packing group, and either passenger aircraft or cargo aircraft packing instructions based on the quantity of material being shipped in one package. This information is provided in the List of Dangerous Goods (or Hazardous Materials Table in 49 CFR 172.101) under the appropriate proper shipping name. A "Y" in front of a packing instruction indicates a limited quantity packing instruction. If shipping dry ice or a limited quantity of a material, then UN specification shipping containers do not need to be used.

3. Determine the proper packaging required for shipping the samples. Except for limited quantity shipments and dry ice, these are UN specification packages that have been tested to meet the packing group of the material being shipped. Specific testing requirements of the packages is listed in Section 6 of the DGR (or 49 CFR 178 of the HMR). All UN packages are stamped with the appropriate UN specification marking. Prior planning is required to have the appropriate packages on hand during a sampling event where hazardous samples are anticipated. Most samples can be shipped in either a 4G fiberboard box, a 1A2 steel drum, or a 1H2 plastic drum. Drums can be purchased in 5- and 20-gallon sizes and are ideal for shipping multiple hazardous samples. When FedEx is used to ship samples containing PCBs, the samples must be shipped in an inner metal packaging (paint can) inside a 1A2 outer steel drum. This method of packaging PCB samples is in accordance with FedEx variation FX-06, listed in Section 2 of the DGR.

4. Place each sample jar in a separate resealable plastic bag. Some UN specification packagings contain the sample jar and plastic bag to be used when shipping the sample.

5. Place each sealed bag inside the approved UN specification container (or other appropriate container if a limited quantity or dry ice) and pack with enough noncombustible, absorbent, cushioning material (such as vermiculite) to prevent breakage and to absorp liquid.

6. Place chain-of-custody forms in a resealable plastic bag and either attach it to the inside lid of the container or place it on top inside the container. Place instructions for returning the container to the shipper on the inside lid of the container as appropriate. Close and seal the shipping container in the manner appropriate for the type of container being used.

7. Label and mark each package appropriately. All irrelevant markings and labels need to be removed or obliterated. All outer packagings must be marked with proper shipping name, UN identification number, and name and address of the shipper and the recipient. For carbon dioxide, solid (dry ice), the net weight of the dry ice within the package needs to be marked on the outer package. For limited quantity shipments, the words "limited quantity" or "LTD. QTY." must be marked on the outer package. Affix the appropriate hazard label to the outer package. If the material being shipped contains a subsidiary hazard, then a subsidiary hazard label must also be affixed to the outer package. The subsidiary hazard label is identical to the primary hazard label except that the class or division number is not present. It is acceptable to obliterate the class or division marking on a primary hazard label and use it as the subsidiary hazard label. If using cargo aircraft only packing instructions, then the "Cargo Aircraft Only" label must be used. Package orientation labels (up arrows) must be placed on opposite sides of the outer package. Figure 1 depicts a properly marked and labeled package.

8. If using an overpack (see definition), mark and label the overpack and each outer packaging within the overpack as described in step 7. In addition, the statement "INNER PACKAGES COMPLY WITH PRESCRIBED SPECIFICATIONS" must be marked on the overpack.

9. Attach custody seals, and fill out the appropriate shipping papers as described in Section 2.4.

2.4 SHIPPING PAPERS FOR HAZARDOUS SAMPLES

A "Shippers Declaration for Dangerous Goods" and "Air Waybill" must be completed for each shipment of hazardous samples. FedEx supplies a Dangerous Goods Airbill to its customers; the airbill combines both

the declaration and the waybill. An example of a completed Dangerous Goods Airbill is depicted in Figure 2. A shipper's declaration must contain the following:

- Name and address of shipper and recipient
- Air waybill number (not applicable to the HMR)
- Page ___ of ___
- Deletion of either "Passenger and Cargo Aircraft" or "Cargo Aircraft Only," whichever does not apply
- Airport or city of departure
- Airport or city of destination
- Deletion of either "Non-Radioactive" or "Radioactive," which ever does not apply
- The nature and quantity of dangerous goods. This includes the following information in the following order (obtained from the List of Dangerous Goods in the DGR): proper shipping name, class or division number, UN identification number, packing group number, subsidiary risk, quantity in liters or kilograms (kg), type of packaging used, packing instructions, authorizations, and additional handling information. Authorizations include the words "limited quantity" or "LTD. QTY." if shipping a limited quantity, any special provision numbers listed in the List of Dangerous Goods in the DGR, and the variation "USG-14" when a technical name is required after the proper shipping name but not entered because it is unknown.
- Signature for the certification statement
- Name and title of signatory
- Place and date of signing certification
- A 24-hour emergency response telephone number for use in the event of an incident involving the dangerous good
- Emergency response information attached to the shipper's declaration. This information can be in the form of a material safety data sheet or the applicable North American Emergency Response Guidebook (NAERG; DOT 1996) pages. Figure 3 depicts the appropriate NAERG emergency response information for "Flammable liquids, n.o.s." as an example.

Note that dry ice does not require an attached shipper's declaration. However, the air waybill must include the following on it: "Dry ice, 9, UN1845, ____ x ____ kg." The blanks must include the number of packages and the quantity in kg in each package. If using FedEx to ship dry ice, the air waybill includes a box specifically for dry ice. Simply check the appropriate box and enter in the number of packages and quantity in each package.

The HMR requirements for shipping papers are located in 49 CFR 172 Subpart C.

3.0 POTENTIAL PROBLEMS

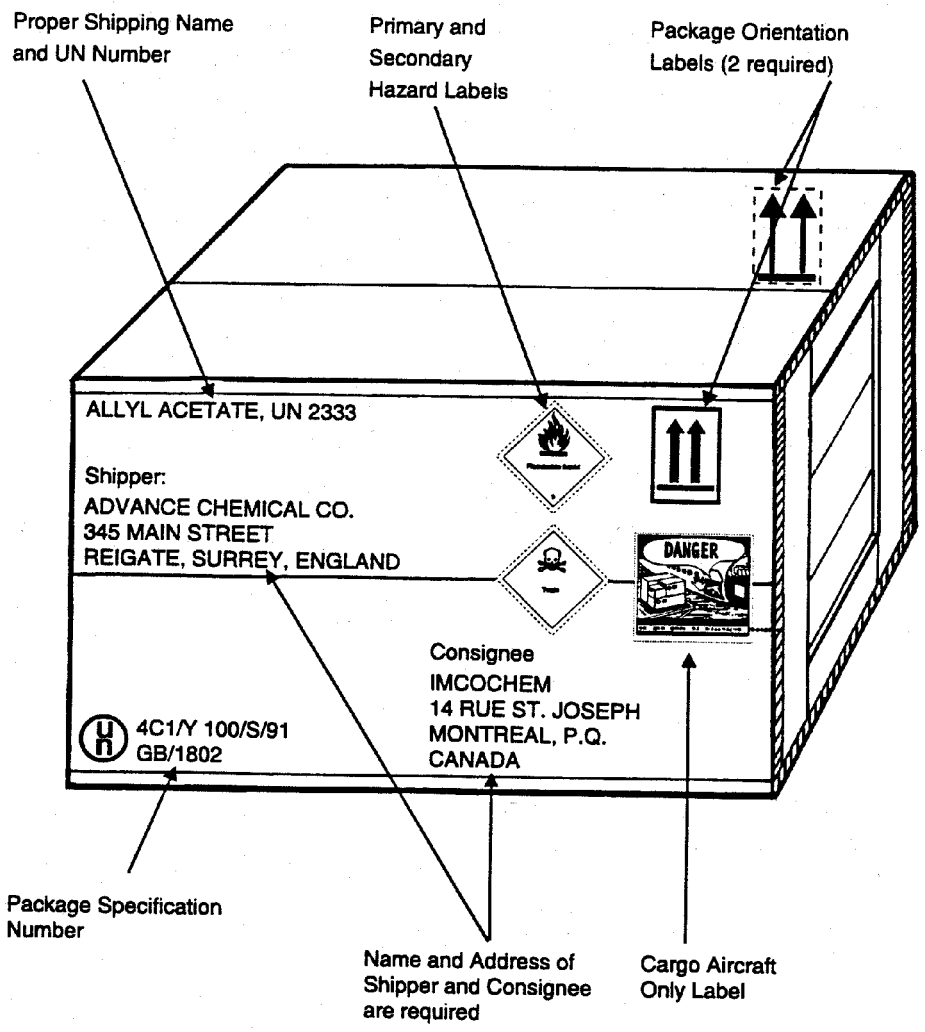
The following potential problems may occur during sample shipment:

- Leaking package. If a package leaks, the carrier may open the package, return the package, and if a dangerous good, inform the Federal Aviation Administration (FAA), which can result in fines.
- Improper labeling and marking of package. If mistakes are made in labeling and marking the package, the carrier will most likely notice the mistakes and return the package to the shipper, thus delaying sample shipment.
- Improper, misspelled, or missing information on the shipper's declaration. The carrier will most likely notice this as well and return the package to the shipper.

Contact FedEx with questions about dangerous goods shipments by calling 1-800-463-3339 and asking for a dangerous goods expert.

FIGURE 1

EXAMPLE OF A CORRECTLY MARKED AND LABELED DANGEROUS GOODS PACKAGE



Source: International Air Transport Association (IATA). 1997.

FIGURE 2

EXAMPLE OF A DANGEROUS GOODS AIRBILL

FedEx *Dangerous Goods Airbill* — Sender's Copy — RETAIN THIS COPY FOR YOUR RECORDS

The World On Time.

11729489

1 From *Please print and press hard.*

Date FILL IN — Sender's FedEx Account Number 1788-8014-4

Sender's Name FILL IN — Phone (312) 856 8700

Company TETRA TECH EM INC

Address 200 E RANDOLPH ST STE 4700 — Dept./Floor/Suite/Room

City CHICAGO — State IL — ZIP 60601

2 Your Internal Billing Reference — First 24 characters will appear on invoice. FILL IN

3 To

Recipient's Name — Phone ( )

Company

Address — To "HOLD" at FedEx location, print FedEx address here — We cannot deliver to P.O. boxes or P.O. ZIP codes. — Dept./Floor/Suite/Room

City — State — ZIP

FILL IN

For HOLD at FedEx Location check here
- [ ] Hold Weekday
- [ ] Hold Saturday — Available for FedEx Priority Overnight and FedEx 2Day to select locations

For WEEKEND Delivery check here
- [ ] Saturday Delivery — Available for FedEx Priority Overnight and FedEx 2Day to select ZIP codes
- [ ] Sunday Delivery — Available for FedEx Priority Overnight to select ZIP codes

4a Express Package Service *Packages up to 150 lbs.* — Delivery commitment may be later in some areas.
- [x] FedEx Priority Overnight — Next business morning
- [ ] FedEx Standard Overnight — Next business afternoon
- [ ] FedEx 2Day — Second business day
- [ ] FedEx Express Saver — Third business day

4b Express Freight Service *Packages over 150 lbs.* — Delivery commitment may be later in some areas.
- [ ] FedEx 1Day Freight* — Next business day
- [ ] FedEx 2Day Freight — Second business day
- [ ] FedEx 3Day Freight — Third business day

* Call for Confirmation:

5 Packaging
- [x] Other Packaging

Dangerous Goods cannot be shipped in FedEx packaging.

6 Special Handling
- [x] Dangerous Goods as per attached Shipper's Declaration
- [ ] Cargo Aircraft Only

7 Payment

Bill to: [x] Sender (Acct. No. in Section 1 will be billed) [ ] Recipient [ ] Third Party [ ] Credit Card [ ] Cash/Check

Enter FedEx Acct. No. or Credit Card No. below

FedEx Account No.

Credit Card No. — Exp. Date

Total Packages	Total Weight	Total Declared Value*
		$ .00

* When declaring a value higher than $100 per shipment, you pay an additional charge. See SERVICE CONDITIONS, DECLARED VALUE, AND LIMIT OF LIABILITY section for further information.

FedEx Use Only

Signature Release Unavailable

PART #154827 • Rev. Date 11/98 ©1994-98 FedEx • PRINTED IN U.S.A.

FedEx Tracking Number 813350883058 — Form I.D. No. 374 — 0204

Service Conditions, Declared Value, and Limit of Liability – By using this Airbill, you agree to the service conditions in our current Service Guide or U.S. Government Service Guide. Both are available on request. SEE BACK OF SENDER'S COPY OF THIS AIRBILL FOR INFORMATION AND ADDITIONAL TERMS. We will not be responsible for any claim in excess of $100 per package whether the result of loss, damage, delay, non-delivery, misdelivery, or misinformation, unless you declare a higher value, pay an additional charge, and document your actual loss in a timely manner. Your right to recover from us for any loss includes minimum value of the package, loss of sales, interest, profit, attorney's fees, costs, and other forms of damage, whether direct, incidental, consequential, or special, and limited to the greater of $100 or the declared value but cannot exceed actual documented loss. The maximum declared value for any FedEx Letter and FedEx Pak is $500. Federal Express may, upon your request, and with some limitations, refund all transportation charges paid.

See the *FedEx Service Guide* for further details

Questions? Call 1•800•Go•FedEx® (800-463-3339) or Visit our Web site at www.fedex.com

Page 1 of 1 Pages

Two completed and signed copies of this Declaration must be handed to the operator.

WARNING

Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties. This Declaration must not, in any circumstances, be completed and/or signed by a consolidator, a forwarder or an IATA cargo agent.

TRANSPORT DETAILS

This shipment is within the limitations prescribed for: (delete non-applicable) PASSENGER AND CARGO AIRCRAFT / ~~CARGO AIRCRAFT ONLY~~

Airport of Departure: Chicago

Airport of Destination: "City sending sample to"

Shipment type: *(delete non-applicable)* NON-RADIOACTIVE / ~~RADIOACTIVE~~

NATURE AND QUANTITY OF DANGEROUS GOODS

Dangerous Goods Identification							
Proper Shipping Name	Class or Division	UN or I.D. No.	Packing Group	Subsidiary Risk	Quantity and Type of Packaging	Packing Instr.	Authorization
Flammable liquid, n.o.s.	3	UN 1993	III	—	4 glass jars in a 1A2 steel drum Net Quantity = 4 L	309	A3 USG-14

Additional Handling Information: NAERG# 128 Attached.

Prepared for AIR TRANSPORT according to: (Customer MUST check one) [ ] 49 CFR [x] ICAO / IATA

I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name and are classified, packaged, marked, and labeled/placarded, and are in all respects in proper condition for transport according to applicable international and national governmental regulations.

Name/Title of Signatory: Me, Environmental Scientist

Place and Date: 200 E Randolph, Chicago, IL xx/xx/xx

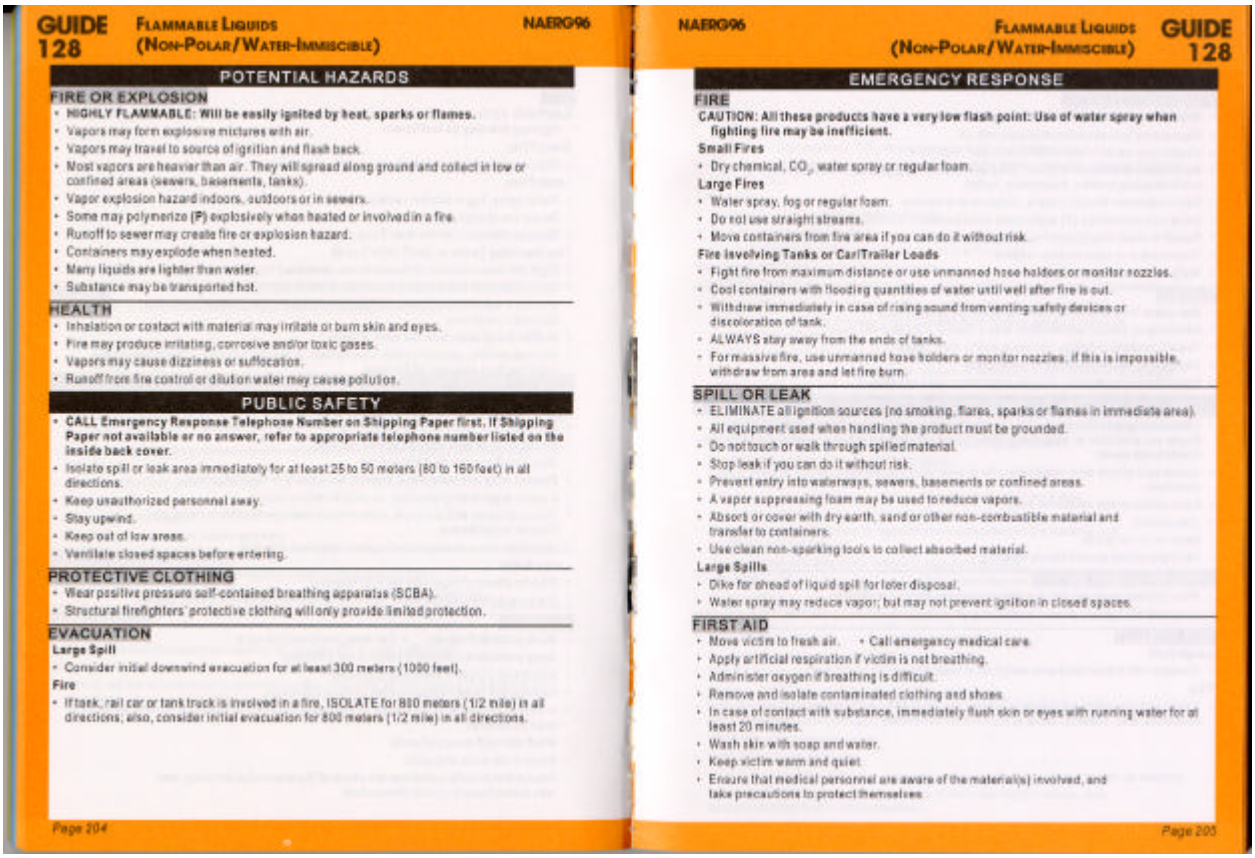
Signature (see warning above): me

Emergency Telephone Number (Required for U.S. Origin or Destination Shipments): FILL IN

IF ACCEPTABLE FOR PASSENGER AIRCRAFT, THIS SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN, OR INCIDENT TO, RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.

FIGURE 3

NAERG EMERGENCY RESPONSE INFORMATION FOR FLAMMABLE LIQUIDS, N.O.S.



GUIDE 128 FLAMMABLE LIQUIDS (NON-POLAR/WATER-IMMISCIBLE) NAERG96

POTENTIAL HAZARDS

FIRE OR EXPLOSION
- **HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**
- Vapors may form explosive mixtures with air.
- Vapors may travel to source of ignition and flash back.
- Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).
- Vapor explosion hazard indoors, outdoors or in sewers.
- Some may polymerize (P) explosively when heated or involved in a fire.
- Runoff to sewer may create fire or explosion hazard.
- Containers may explode when heated.
- Many liquids are lighter than water.
- Substance may be transported hot.

HEALTH
- Inhalation or contact with material may irritate or burn skin and eyes.
- Fire may produce irritating, corrosive and/or toxic gases.
- Vapors may cause dizziness or suffocation.
- Runoff from fire control or dilution water may cause pollution.

PUBLIC SAFETY
- **CALL Emergency Response Telephone Number on Shipping Paper first. If Shipping Paper not available or no answer, refer to appropriate telephone number listed on the inside back cover.**
- Isolate spill or leak area immediately for at least 25 to 50 meters (80 to 160 feet) in all directions.
- Keep unauthorized personnel away.
- Stay upwind.
- Keep out of low areas.
- Ventilate closed spaces before entering.

PROTECTIVE CLOTHING
- Wear positive pressure self-contained breathing apparatus (SCBA).
- Structural firefighters' protective clothing will only provide limited protection.

EVACUATION

Large Spill
- Consider initial downwind evacuation for at least 300 meters (1000 feet).

Fire
- If tank, rail car or tank truck is involved in a fire, ISOLATE for 800 meters (1/2 mile) in all directions; also, consider initial evacuation for 800 meters (1/2 mile) in all directions.

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NAERG96 FLAMMABLE LIQUIDS (NON-POLAR/WATER-IMMISCIBLE) GUIDE 128

EMERGENCY RESPONSE

FIRE

CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.

Small Fires
- Dry chemical, CO_2, water spray or regular foam.

Large Fires
- Water spray, fog or regular foam.
- Do not use straight streams.
- Move containers from fire area if you can do it without risk.

Fire Involving Tanks or Car/Trailer Loads
- Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.
- Cool containers with flooding quantities of water until well after fire is out.
- Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.
- ALWAYS stay away from the ends of tanks.
- For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn.

SPILL OR LEAK
- ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).
- All equipment used when handling the product must be grounded.
- Do not touch or walk through spilled material.
- Stop leak if you can do it without risk.
- Prevent entry into waterways, sewers, basements or confined areas.
- A vapor suppressing foam may be used to reduce vapors.
- Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.
- Use clean non-sparking tools to collect absorbed material.

Large Spills
- Dike far ahead of liquid spill for later disposal.
- Water spray may reduce vapor; but may not prevent ignition in closed spaces.

FIRST AID
- Move victim to fresh air. • Call emergency medical care.
- Apply artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Remove and isolate contaminated clothing and shoes.
- In case of contact with substance, immediately flush skin or eyes with running water for at least 20 minutes.
- Wash skin with soap and water.
- Keep victim warm and quiet.
- Ensure that medical personnel are aware of the material(s) involved, and take precautions to protect themselves.

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Source: DOT and others. 1996.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

MONITORING WELL INSTALLATION

SOP NO. 020

REVISION NO. 3

Last Reviewed: December 2000

K Riesing

Quality Assurance Approved

December 19, 2000

Date

1.0 BACKGROUND

Groundwater monitoring wells are designed and installed for a variety of reasons including: (1) detecting the presence or absence of contaminants, (2) collecting groundwater samples representative of in situ aquifer chemical characteristics, or (3) measuring water levels for determining groundwater potentiometric head and groundwater flow direction.

Although detailed specifications for well installation may vary in response to site-specific conditions, some elements of well installation are common to most situations. This standard operating procedure (SOP) discusses common methods and minimum standards for monitoring well installation for Tetra Tech EM Inc. (Tetra Tech) projects. The SOP is based on widely recognized methods described by the U.S. Environmental Protection Agency (EPA) and American Society for Testing and Materials (ASTM). However, well type, well construction, and well installation methods will vary with drilling method, intended well use, subsurface characteristics, and other site-specific criteria. In addition, monitoring wells should be constructed and installed in a manner consistent with all local and state regulations. Detailed specifications for well installation should be identified within a site-specific work plan, sampling plan, or quality assurance project plan (QAPP).

General specifications and installation procedures for the following monitoring well components are included in this SOP:

- Monitoring well materials
  - Casing materials
  - Well screen materials
  - Filter pack materials
  - Annular sealant (bentonite pellets or chips)
  - Grouting materials
  - Tremie pipe
  - Surface completion and protective casing materials
  - Concrete surface pad and bumper posts
  - Uncontaminated water
- Monitoring well installation procedures
  - Well screen and riser placement
  - Filter pack placement
  - Temporary casing retrieval
  - Annular seal placement

  - Grouting
  - Surface completion and protective casing (aboveground and flush-mount)
  - Concrete surface pad and bumper posts
  - Permanent and multiple casing well installation

- Recordkeeping procedures
  - Surveying
  - Permits and well construction records
  - Monitoring well identification

Well installation methods will depend to some extent on the boring method. Specific boring or drilling protocols are detailed in other SOPs. The boring method, in turn, will depend on site-specific geology and hydrogeology and project requirements. Boring methods commonly used for well installation include:

- Hollow-stem augering
- Cable tool drilling
- Mud rotary drilling
- Air rotary drilling
- Rock coring

The hollow-stem auger method is preferred in areas where subsurface materials are unconsolidated or loosely consolidated and where the depth of the boring will be less than 100 feet. This maximum effective depth for hollow-stem augering depends on the diameter of the augers, the formation characteristics, and the strength and durability of the drilling equipment. This method is preferred because under the right conditions it is cost effective, addition of water into the subsurface is limited, continuous soil samples can easily be collected, and monitoring wells can easily be constructed within the hollow augers.

Cable tool drilling is a preferred method when the subsurface contains boulders, coarse gravels, or flowing sands, or when the operational depth of the hollow-stem auger is exceeded. However, this method is slow.

Rotary methods are generally used when other methods cannot be used. The use of drilling fluids or large amounts of water to maintain an open borehole, and the difficulty in obtaining representative

samples limit the utility of rotary methods. However, rotary methods can be used to quickly and effectively drill deep wells through consolidated or unconsolidated materials. Modifications to this method such as dual-tube drilling procedures, drill-through casing hammers, or eccentric-type drill systems, can reduce the amount of fluids introduced into the well borehole.

Rock coring is an effective method when drilling in competent consolidated rock. Intact, continuous cores can be obtained, and limited amounts of fluid are required if the formations are not fractured.

1.1 PURPOSE

This SOP establishes the requirements and procedures for monitoring well installation. Monitoring wells should be designed to function properly throughout the duration of the monitoring program. The performance objectives for monitoring well installation are as follows:

- Ensure that the monitoring well will provide water samples representative of in situ aquifer conditions.
- Ensure that the monitoring well construction will last for duration of the project.
- Ensure that the monitoring well will not serve as a conduit for vertical migration of contaminants, particularly vertical migration between discrete aquifers.
- Ensure that the well diameter is adequate for all anticipated downhole monitoring and sampling equipment.

1.2 SCOPE

This SOP applies to the installation of monitoring wells. Although some of the procedures may apply to the installation of water supply wells, this SOP is not intended to cover the design and construction of such wells. The SOP identifies several well drilling methods related to monitoring well installation, but the scope of this SOP does not include drilling methods.

Other relevant SOPs include SOP 002 for decontamination of drilling and well installation equipment, SOP 005 for soil sampling, SOP 021 for monitoring well development, SOPs 010 and 015 for

groundwater sampling from monitoring wells, and SOP 014 for measuring static water levels within monitoring wells.

1.3 DEFINITIONS

Annulus: The space between the monitoring well casing and the wall of the well boring.

Bentonite seal: A colloidal clay seal separating the sand pack from the annular grout seal.

Centralizer: A stainless-steel or plastic spacer that keeps the well screen and casing centered in the borehole.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout seal: A fluid mixture of (1) bentonite and water, (2) cement, bentonite, and water, or (3) cement and water placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Tremie pipe: A rigid pipe used to place the well filter pack, bentonite seal, or grout seal. The tremie pipe is lowered to the bottom of the well or area to be filled and pulled up ahead of the material being placed.

Well casing: A solid piece of pipe, typically polyvinyl chloride (PVC) or stainless steel, used to keep a well open in either unconsolidated material or unstable rock.

Well screen: A PVC or stainless steel pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

1.4 REFERENCES

American Society for Testing and Materials. 1995. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. D5092-90. West Conshohocken, Pennsylvania.

California Department of Toxic Substances Control. 1994. Monitoring Well Design and Construction for Hydrogeologic Characterization. Guidance for Groundwater Investigations. August.

Driscoll, F.G. 1986. *Groundwater and Wells (Second Edition).* Johnson Division, UOP, Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agency (EPA). 1986. RCRA Ground Water Monitoring Technical Enforcement Guidance Document. Office of Solid Waste and Emergency Response. Washington, DC. OSWER-9950-1. September.

EPA. 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development, Environmental Monitoring Systems Laboratory. Washington, DC. EPA/600-4-89/034. March. On-Line Address: http://www.epa.gov/swerust1/cat/wwelldct.pdf

EPA. 1994. Monitor Well Installation. Environmental Response Team SOP #2048 (Rev. #0.0, 03/18/96). On-Line Address: http://www.ert.org/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

Well installation requires a completed boring with stable or supported walls. The type of drilling rig needed to complete the boring and the well construction materials required for monitoring well installation will depend on the drilling method used, the geologic formations present, and chemicals of concern in groundwater. The rig and support equipment used to drill the borehole is usually used to install the well. Under most conditions, the following items are also required for the proper installation of monitoring wells:

- Tremie pipe and funnel
- Bentonite pellets or chips
- Grouting supplies
- Casing materials
- Well screen materials
- Filter pack materials

- Surface completion materials (protective casing, lockable and watertight well cover, padlock)
- Electronic water level sounding device for water level measurement
- Measuring tape with weight for measuring the depth of the well and determining the placement of filter pack materials
- Decontamination equipment and supplies
- Site-specific work plan, field sampling plan, health and safety plan, and QAPP
- Monitoring Well Completion Record (see Figure 1)

2.0 MONITORING WELL INSTALLATION PROCEDURES

This section presents standard procedures for monitoring well installation and is divided into three subsections. Section 2.1 addresses monitoring well construction materials, while Section 2.2 describes typical monitoring well installation procedures. Section 2.3 addresses recordkeeping requirements associated with monitoring well installation. Monitoring well installation procedures described in work plans, sampling plans, and QAPPs should be fully consistent with the procedures outlined in this SOP as well as any applicable local and state regulations and guidelines.

2.1 MONITORING WELL CONSTRUCTION MATERIALS

Monitoring well construction materials should be specified in the site-specific work plan as well as in the statement of work for any subcontractors assisting in the well installation. Well construction materials that come in contact with groundwater should not measurably alter the chemical quality of groundwater samples with regard to the constituents being examined. The riser, well screen, and filter pack and annular sealant placement equipment should be steam cleaned or high-pressure water cleaned immediately prior to well installation. Alternatively, these materials can be certified by the manufacturer as clean and delivered to the site in protective wrapping. Samples of the filter pack, annular seal, and mixed grout should be retained as a quality control measure until at least one round of groundwater sampling and analysis is completed.

This section discusses material specifications for the following well construction components: casing, well screen, filter pack, annular sealant (bentonite pellets or chips), grout, tremie pipes, surface

completion components (protective casing, lockable and water tight cap, and padlock), concrete surface pad, and uncontaminated water. Figure 2 shows the construction details of a typical monitoring well.

2.1.1 Casing Materials

The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. If the casing has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the casing should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002). The ends of each casing section should be either flush-threaded or beveled for welding.

Schedule 40 or Schedule 80 PVC casing is typically used for monitoring well installation. Either type of casing is appropriate for monitoring wells with depths less than 100 feet below ground surface (bgs). If the well is deeper than 100 feet bgs, Schedule 80 PVC should be used.

Stainless steel used for well casing is typically Type 304 and is of 11-gauge thickness.

2.1.2 Well Screen Materials

Well screens should be new, machine-slotted or continuous wrapped wire-wound, and composed of materials most suited for the monitoring environment based on site characterization findings. Well screens are generally constructed of the same materials used for well casing (PVC or stainless steel). The screen should be plugged at the bottom with the same material as the well screen. Alternatively, a short (1- to 2-foot) section of casing material with a bottom (sump) should be attached below the screen. This assembly must be able to withstand installation and development stresses without becoming dislodged or damaged. The length of the slotted area should reflect the interval to be monitored.

If the well screen has not been certified as clean by the manufacturer or delivered to and maintained in clean condition at the site, the screen should be steam cleaned or high-pressure water cleaned with water from a source of known chemistry immediately prior to installation (see Tetra Tech SOP No. 002).

The minimum internal diameter of the well screen should be chosen based on the particular application. A minimum diameter of 2 inches is usually needed to allow for the introduction and withdrawal of sampling devices. Typical monitoring well screen diameters are 2 inches and 4 inches.

The slot size of the well screen should be determined relative to (1) the grain size of particles in the aquifer to be monitored and (2) the gradation of the filter pack material.

Screen length and monitoring well diameter will depend on site-specific considerations such as intended well use, contaminants of concern, and hydrogeology. Some specific considerations include the following:

- Water table wells should have screens of sufficient length and diameter to monitor the water table and provide sufficient sample volume under high and low water table conditions.
- Wells with low recharge should have screens of sufficient length and diameter so that adequate sample volume can be collected.
- Wells should be screened over sufficiently short intervals to allow for monitoring of discrete migration pathways.
- Where light nonaqueous-phase liquids (LNAPL) or contaminants in the upper portion of a hydraulic unit are being monitored, the screen should be set so that the upper portion of the water-bearing zone is below the top of the screen.
- Where dense nonaqueous-phase liquids (DNAPL) are being monitored, the screen should be set within the lower portion of the water-bearing zone, just above a relatively impermeable lithologic unit.
- The screened interval should not extend across an aquiclude or aquitard.
- If contamination is known to be concentrated within a portion of a saturated zone, the screen should be constructed in a manner that minimizes the potential for cross-contamination within the aquifer.
- If downhole geophysical surveys are to be conducted, the casing and screen must be of sufficient diameter and constructed of the appropriate material to allow for effective use of the geophysical survey tools.
- If aquifer tests are to be conducted in a monitoring well, the slot size must allow sufficient flux to produce the required drawdown and recovery. The diameter of the well must be sufficient to house the pump and monitoring equipment, and allow sufficient

water flux (in combination with the screen slot size) to produce the required drawdown or recovery.

2.1.3 Filter Pack Materials

The primary filter pack consists of a granular material of known chemistry and selected grain size and gradation. The filter pack is installed in the annulus between the well screen and the borehole wall. The grain size and gradation of the filter pack are selected to stabilize the hydrologic unit adjacent to the screen and to prevent formation material from entering the well during development. After development, a properly filtered monitoring well is relatively free of turbidity.

A secondary filter pack is a layer of material placed in the annulus directly above the primary filter pack and separates the filter pack from the annular sealant. The secondary filter pack should be uniformly graded fine sand, with 100 percent by weight passing through a No. 30 U.S. Standard sieve, and less than 2 percent by weight passing through a No. 200 U.S. Standard sieve.

2.1.4 Annular Sealant (Bentonite Pellets or Chips)

The materials used to seal the annulus may be prepared as a slurry or used as dry pellets, granules, or chips. Sealants should be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well.

Bentonite (sodium montmorillonite) is the most commonly used annular sealant and is furnished in sacks or buckets in powder, granular, pelletized, or chip form. Bentonite should be obtained from a commercial source and should be free of impurities that may adversely impact the water quality in the well. Pellets are compressed bentonite powder in roughly spherical or disk shapes. Chips are large, coarse, irregularly shaped units of bentonite. The diameter of the pellets or chips should be less than one-fifth the width of the annular space into which they will be placed in order to reduce the potential for bridging. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.2 inch in diameter. Bentonite slurry is prepared by mixing powdered or granular bentonite with water from a source of known chemistry.

2.1.5 Grouting Materials

The grout backfill that is placed above the bentonite annular seal is ordinarily liquid slurry consisting of either (1) a bentonite (powder, granules, or both) base and water, (2) a bentonite and Portland cement base and water, or (3) a Portland cement base and water. Often, bentonite-based grouts are used when flexibility is desired during the life of the well installation (for example, to accommodate freeze-thaw cycles). Cement- or bentonite-based grouts are often used when cracks in the surrounding geologic material must be filled or when adherence to rock units, or a rigid setting is desired.

Each type of grout mixture has slightly different characteristics that may be appropriate under various physical and chemical conditions. However, quick-setting cements containing additives are not recommended for use in monitoring well installation because additives may leach from the cement and influence the chemistry of water samples collected from the well.

2.1.6 Tremie Pipe

A tremie pipe is used to place the filter pack, annular sealant, and grouting materials into the borehole. The tremie pipe should be rigid, have a minimum internal diameter of 1.0 inch, and be made of PVC or steel. The length of the tremie pipe should be sufficient to extend to the full depth of the monitoring well.

2.1.7 Surface Completion and Protective Casing Materials

Protective casings that extend above the ground surface should be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid with a locking device to prevent vandalism. Sufficient clearance, usually 6 inches, should be maintained between the top of the riser and the top of protective casing. A water-tight well cap should be placed on the top of the riser to seal the well from surface water infiltration in the event of a flood. A weep hole should be drilled in the casing a minimum of 6 inches above the ground surface to enable water to drain out of the annular space.

Flush-mounted monitoring wells (wells that do not extend above ground surface) require a water-tight protective cover of sufficient strength to withstand heavy traffic. The well riser should be fitted with a locking water-tight cap.

2.1.8 Concrete Surface Pad and Bumper Posts

A concrete surface pad should be installed around each well when the outer protective casing is installed. The surface pad should be formed around the well casing. Concrete should be placed into the formed pad and into the borehole (on top of the grout), typically to a depth of 1 to 3 feet bgs (depending on state, federal, and local regulations). The protective casing is then installed into the concrete. As a general guideline, if the well casing is 2 inches in diameter, the concrete pad should be 3 feet square and 4 inches thick. If the well casing is 4 inches in diameter, the pad should be 4 feet square and 6 inches thick. Round concrete pads are also acceptable.

The finished pad should be sloped so that drainage flows away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed around the pad to protect the well. Bumper posts, consisting of steel pipes 3 to 4 inches in diameter and at least 5 feet long, should be installed in a radial pattern around the protective casing, beyond the edges of the cement pad. The base of the bumper posts should be installed 2 feet bgs in a concrete footing; the top of the post should be capped or filled with concrete.

2.1.9 Uncontaminated Water

Water used in the drilling process, to prepare grout mixtures, and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry. The water should not contain constituents that could compromise the integrity of the monitoring well installation.

2.2 MONITORING WELL INSTALLATION PROCEDURES

This section describes the procedures used to install a single-cased monitoring well, with either temporary casing or hollow-stem augers to support the walls of the boring in unconsolidated formations. The procedures are described in the order in which they are conducted, and include: (1) placement of well screen and riser pipe, (2) placement of filter pack, (3) progressive retrieval of temporary casing, (4) placement of annular seal, (5) grouting, (6) surface completion and installation of protective casing, and (7) installation of concrete pad and bumper posts.

The additional steps necessary to install a well with permanent or multiple casing strings are described at the end of this section.

2.2.1 Well Screen and Riser Placement

After the total depth of the boring is confirmed and the well screen depth interval and the height of the aboveground completion are determined, the screen and riser is assembled from the bottom up as it is lowered down the hole. The following procedures should be followed:

1. Measure the total depth of the boring using a weighted tape.
2. Determine the length of screen and casing materials required to construct the well.
3. Assemble the well parts from the bottom up, starting with the well sump or cap, well screen, and then riser pipe. Progressively lower the assembled length of pipe.
4. The length of the assembled pipe should not extend above the top of the installation rig.

The well sump or cap, well screen, and riser should be certified clean by the manufacturer or should be decontaminated before assembly and installation. No grease, oil, or other contaminants should contact any portion of the assembly. Flush joints should be tightened, and welds should be water tight and of good quality. The riser should extend above grade and be capped temporarily to prevent entrance of foreign materials during the remaining well completion procedures.

When the well screen and riser assembly is lowered to the predetermined level, it may float and require a method to hold it in place. For borings drilled using cable tool or air rotary drilling methods, centralizers should be attached to the riser at intervals of between 20 and 40 feet.

2.2.2 Filter Pack Placement

The filter pack is placed after the well screen and riser assembly has been lowered into the borehole. The steps below should be followed:

1. Determine the volume of the annular space in the filter pack interval. The filter pack should extend from the bottom of the borehole to at least 2 feet above the top of the well screen.
2. Assemble the required material (sand pack and tremie pipe).
3. Lower a clean or decontaminated tremie pipe down the annulus to within 1 foot of the base of the hole.
4. Pour the sand down the tremie pipe using a funnel; pour only the quantity estimated to fill the first foot.
5. Check the depth of sand in the hole using a weighted tape.
6. Pull the drill casing up ahead of the sand to keep the sand from bridging.
7. Continue with this process (steps 4 through 6) until the filter pack is at the appropriate depth.

If bridging of the filter pack occurs, break out the bridge prior to adding additional filter pack material. For wells less than 30 feet deep installed inside hollow-stem augers, the sand may be poured in 1-foot lifts without a tremie pipe.

Sufficient measurements of the depth to the filter pack material and the depth of the bottom of the temporary casing should be made to ensure that the casing bottom is always above the filter pack. The filter pack should extend 2 feet above the well screen (or more if required by state or local regulations). However, the filter pack should not extend across separate hydrogeologic units. The final depth interval, volume, and type of filter pack should be recorded on the Monitoring Well Completion Record (Figure 1).

A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack. A measured volume of secondary filter material should be added to extend 1 to 2 feet above the primary filter pack. As with the primary filter pack, a secondary filter pack must not extend into an overlying hydrologic unit. An on-site geologist should evaluate the

need for a secondary filter pack by considering the gradation of the primary filter pack, the hydraulic head difference between adjacent units, and the potential for grout intrusion into the primary filter pack.

The secondary filter material is poured into the annular space through tremie pipe as described above. Water from a source of known chemistry may be added to help place the filter pack into its proper location. The tremie pipe or a weighed line inserted through the tremie pipe can be used to measure the top of the secondary filter pack as work progresses. The amount and type of secondary filter pack used should be recorded on the Monitoring Well Completion Record (Figure 1).

2.2.3 Temporary Casing Retrieval

The temporary casing or hollow-stem auger should be withdrawn in increments. Care should be taken to minimize lifting the well screen and riser assembly during withdrawal of the temporary casing or auger. It may be necessary to place the top head of the rig on the riser to hold it down. To limit borehole collapse in formations consisting of unconsolidated materials, the temporary casing or hollow-stem auger is usually withdrawn until the lowest point of the casing or auger is at least 2 feet, but no more than 5 feet, above the filter pack. When the geologic formation consists of consolidated materials, the lowest point of the casing or auger should be at least 5 feet, but no more than 10 feet, above the filter pack. In highly unstable formations, withdrawal intervals may be much less. After each increment, the depth to the primary filter pack should be measured to check that the borehole has not collapsed or that bridging has not occurred.

2.2.4 Annular Seal Placement

A bentonite pellet, chip, or slurry seal should be placed between the borehole and the riser on top of the primary or secondary filter pack. This seal retards the movement of grout into the filter pack. The thickness of the bentonite seal will depend on state and local regulations, but the seal should generally be between 3 and 5 feet thick.

The bentonite seal should be installed using a tremie pipe, lowered to the top of the filter pack and slowly raised as the bentonite pellets or slurry fill the space. Care must be taken so that bentonite pellets or

chips do not bridge in the augers or tremie pipe. The depth of the seal should be checked with a weighted tape or the tremie pipe.

If a bentonite pellet or chip seal is installed above the water level, water from a known source should be added to allow proper hydration of the bentonite. Sufficient time should be allowed for the bentonite seal to hydrate. The volume and thickness of the bentonite seal should be recorded on the Monitoring Well Completion Record (Figure 1).

2.2.5 Grouting

Grouting procedures vary with the type of well design. The volume of grout needed to backfill the remaining annular space should be calculated and recorded on the Monitoring Well Completion Record (Figure 1). The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss. Bentonite grouts should not be used in arid regions because of their propensity to desiccate. Typical grout mixtures include the following:

- Bentonite grout: about 1 to 1.25 pounds of bentonite mixed with 1 gallon of water
- Cement-bentonite grout: about 5 pounds of bentonite and one 94-pound bag of cement mixed with 7 to 8 gallons of water
- Cement grout: one 94-pound bag of cement mixed with 6 to 7 gallons of water

The grout should be installed by gravity feed through a tremie pipe. The grout should be mixed in batches in accordance with the appropriate requirements and then pumped into the annular space until full-strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The tremie pipe should then be removed to allow the grout to cure.

The riser should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser. For bentonite grouts, curing times are typically around 24 hours; curing times for cement grouts are typically 48 to 72 hours. However, the curing time required will vary with grout content and climatic conditions. The curing time should be documented in the Monitoring Well Completion Record (Figure 1).

2.2.6 Surface Completion and Protective Casing

Aboveground completion of the monitoring well should begin once the grout has set (no sooner than 24 hours after the grout was placed). The protective casing is lowered over the riser and set into the cured grout. The protective casing should extend below the ground surface to a depth below the frost line (typically 3 to 5 feet, depending on local conditions). The protective casing is then cemented in place. A minimum of 6 inches of clearance should be maintained between the top of the riser and the protective casing. A 0.5-inch diameter drainage or weep hole should be drilled in the protective casing approximately 6 inches above the ground surface to enable water to drain out of the annular space between the casing and riser. A water-tight cap should be placed on top of the riser to seal the well from surface water infiltration in the event of a flood. A lock should be placed on the protective casing to prevent vandalism.

For flush-mounted monitoring wells, the well cover should be raised above grade and the surrounding concrete pad sloped so that water drains away from the cover. The flush-mount completion should be installed in accordance with applicable state and local regulations.

2.2.7 Concrete Surface Pad and Bumper Posts

The concrete pad installed around the monitoring well should be sloped so that the drainage will flow away from the protective casing and off the pad. The finished pad should extend at least 1 inch below grade. If the monitoring wells are located in high traffic areas, a minimum of three bumper posts should be installed in a radial pattern around the protective casing, outside the cement pad. Specifications for concrete surface pads and bumper posts are described in Section 2.1.8.

2.2.8 Permanent and Multiple Casing Well Installation

When wells are installed through multiple saturated zones, special well construction methods should be used to assure well integrity and limit the potential for cross-contamination between geologic zones. Generally, these types of wells are necessary if relatively impermeable layers separate hydraulic units. Two procedures that may be used are described below.

In the first procedure, the borehole is advanced to the base of the first saturated zone. Casing is then anchored in the underlying impermeable layer (aquitard) by advancing the casing at least 1 foot into the aquitard and grouting to the surface. After the grout has cured, a smaller diameter borehole is drilled through the grout. This procedure is repeated until the zone of interest is reached. After the zone is reached, a conventional well screen and riser are set. A typical well constructed in this manner is shown on Figure 3.

A second acceptable procedure involves driving a casing through several saturated layers while drilling ahead of the casing. However, this method is not acceptable when the driven casing may structurally damage a competent aquitard or aquiclude and result in cross-contamination of the two saturated layers. This method should also be avoided when highly contaminated groundwater or nonaqueous-phase contamination may be dragged down into underlying uncontaminated hydrologic units.

2.3 RECORDKEEPING PROCEDURES

Recordkeeping procedures associated with monitoring well installation are described in the following sections. These include procedures for surveying, obtaining permits, completing well construction records, and identifying monitoring wells.

2.3.1 Surveying

Latitude, longitude, and elevation at the top of the riser should be determined for each monitoring well. A permanent notch or black mark should be made on the north side of the riser. The top of the riser and ground surface should be surveyed.

2.3.2 Permits and Well Construction Records

Local and state regulations should be reviewed prior to monitoring well installation, and any required well permits should be in-hand before the driller is scheduled.

Monitoring well installation activities should be documented in both the field logbook and on the Monitoring Well Completion Record (Figure 1). Geologic logs should be completed and, if necessary, filed with the appropriate regulatory agency within the appropriate time frame.

2.3.3 Monitoring Well Identification

Each monitoring well should have an individual well identification number or name. The well identification may be stamped in the metal surface upon completion or permanently marked by using another method. Current state and local regulations should be checked for identification requirements (such as township, range, section, or other identifiers in the well name).

FIGURE 1

MONITORING WELL COMPLETION RECORD

TETRATECH EM INC

MONITORING WELL COMPLETION RECORD

MONITORING WELL
MONITORING WELL NO.: _____
PROJECT: _____
SITE: _____
BOREHOLE NO.: _____
WELL PERMIT NO.: _____
TOC TO BOTTOM OF WELL: _____

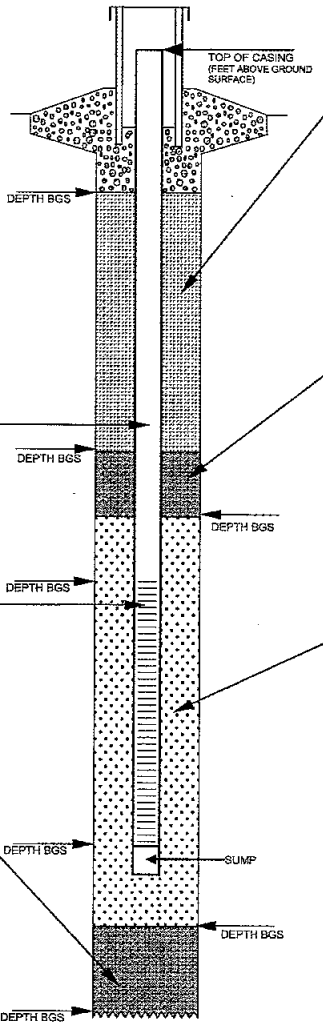
DRILLING INFORMATION
DRILLING BEGAN:
DATE: _____ TIME: _____
WELL INSTALLATION BEGAN:
DATE: _____ TIME: _____
WELL INSTALLATION FINISHED:
DATE: _____ TIME: _____
DRILLING CO.: _____
DRILLER: _____
LICENSE: _____
DRILL RIG: _____
DRILLING METHOD:
❑ HOLLOW-STEM AUGER
❑ AIR ROTARY
❑ OTHER: _____
DIAMETER OF AUGERS:
ID: _____ OD: _____

WELL CASING
❑ SCHEDULE 40 PVC
❑ OTHER: _____
PRODUCT: _____
MFG. BY: _____
CASING DIAMETER:
ID: _____ OD: _____
LENGTH OF CASING: _____

WELL SCREEN
❑ SCHEDULE 40 PVC
❑ OTHER: _____
PRODUCT: _____
MFG. BY: _____
CASING DIAMETER:
ID: _____ OD: _____
SLOT SIZE: _____
LENGTH OF SCREEN: _____

BOREHOLE BACKFILL
AMOUNT CALCULATED: _____
AMOUNT USED: _____
❑ BENTONITE CHIPS, SIZE: _____
❑ BENTONITE PELLETS, SIZE: _____
❑ SLURRY: _____
❑ FORMATION COLLAPSE: _____
❑ OTHER: _____
PRODUCT: _____
MFG. BY: _____
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: _____

SURFACE COMPLETION
❑ FLUSH MOUNT
❑ ABOVE GROUND WITH BUMPER POST
❑ CONCRETE ❑ ASPHALT



SURVEY INFORMATION
TOC ELEVATION: _____
GROUND SURFACE ELEVATION: _____
NORTHING: _____
EASTING: _____
DATE SURVEYED: _____
SURVEY CO.: _____

ANNULAR SEAL
VOLUME CALCULATED: _____
AMOUNT USED: _____
❑ GROUT FORMULA (PERCENTAGES)
PORTLAND CEMENT: _____
BENTONITE: _____
WATER: _____
❑ PREPARED MIX
PRODUCT: _____
MFG. BY: _____
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: _____

BENTONITE SEAL
VOLUME CALCULATED: _____
AMOUNT USED: _____
❑ PELLETS, SIZE: _____
❑ CHIPS, SIZE: _____
❑ OTHER: _____
PRODUCT: _____
MFG. BY: _____
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: _____
AMOUNT OF WATER USED: _____

FILTER PACK
❑ PREPACKED FILTER
VOLUME CALCULATED: _____
AMOUNT USED: _____
❑ SAND, SIZE: _____
PRODUCT: _____
MFG. BY: _____
METHOD INSTALLED:
❑ POURED ❑ TREMIE
❑ OTHER: _____
WATER LEVEL: _____
(BTOC AFTER WELL INSTALLATION)

CENTRALIZERS USED?
❑ YES ❑ NO;
CENTRALIZER DEPTHS: _____

LEGEND
BGS = BELOW GROUND SURFACE
BTOC = BELOW TOP OF CASING
N/A = NOT APPLICABLE
NR = NOT RECORDED
TOC = TOP OF CASING
ID = INSIDE DIAMETER
OD = OUTSIDE DIAMETER

FIGURE 2

MONITORING WELL CONSTRUCTION DIAGRAM

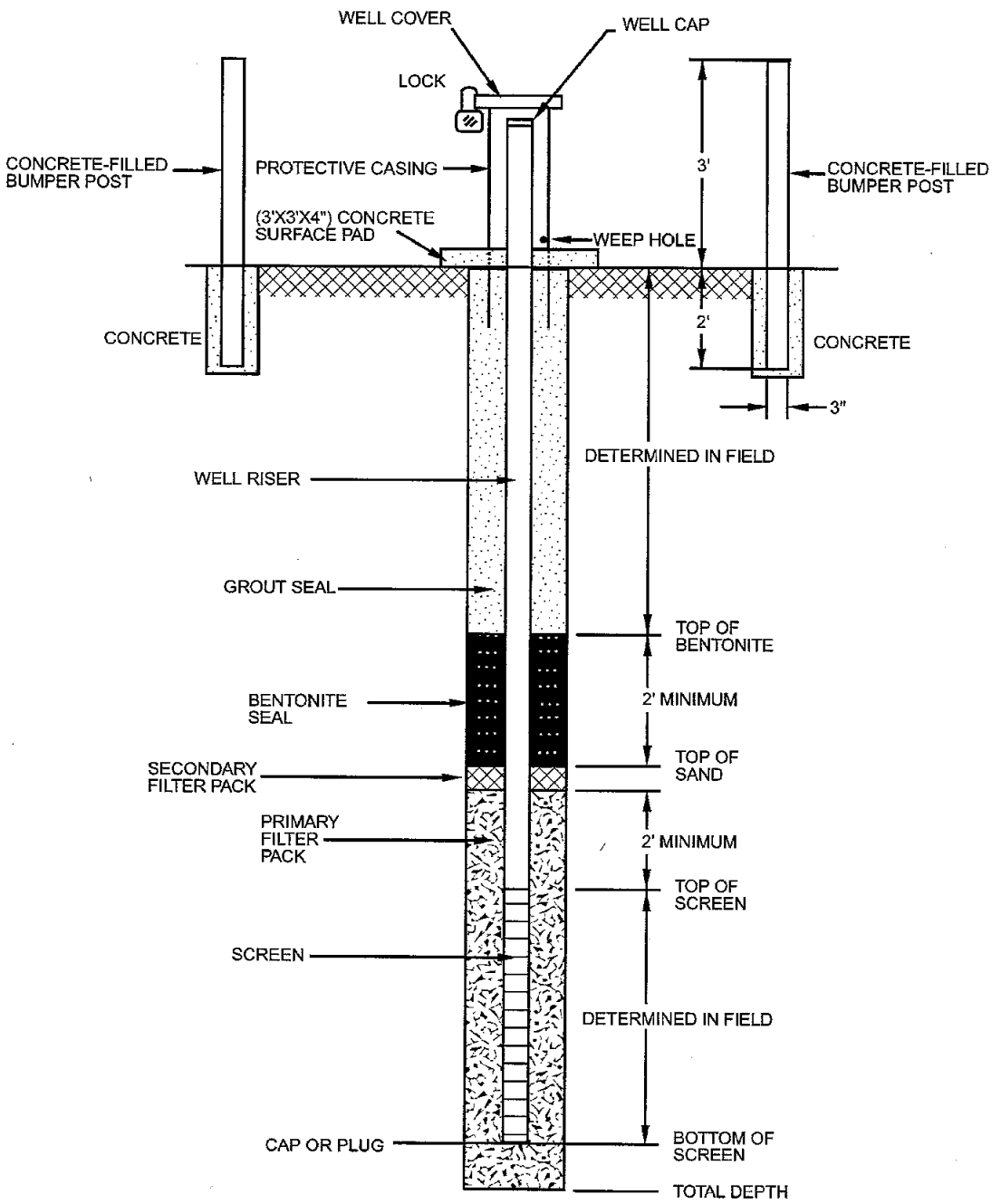
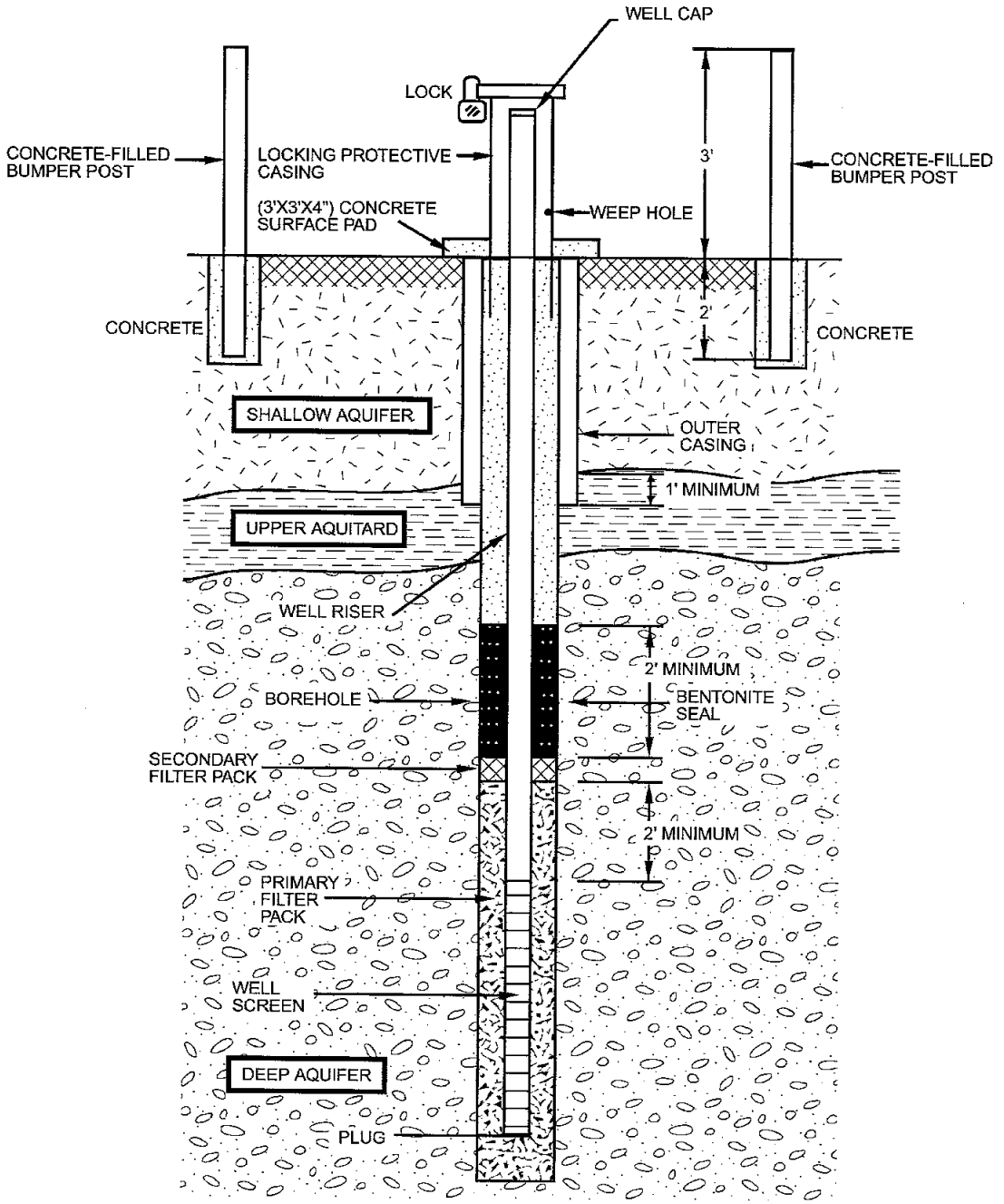


FIGURE 3

MULTIPLE CASING WELL CONSTRUCTION DIAGRAM



SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

MONITORING WELL DEVELOPMENT

SOP NO. 021

REVISION NO. 3

Last Reviewed: October 2000

R Miesing

Quality Assurance Approved

October 5, 2000

Date

1.0 BACKGROUND

All drilling methods impair the ability of an aquifer to transmit water to a drilled hole. This impairment is typically a result of disturbance of soil grains (smearing) or the invasion of drilling fluids or solids into the aquifer during the drilling process. The impact to the hydrologic unit surrounding the borehole must be remediated so that the well hydraulics and samples collected from the monitoring well are representative of the aquifer.

Well development should be conducted as an integral step of monitoring well installation to remove the finer-grained material, typically clay and silt, from the geologic formation near the well screen and filter pack. (Monitoring well installation is discussed in standard operating procedure [SOP] No. 020.) The fine-grained particles may interfere with water quality analyses and alter the hydraulic characteristics of the filter pack and the hydraulic unit adjacent to the well screen. Well development improves the hydraulic connection between water in the well and water in the formation. The most common well development methods are surging, jetting, overpumping, and bailing.

The health and safety plan for the site should be followed to avoid exposure to chemicals of concern. Water, sediment, and other waste removed from a monitoring well should be disposed of in accordance with applicable federal, state, and local requirements.

1.1 PURPOSE

This SOP establishes the requirements and procedure for monitoring well development. Well development improves the hydraulic characteristics of the filter pack and borehole wall by performing the following functions:

- Reducing the compaction and the intermixing of grain sizes produced during drilling by removing fine material from the pore spaces.
- Removing the filter cake or drilling fluid film that coats the borehole as well as much or all of the drilling fluid and natural formation solids that have invaded the formation.
- Creating a graded zone of sediment around the screen, thereby stabilizing the formation so that the well can yield sediment-free water.

1.2 SCOPE

This SOP applies to the development of newly installed monitoring wells. The SOP identifies the most commonly used well development methods; these methods can be used individually or in combination to achieve the most effective well development. Selection of a particular method will depend on site conditions, equipment limitations, and other factors. The method selected and the rationale for selection should be documented in a field logbook or appropriate project reports.

1.3 DEFINITIONS

Aquifer: A geologic formation, group of formations, or part of a formation that is saturated and capable of storing and transmitting water.

Aquitard: a geologic formation, group of formations, or part of a formation through which virtually no water moves.

Bailer: A cylindrical sampling device with valves on either end, used to extract water from a well or borehole.

Bentonite seal: A colloidal (extremely fine particle that will not settle out of solution) clay seal separating the sand pack from the surface seal.

Drilling fluid: A fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

Filter pack: A clean, uniform sand or gravel placed between the borehole wall and the well screen to prevent formation material from entering the screen.

Grout seal: A fluid mixture of (1) cement and water or (2) cement, bentonite, and water that is placed above the bentonite seal between the casing and the borehole wall to secure the casing in place and keep water from entering the borehole.

Hydraulic conductivity: A measure of the ease with which water moves through a geologic formation. Hydraulic conductivity, K, is typically measured in units of distance per time in the direction of groundwater flow.

Hydrologic units: Geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units.

Oil air filter: A filter or series of filters placed in the airflow line from an air compressor to reduce the oil content of the air.

Oil trap: A device used to remove oil from the compressed air discharged from an air compressor.

Riser: The pipe extending from the well screen to or above the ground surface.

Specific conductance: A measure of the ability of the water to conduct an electric current. Specific conductance is related to the total concentration of ionizable solids in the water and is inversely proportional to electrical resistance.

Static water level: The elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

Transmissivity: The volume of water transmitted per unit width of an aquifer over the entire thickness of the aquifer flow, under a unit hydraulic gradient.

Well screen: A cylindrical pipe with openings of a uniform width, orientation, and spacing used to keep materials other than water from entering the well and to stabilize the surrounding formation.

Well screen jetting (hydraulic jetting): A jetting method used for development; nozzles and a high pressure pump are used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

1.4 REFERENCES

American Society for Testing and Materials. 1990. Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers. D5092-90. West Conshohocken, Pennsylvania.

California Department of Toxic Substances Control. 1994. Monitoring Well Design and Construction for Hydrogeologic Characterization. Guidance for Groundwater Investigations. August.

Driscoll, F.G. 1986. *Groundwater and Wells (Second Edition).* Johnson Division, UOP, Inc. St. Paul, Minnesota.

U.S. Environmental Protection Agency (EPA). 1991. Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells. Office of Research and Development, Environmental Monitoring Systems Laboratory. Washington, DC. EPA/600-4-89/034. March. On-Line Address: http://www.epa.gov/swerust1/cat/wwelldct.pdf

EPA. 1994. Well Development. Environmental Response Team SOP #2044 (Rev. #0.0, 10/03/94). On-Line Address: http://www.ert.org/media_resrcs/media_resrcs.asp?Child1=

1.5 REQUIREMENTS AND RESOURCES

The type of equipment used for well development will depend on the well development method. Well development methods and the equipment required are discussed in Section 2.1 of this SOP. In general, monitoring wells should be developed shortly after they are installed but no sooner than 24 hours after the placement of the grout seal, depending on the grout cure rate and well development method. Most drilling or well development rigs have pumps, air compressors, bailers, surge blocks, and other equipment that can be used to develop a monitoring well.

All downhole equipment should be properly decontaminated before and after each well is developed. See SOP No. 002 (General Equipment Decontamination) for details.

2.0 WELL DEVELOPMENT PROCEDURES

This section describes common well development methods, factors to be considered in selecting a well development method, procedures for initiating well development, well development duration, and calculations typically made during well development. In addition to this, procedures described in any

work plans for well development should be fully consistent with local and state regulations and guidelines.

2.1 WELL DEVELOPMENT METHODS

Well development methods vary with the physical characterization of hydrologic units in which the monitoring well is screened and the drilling method used. The most common methods include mechanical surging, overpumping, air lift pumping, backwashing, surge bailing, and well jetting. These methods may be effective alone or may need to be combined (for example, overpumping combined with backwashing). Factors such as well design and hydrogeologic conditions will determine which well development method will be most practical and cost-effective. Commonly used well development methods are described in Sections 2.1.1 through 2.1.6.

The use of chemicals for monitoring well development should be avoided as much as possible. Introduction of chemicals may significantly alter groundwater chemistry in and around the well.

2.1.1 Mechanical Surging

The mechanical surging method forces water to flow in and out of the well screen by operating a plunger (or surge block) in the casing, similar to a piston in a cylinder. A typical surge block is shown in Figure 1. The surge block should fit snugly in the well casing to increase the surging action. The surge block is attached to a drill rod or drill stem and is of sufficient weight to cause the block to drop rapidly on the down stroke, forcing water contained in the borehole into the aquifer surrounding the well. In the recovery stroke or upstroke, water is lifted by the surge block, allowing water and fine sediments to flow back into the well from the aquifer. Down strokes and recovery strokes are usually 3 to 5 feet in length.

The surge block should be lowered into the water column above the well screen. The water column will effectively transmit the action of the block to the filter pack and hydrologic unit adjacent to the well screen. Development should begin above the screen and move progressively downward to prevent the surge block from becoming sand locked in the well. The initial surging action should be relatively gentle, allowing any material blocking the screen to break up, go into suspension, and then move into the well. As water begins to move easily both in and out of the screen, the surge block is usually lowered in

increments to a level just above the screen. As the block is lowered, the force of the surging movement should be increased. In wells equipped with long screens, it may be more effective to operate the surge block in the screen to concentrate its actions at various levels.

A pump or bailer should be used periodically to remove dislodged sediment that may have accumulated at the bottom of the well during the surging process. The pump or bailer should be moved up and down at the bottom of the well to suspend and collect as much sediment as possible.

The accumulation of material developed from a specific screen interval can be measured by sounding the total depth of the well before and after surging. Continue surging until little or no sand accumulates.

2.1.2 Overpumping

Overpumping involves pumping the well at a rate substantially higher than it will be pumped during well purging and groundwater sampling. This method is most effective on coarse-grained formations and is usually conducted in conjunction with mechanical surging or backwashing. Overpumping is commonly implemented using a submersible pump. In cases were the water table is less than 30 feet from the top of the casing, it is possible to overpump the well with a centrifugal pump. The intake pipe is lowered into the water column at a depth sufficient to ensure that the water in the well is not drawn down to the pump intake level. The inflow of water at the well screen is not dependent on the location of the pump intake as long as it remains submerged.

Overpumping will induce a high velocity water flow, resulting in the flow of sand, silt, and clay into the well, opening clogged screen slots and cleaning formation voids and fractures. The movement of these particles at high flow rates should eliminate particle movement at the lower flow rates used during well purging and sampling. The bridging of particles against the screen because of the flow rate and direction created by overpumping may be overcome by using mechanical surging or backwashing in conjunction with this method.

2.1.3 Air Lift Pumping

Air lift pumping uses a two-pipe system consisting of an air injection pipe and a discharge pipe. In this well development method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation provides a surging action that can dislodge fine-grained particles in the vicinity of the well screen. Subsequently applying a steady low pressure removes the fines drawn into the well by the surging action.

The bottom of the air lift should be at least 10 feet above the top of the well screen. Air is injected through an inner pipe at sufficient pressure to bubble out directly into the surrounding discharge pipe. The bubbles formed by the injected air cause the column of water in the discharge pipe to be lifted upward and allow water from the aquifer to flow into the well. This arrangement prevents injected air from entering the well screen. Pumping air through the well screen and into the filter pack and adjacent hydrologic unit should be avoided because it can cause air entrainment, inhibiting future sampling efforts and possibly altering groundwater chemistry.

The air injected into the well should be filtered using an oil/air filter and oil trap to remove any compressor lubricant entrained in the air. Air pressures required for this well development method are relatively low; an air pressure of 14.8 pounds per square inch should move a 30-foot column of water. For small-diameter, shallow wells where the amount of development water is likely to be limited, tanks of inert gas (such as nitrogen) can be used as an alternative to compressed air.

2.1.4 Backwashing

Effective development procedures should cause flow reversals through the screen openings that will agitate the sediment, remove the finer fraction, and then rearrange the remaining formation particles. Backwashing overcomes the bridging that results from overpumping by allowing the water that is pumped to the top of the well to flow back through the submersible pump and out through the well screen. The backflow portion of the backwashing cycle breaks down bridging, and the inflow then moves the fine material toward the screen and into the well.

Some wells respond satisfactorily to backwashing techniques, but the surging effect is not vigorous enough to obtain maximum results in many cases.

A variation of backwashing may be effective in low-permeability formations. After the filter pack is installed on a monitoring well, clean water is circulated down the well casing, out through the well screen and filter pack, and up through the open borehole before the grout or bentonite seal is placed in the annulus. Flow rates should be controlled to prevent floating the filter pack. Because of the low hydraulic conductivity of the formation, negligible amounts of water will infiltrate into the formation. Immediately after this procedure, the bentonite seal should be installed, and the nonformation water should be pumped out of the well and filter pack.

2.1.5 Surge Bailing

Surge bailing can be an effective well development method in relatively clean, permeable formations where water flows freely into the borehole. A bailer made of stainless steel or polyvinyl chloride and slightly smaller than the well casing diameter is allowed to fall freely through the borehole until it strikes the groundwater surface. The contact of the bailer produces a downward force and causes water to flow outward through the well screen, breaking up bridging that has developed around the screen. As the bailer fills and is rapidly withdrawn from the well, the drawdown created causes fine particles to flow through the well screen and into the well. Subsequent bailing can remove these particles from the well. Lowering the bailer to the bottom of the well and using rapid short strokes to agitate and suspend solids that have settled to the well bottom can enhance removal of sand and fine particles. Bailing should continue until the water is free of suspended particles.

2.1.6 Well Jetting

Well jetting can be used to develop monitoring wells in both unconsolidated and consolidated formations. Water jetting can open fractures and remove drilling mud that has penetrated the aquifer. The discharge force of the jetting tool is concentrated over a small area of the well screen. As a result, the tool must be rotated constantly while it is raised and lowered in a very small increments to be sure that all portions of the screen are exposed to the jetting action.

Jetting is relatively ineffective on the fine screens typically used in monitoring wells (slot sizes from 0.01 to 0.02 inch). In addition, jetting requires the introduction of external water into the well and surrounding formation. This water should be obtained from a source of known chemistry. Water introduced for development should be completely removed from the aquifer immediately after development.

The use of compressed air as a jetting agent should not be employed for development of monitoring wells. Compressed air could entrain air in the formation, introduce oil into the formation, and damage the well screen.

2.2 FACTORS TO CONSIDER WHEN SELECTING A WELL DEVELOPMENT METHOD

It is important to check federal, state, and local regulatory requirements for monitoring well development requirements. This SOP may be changed to accommodate applicable regulations, site conditions, or equipment limitations.

The type of geologic material, the design and completion of the well, and the type of drilling method used are all factors to be considered during the development of a monitoring well.

Monitoring well development should usually be started slowly and gently and then performed with increasing vigor as the well is developed. Most well development methods require the application of sufficient energy to disturb the filter pack, thereby freeing fine particles and allowing them to be drawn into the well. The coarser particles then settle around and stabilize the screen.

Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that strata material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the formation. In addition, development methods should be carefully selected based upon the potential contaminants present, the quantity of wastewater generated, and requirements for containerization or treatment of wastewater.

For small diameter and small volume wells, a development bailer can be used in place of a submersible pump in the pumping method. Similarly, a bailer can be used in much the same fashion as a surge block in small diameter wells.

Any time an air compressor is used for well development, it should be equipped with an oil air filter or oil trap to minimize the introduction of oil into the screened area. The presence of oil could impact the organic constituent concentrations of the water samples collected from the well.

The presence of light nonaqueous phase liquid (LNAPL) can impact monitoring well development. Water jetting or vacuum-enhanced well development may assist in breaking down the smear zone in the LNAPL. Normal development procedures are conducted in the water-saturated zone and do not affect the LNAPL zone.

2.3 INITIATING WELL DEVELOPMENT

Newly completed monitoring wells should be developed as soon as practical, but no sooner than 24 hours after grouting is completed if rigorous well development methods are used. Development may be initiated shortly after well installation if the development method does not interfere with the grout seal. State and local regulations should be checked for guidance. The following general well development steps can be used with any of the methods described in Section 2.1.

1. Assemble the necessary equipment on a plastic sheet around the well. This may include a water level meter (or oil/water interface probe if LNAPL or dense nonaqueous phase liquid is present); personal protective equipment; pH, conductivity, temperature, and turbidity meters; air monitoring equipment; Well Development Data Sheets (see Figure 2); a watch; and a field logbook.

2. Open the well and take air monitoring readings at the top of the well casing and in the breathing zone. See SOP No. 003 (Organic Vapor Air Monitoring) for additional guidance.

3. Measure the depth to water and the total depth of the monitoring well. See SOP No. 014 (Static Water Level, Total Well Depth, and Immiscible Layer Measurement) for additional guidance.

4. Measure the initial pH, temperature, turbidity, and specific conductance of the groundwater from the first groundwater that comes out of the well. Note the time, initial

color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. See SOPs No. 011 (Field Measurement of Water Temperature), 012 (Field Measurement of pH), 013 (Field Measurement of Specific Conductance), and 088 (Field Measurement of Water Turbidity) for additional guidance.

5. Develop the well using one or more of the methods described in Section 2.1 until the well is free of sediments and the groundwater turbidity has reached acceptable levels. Record the development method and other pertinent information on a Well Development Data Sheet see Figure 2) or in a field logbook.

6. Containerize any groundwater produced during well development if groundwater contamination is suspected. The containerized water should be sampled and analyzed to determine an appropriate disposal method.

7. Do not add water to assist in well development unless the water is from a source of known chemical quality and the addition has been approved by the project manager. If water is added, five times the amount of water introduced should be removed during development.

8. Continue to develop the well, repeating the water quality measurements for each borehole volume. Development should continue until each water quality parameter is stable to within 10 percent. Development should also continue until all the water added during development (if any) is removed or the water has a turbidity of less than 50 nephelometric turbidity units. This level may only be attainable after allowing the well to settle and testing at low flow sampling rates.

9. At the completion of well development, measure the final pH, temperature, turbidity, and specific conductance of the groundwater. Note the color, clarity, and odor of the water. Record the results on a Well Development Data Sheet (see Figure 2) or in a field logbook. In addition to the final water quality parameters, the following data should be noted on the Well Development Data Sheet: well identification, date(s) of well installation, date(s) and time of well development, static water level before and after development, quantity of water removed and time of removal, type and capacity of pump or bailer used, and well development technique.

All contaminated water produced during development should be containerized in drums or storage vessels properly labeled with the date collected, generating address, well identification, and consultant contact number.

2.4 DURATION OF WELL DEVELOPMENT

Well development should continue until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. When pH, temperature, turbidity, and specific conductance readings stabilize and the water is visually clear of suspended solids, the water is representative of formation water. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment free sample in a matter of minutes, whereas bailing the well may require several hours of continuous effort to obtain a clear sample.

An on-site project geologist should make the final decision as to whether well development is complete. This decision should be documented on a Well Development Data Sheet (see Figure 2) or in a field logbook.

2.5 CALCULATIONS

It is necessary to calculate the volume of water in the well. Monitoring well diameters are typically 2, 3, 4, or 6 inches. The height of water column (in feet) in the well can be multiplied by the following conversion factors to calculate the volume of water in the well casing.

Well Diameter (inches)	Volume (gallon per foot)
2	0.1631
3	0.3670
4	0.6524
6	1.4680

3.0 POTENTIAL PROBLEMS

The following potential problems can occur during development of monitoring wells:

- In some wells the pH, temperature, and specific conductance may stabilize but the water remains turbid. When this occurs, the well may still contain construction materials (such as drilling mud in the form of a mud cake) and formation soils that have not been washed out of the borehole. Excessive or thick drilling muds cannot be flushed out of a borehole with one or two well volumes of flushing. Continuous flushing over a period of several days may be necessary to complete well development. If the well is completed in a silty zone, it may be necessary to sample with low flow methods or filtering.

- Mechanical surging and well jetting disturb the formation and filter pack more than other well development methods. In formations with high clay and silt contents, surging and jetting can cause the well screen to become clogged with fines. If an excessive amount of fines is produced, sand locking of the surge block may result. Well development with these methods should be initiated gently to minimize disturbance of the filter pack and to prevent damage to the well screen.

- Effective overpumping may involve the discharge of large amounts of groundwater. This method is not recommended when groundwater extracted during well development is contaminated with hazardous constituents. If the hazardous constituents are organic compounds, this problem can be partially overcome by passing the groundwater through an activated carbon filter.

- When a well is developed by mechanical surging or bailing, rapid withdrawal of the surge block or bailer can result in a large external pressure outside of the well. If the withdrawal is too rapid and this pressure is too great, the well casing or screen can collapse.

- A major disadvantage of well jetting is that an external supply of water is needed. The water added during well jetting may alter the hydrochemistry of the aquifer; therefore, the water added in this development procedure should be obtained from a source of known chemistry. In addition, the amount of water added during well development and the amount lost to the formation should be recorded.

- The use of air in well development can chemically alter the groundwater, either directly through chemical reaction or indirectly as a result of impurities introduced through the air stream. In addition, air entrainment within the formation can interfere with the flow of groundwater into the monitoring well. Consequently, air should not be injected in the immediate vicinity of the well screen.

FIGURE 1

SCHEMATIC DRAWING OF A SURGE BLOCK

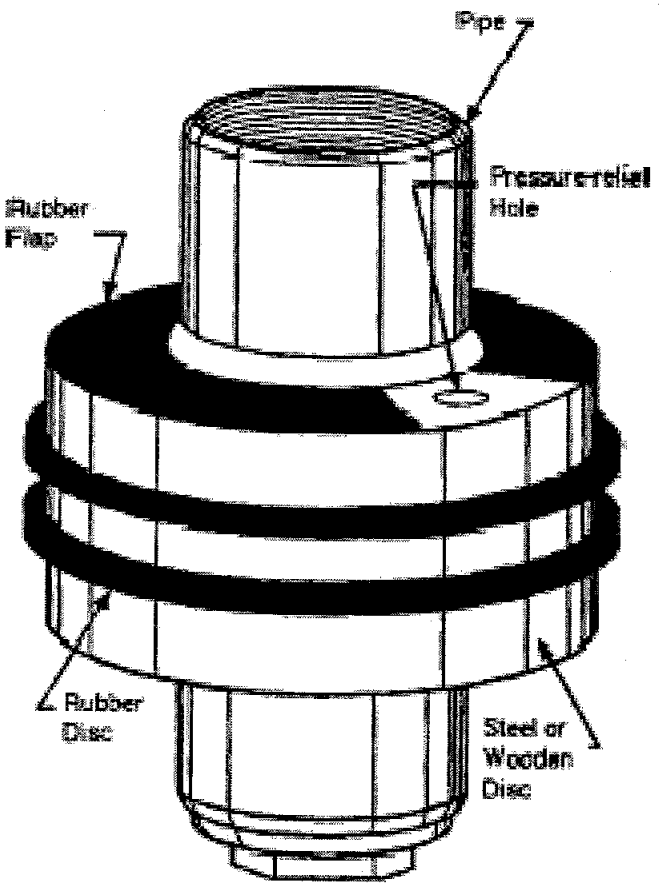


FIGURE 2

WELL DEVELOPMENT DATA SHEET

Sheet ___ of ___

WELL DEVELOPMENT DATA SHEET

BORING NO. _____ **WELL NO.** _____

Project _____
Project No. _____
Date(s) of Installation _____
Date(s) of Development _____
Personnel/Company _____
_____
Type of Rig Used _____

Casing Diameter/Type _____
Borehole Diameter _____
Screened Interval(s) _____
Total Length of Well Casing _____
Measured Total Depth (TOC) Initial _____
Final _____
Initial Depth to Water
(TOC) _____ Date _____ Time _____
Stabilized Depth to Water
(TOC) _____ Date _____ Time _____

DEVELOPMENT TECHNIQUE(S) EQUIPMENT TYPE/CAPACITY

___ Surging _____
___ Overpumping _____
___ Air Lift Pumping _____
___ Backwashing _____
___ Bailing _____
___ Well Jetting _____

FLUIDS ADDED

Lost Drilling Fluid: _____ Gallons
Lost Purge Water: _____ Gallons
Water During Installation: _____ Gallons
Total Fluids Added: _____ Gallons
Source of Added Water: _____
Sample Collected of Added Water: Y N
Sample Designation of Added Water: _____

PURGE VOLUME CALCULATION

Casing Volume: _____ Ft. of water
x _____ Gallons/Foot
= _____ Gallons per Single Casing Volume
Sand Pack Volume: _____ Ft. of Saturated Sand Pack
x _____ Gallons/Foot (borehole diameter)
= _____ Gallons (in borehole)
- _____ Gallons of Casing Volume
= _____ x 0.3 (Assuming porosity = 30%)
= _____ Gallons Within Sand Pack
Single Purge Volume: _____ Gallons (Casing Vol. + Sand Pack Vol. + Fluids Added)
Minimum Purge Volume: _____ Gallons
Actual Purge Volume: _____ Gallons
Volume Measured by: _____
Rate of Development _____ Gallons/Minute (Hour, Day)
Pumping Rate/Depth _____ @ _____ Ft. (Below Grd.)
Immiscible Phases Present: Y N Thickness _____

Development Criteria: _____

Total Volume Discharged	Rate of Discharge	Time	Temp	pH	Specific* Conductance	Turbidity (NTU)	D.O., Clarity, Odor, PID Readings, Other:

Development Completed at _____ Gallons Discharged. Date: _____ Time: _____

Personnel: _____
_____

* Specific Conductance readings temperature compensated to 25°C, if not, report temperatures at which reading obtained.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

RECORDING OF NOTES IN FIELD LOGBOOK

SOP NO. 024

REVISION NO. 1

Last Reviewed: November 1999

Quality Assurance Approved	*May 18, 1993* Date

1.0 BACKGROUND

The field logbook should contain detailed records of all the field activities, interviews of people, and observations of conditions at a site. Entries should be described in as much detail as possible, so that personnel can accurately reconstruct the activities and events which have taken place during field assignments. Field logbooks are considered accountable documents in enforcement proceedings and may be subject to review. Therefore, the entries in the logbook must be accurate, detailed, and reflect the importance of the field events.

1.1 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide guidance to ensure that logbook documentation for any field activity is correct, complete, and adequate. Logbooks are used for identifying, locating, labeling, and tracking samples. A logbook should document any deviations from the project approach, work plans, quality assurance project plans, health and safety plans, sampling plans, and any changes in project personnel. They also serve as documentation of any photographs taken during the course of the project. In addition, the data recorded in the logbook may assist in the interpretation of analytical results. A complete and accurate logbook also aids in maintaining good quality control. Quality control is enhanced by the proper documentation of all observations, activities, and decisions.

1.2 SCOPE

This SOP establishes the general requirements and procedures for recording notes in the field logbook.

1.3 DEFINITIONS

None

1.4 REFERENCES

Compton, R.R. 1985. *Geology in the Field.* John Wiley and Sons. New York, N.Y.

1.5 REQUIREMENTS AND RESOURCES

The following items are required for field notation:

- Field logbooks
- Ballpoint pens with permanent ink
- 6-inch ruler (optional)

Field logbooks should be bound (sewn) with water resistant and acid-proof covers; they should have preprinted lines and wide columns. They should be approximately 7 1/2 by 4 1/2 inches or 8 1/2 by 11 inches in size. Loose-leaf sheets are not acceptable for field notes. If notes are taken on loose paper, they must be transcribed as soon as possible into a regular field logbook by the same person who took the notes.

Logbooks can be obtained through the Document Control Administrator (DCA) for each office. The DCA will have assigned each logbook an identification number. The DCA will make sure the pages in the logbooks are preprinted with consecutive numbers or are consecutively numbered by hand. If the numbers are written by hand, then numbers should be circled so that they are not confused with data.

2.0 PROCEDURES

The following subsections provide general guidelines and formatting requirements for field logbooks and detailed procedures for completing field logbooks.

2.1 GENERAL GUIDELINES

- A separate field logbook must be maintained for each project. If a site consists of multiple subsites, designate a separate logbook for each subsite. For special tasks, such as periodic well water-level measurements, data from multiple subsites may be entered into one logbook which contains only one type of information.
- All logbooks must be bound and contain consecutively numbered pages.
- No pages can be removed from the logbook for any purpose.

- All field activities, meetings, photographs, and names of personnel must be recorded in the site logbook.
- All logbooks pertaining to a site or subsite should be assigned a serial number based on the date the logbook is issued to the project manager. The first logbook should be assigned number 1, the next logbook issued assigned number 2, and so on. The project manager is to maintain a record of all logbooks issued under the project.
- All information must be entered with a ballpoint pen with waterproof ink. Do not use pens with "wet ink," because the ink may wash out if the paper gets wet. Pencils are not permissible for field notes because information can be erased. The entries should be written dark enough so that the logbook can be easily photocopied.
- Do not enter information in the logbook that is not related to the project. The language used in the logbook should be factual and objective.
- Begin a new page for each day's notes.
- Write notes on every line of the logbook. If a subject changes and an additional blank space is necessary to make the new subject title standout, skip one line before beginning the new subject. Do not skip any pages or parts of pages unless a day's activity ends in the middle of a page.
- Draw a diagonal line on any blank spaces of four lines or more to prevent unauthorized entries.

2.2 LOGBOOK FORMAT

The layout and organization of each field logbook should be consistent with other field logbooks.

Guidelines for the cover, spine, and internal pagination are discussed below.

2.2.1 FORMAT OF FIELD LOGBOOK COVER AND SPINE

Write the following information in clear capital letters on the front cover of each logbook.

- Logbook identification number (assigned by the DCA)
- The serial number of the logbook (assigned by the project manager)
- Name of the site, city, and state

- Name of subsite if applicable
- Type of activity
- Beginning and ending dates of activities entered into the logbook
- "Tetra Tech EM Inc." City and State
- "REWARD IF FOUND"

Some of the information listed above, such as the list of activities and ending dates, should be entered after the entire logbook has been filled or after it has been decided that the remaining blank pages in the logbook will not be filled.

The spine of the logbook should contain an abbreviated version of the information on the cover. For example: "1, Col. Ave., Hastings, 5/88 - 8/88."

2.2.2 First Page of the Field Logbook

Spaces are usually provided on the inside front cover (or the opening page in some logbooks), for the company name ("Tetra Tech EM Inc."), address, and telephone number. If preprinted spaces for this information are not provided in the logbook, write the information on the first available page.

2.3 ENTERING INFORMATION IN THE LOGBOOK

Enter the following information at the beginning of each day or whenever warranted during the course of a day:

- Date
- Starting time
- Specific location
- General weather conditions and approximate temperature

- Names of personnel present at the site. Note the affiliation(s) and designation(s) of all personnel.
- Equipment calibration and equipment models used.
- Changes in instructions or activities at the site.
- Levels of personal protective clothing and equipment.
- A general title of the first task undertaken (for example, well installation at MW-11, decon at borehole BH-11, groundwater sampling at MW-11).
- Provide an approximate scale for all diagrams. If this can't be done, write "not to scale" on the diagram. Indicate the north direction on all maps and cross-sections. Label features on each diagram.
- Corrections should be made by drawing a single line through the entry being corrected. Initial and date any corrections made in the logbook.
- The person recording notes is to initial each page after the last entry. No information will be entered in the area following these initials.
- At the end of the day, the person recording notes is to sign and date the bottom of the last page. Indicate the end of the work day by writing "Left site at (time)." A diagonal line will be drawn across any blank space to the bottom of the page.

The following information should be recorded in the logbook after taking a photograph:

- Time, date, location, direction, and if appropriate, weather conditions
- Description of the subject photographed and the reason for taking the picture
- Sequential number of the photograph and the film roll number (if applicable)
- Name of the photographer

The following information should be entered into the logbook when taking samples:

- Location description
- Names of samplers
- Collection time
- Designation of samples as a grab or composite sample
- Type of sample (water, sediment, soil gas, etc.)

- On-site measurement data (pH, temperature, specific conductivity)
- Field observations (odors, colors, weather, etc.)
- Preliminary sample description
- Type of preservative used
- Instrument readings

2.4 PRECAUTIONS

Custody of field logbooks must be maintained at all times. Field personnel must keep the logbooks in a secure place (locked car, trailer, or field office) when the logbook is not in personal possession. Logbooks are official project documents and must be treated as such.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

BOREHOLE LOGGING

SOP NO. 026

REVISION NO. 2

Last Reviewed: November 1999

February 2, 1993

Quality Assurance Approved Date

1.0 BACKGROUND

The objective of logging a borehole is to document the details of the soil and rock recovered from the borehole. These details include soil type, color, grain size variation, grain characteristics, staining, odor, moisture content, plasticity, blowcounts, soil sample interval, soil recovery, and sample numbers. These data are used to reconstruct the borehole's stratigraphy, which can then be correlated with similar data from other boreholes in the region to produce geological and hydrogeological cross sections. These cross sections, along with various soil characteristics, and additional hydrogeological data, are used to prepare models that show the migration of groundwater and of any associated contaminants.

Tetra Tech EM Inc. (Tetra Tech) has adopted a modified version of the Unified Soil Classification System (USCS) for borehole logging. The USCS classifies soils based on texture and liquid limits. The system consists of 15 soil groups, each identified by a two-letter symbol. The major divisions within the USCS (the first letter in each two-letter symbol) denote particle size: coarse-grained soils are sands (S) and gravels (G); fine-grained soils are silts (M) and clays (C). In coarse-grained soils, the second letter in the classification refers to the grading (sorting) of the soils. Thus (W) represents clean, well graded (poorly sorted) materials, while (P) represents clean, poorly graded (well sorted) materials. In fine-grained soils, the silts and clays are further subdivided in terms of liquid limits,with (L) indicating soils with low liquid limits and (H) representing soils with high liquid limits.

1.1 PURPOSE

The purpose of this standard operating procedure (SOP) is to ensure that all the pertinent information that can be obtained from drilling a borehole is logged completely, accurately, and consistently.

1.2 SCOPE

This SOP applies to all Tetra Tech personnel involved in the logging of a borehole. Preprinted borehole log forms are available, and all personnel involved in borehole logging will use a form to document field activities. Attachment A contains a sample field borelog form.

1.3 DEFINITIONS

Definitions of terms that relate to borehole logging are presented below. Definitions of soil types are taken from the American Society for Testing and Materials (ASTM 1985).

Blow Counts: The number of blows delivered by a 140-pound hammer dropped 30 inches required to drive a 1.5-inch inside diameter core sampler down a certain depth, generally 6 inches.

Unified Soil Classification System (USCS): A geotechnical classification in which soils are classified into four major divisions (coarse-grained, fine-grained, organic soils, and peat). The coarse-grained soils are classified according to grain size, whereas the fine-grained soils are classified according to plasticity characteristics. A total of 15 soil types are recognized. Each is indicated by a different two-letter group symbol, such as SP, ML, and GW.

Well Graded Sediment/Soil: An engineering term describing a soil or unconsolidated sediment consisting of particles of several or many sizes. The opposite is "poorly graded," in which the soil or sediment particles are of nearly the same size. In the geological literature, "well graded" and "poorly graded" sedimentshoils are referred to as "poorly sorted" and "well sorted," respectively.

Clay: A fine-grained soil passing a No. 200 (75- micron [µm]) sieve that can be made to exhibit plasticity (putty-like properties) within a range of water contents and that exhibits considerable strength when air-dry.

Gravel: Particles of rock that will pass a 3-inch (75-millimeter [mm]) sieve and be retained on a No. 4 (4.75-mm) sieve with the following subdivisions: coarse - passes a 3-inch (75-mm) sieve and is retained on a 0.75-inch (19-mm) sieve; fine -passes a 0.75-inch (19-mm) sieve and is retained on a No. 4 (4.75-mm) sieve.

Organic Clay: A clay with sufficient organic content to influence the soil properties. For classification, an organic clay is a soil that would be classified as a clay, except that its liquid limit value after oven drying is less than 75 percent of its liquid limit value before oven drying.

Peat: A soil composed primarily of vegetable tissue in various stages of decomposition, usually with an organic odor, a dark brown to black color, a spongy consistency, and a texture ranging from fibrous to amorphous.

Sand: Particles of rock that will pass a No. 4 (4.75-mm) sieve and be retained on a No. 200 (75-pm) sieve with the following subdivisions: coarse - passes a No. 4 (4.75-mm) sieve and is retained on No. 10 (2.00-mm) sieve; medium - passes a No. 10 (2.00-mm) sieve and is retained on a No. 40 (425-pm) sieve; fine - passes a No. 40 (425-pm) sieve and is retained on a No. 200 (75-pm) sieve.

Silt: A fine-grained soil passing a No. 200 (75-pm) sieve that is nonplastic or very slightly plastic and that exhibits little or no strength when air dry.

1.4 REFERENCES

American Geological Institute (AGI). 1972. "Data Sheet." Alexandria, Virginia.

AGI. 1987. *Glossary* of *Geology.* Alexandria, Virginia.

American Society for Testing and Materials (ASTM). 1985. *Annual* ***Book of*** *ASTM Standard.* Philadelphia, Pennsylvania.

Fetter, C.W. 1988. *Applied Hydrogeology.* Merrill Publishing Company. Columbus, Ohio.

Holtz, R.D., and W.D. Kovacs. 1981. *An Introduction to Geotechnical Engineering.* Prentice-Hall Inc. Englewood Cliffs, New Jersey.

1.5 REQUIREMENTS AND RESOURCES

To log the borehole, one person at the drill site should be a geoscientist or someone who has a knowledge of soil types and their physical characteristics. The following supplies will be required at the drill site for borehole logging:

Clipboard: Provides a support for completing the field borelog forms. A suitable clipboard measures 12 by 9 inches, is hinged, and of three-leaf metal construction with up to a 1-inch depth for storing papers, borehole log forms, field notebooks, and so on. Tetra Tech has provided a variety of frequently used items such as a laminated color chart, Tetra Tech EM Inc. - Environmental SOP No. 026 USCS table, and examples of soil samples on the metal clipboards for reference in the field.

Borehole Log Form: A preprinted blank form on which all the subsurface information is noted. Tetra Tech has designed and printed this form for all borehole logging purposes. A completed sample field borelog form is presented in Attachment A.

United Soil Classification System (USCS) Table: A USCS table is needed to determine the group to which any retrieved soil belongs. Tetra Tech has laminated a copy of this table on the metal clipboards for reference in the field.

Color Chart: Contains all the possible rock, sediment, and soil colors with which the material retrieved from the borehole can be compared. In this chart, the color is described (for example, light brownish gray) and given a corresponding color code (for example, 5 YR 6/1). The Munsell Soil Color Chart or the Geological Society of America rock color chart can be used.

Hand Lens: A pocket-size magnifying glass with a magnification of approximately 10 to 20 times. It is particularly helpful in examining fine-grained materials in order to accurately describe the composition, shape, size, roundness, and color of the rock/soil particles.

Pocket Knife: Used to split recovered soil samples in any desired direction. It is also a convenient tool for isolating part of a soil/sediment sample for closer examination.

Hammer: Has many possible uses at the drill site. It is particularly handy for splitting borehole samples of rocks.

Sample Bottles: Used to collect soil and groundwater samples retrieved during boring.

Ruler: A 1-foot ruler with markings in millimeters and fractions of an inch will be needed to measure the diameters of coarse-grained sediments.

Adhesive Tape, Scissors, and Markers: Useful for securing the sample bottle caps and for labeling the bottles.

Soil Samples for Reference: Small samples of various soil types that are classified by grain size and roundness. These samples serve as a useful reference in maintaining consistency in classifying borehole soils at the drill site. Tetra Tech has laminated some examples of prominent soil samples on the metal clipboards for reference in the field.

Hydrochloric Acid: A small bottle of dilute hydrochloric acid (HCI) consisting of one part HCl to three parts water. This will be used to identify calcium carbonate-bearing soils or sediments.

Miscellaneous Reference Charts: These charts include explanations and drawings of technical terms that are frequently used in logging boreholes. Examples include a soil description summary table (see Attachment B), cohesive

soil consistency chart, blow counts versus soil stiffness correlation chart, granular soil density chart, moisture table, percentage-composition estimation chart, and particle roundness sketches. Tetra Tech has laminated these charts on metal clipboards for reference in the field.

Photoionization Detector (PID): Used to monitor possible emissions of hazardous gases from the borehole. The unit comes with an operating instruction manual.

Moisture Measuring Unit: Used to measure the moisture content of a soil sample in the field. The unit comes with operating instructions.

Draeger Tube: A colorimetric tube used to measure the concentrations of a variety of inorganic and organic vapors and gases. Allows on-site personnel to take necessary health and safety precautions. The unit comes with operating instructions.

Combustible Gas Indicator: Used to monitor the level of combustible gases that may be present at the drill site. Warns on-site personnel of any danger of explosion. It is of special value for drilling at sites that have a potential for emitting methane.

Work Table: The table is needed to set up equipment, borehole samples, and various
supplies.

Tent or Canopy: Used to protect the field borelog forms and other documents from rain or snow.

2.0 PROCEDURE

The following subsections detail the procedure for borehole logging.

2.1 GETTING ORGANIZED AT THE DRILL SITE

Borehole logging requires setting up a small office and a small laboratory at the drill site. As the borehole material is pulled up and retrieved for sampling, testing, or inspection, a variety of subtasks must becompleted in a certain sequence and in a limited time span. It is

important, therefore, that all the supplies and equipment be well organized and the tasks be clearly understood by the persons who are supposed to log the borehole.

2.2 LOGGING A BOREHOLE

Preprinted borelog forms are available to ensure that pertinent information is recorded by field personnel. Borelog forms will be completed by field personnel during drilling operations.

Instructions for completing the sample form (see Attachments A and B) are given below.

1. General: At the beginning of each day, use a new borelog sheet. The new sheet should continue at the depth where previous day's drilling was terminated.

   Where appropriate, use the following abbreviations:

   M = Missing
   NA = Not applicable
   ND = Not done

2. Location of Borehole: Draw a sketch map of the borehole site in the space provided at the upper left comer of the borelog form. Mark the precise location of the borehole with an "X" and clearly label it (for example, BH-12). Also draw and label prominent features in the vicinity of the borehole, such as railroads, streets, buildings, fencelines, and other landmarks. The direction to north should be shown (TN). Give an approximate scale.

3. Job No., Client, etc.: Enter this information as appropriate. Print the name(s) of the person(s) who logged the segment shown on any particular page of the borelog form.

4. Site, Subsite, Borehole Designation, etc.: This part of the form is self-explanatory. Enter "Sheet__of__" on each page after the borehole is completed.

5. Sampler Type: Choose abbreviations from the following list:

   CHP = Constant head probe
   GP = Geoprobe
   GWP = Groundwater probe
   SGP = Soil-gas probe
   SS = Split spoon
   ST = Shelby tube
   __ = Other (specify)

6. Sample Depth: Record the top and bottom depths of the segment drilled. The fraction of a foot should be recorded in decimals (for example, 5.6 feet) and not in inches.

7. Blows/6" Sampler: Record the number of blows in each 6-inch interval. If more than 100 blows are counted in the 6-inch interval, then record only 100. In this column, the hammer weight should be entered immediately below the blow count for the first entry of each day, after which the hammer weight should be recorded only if it is changed.

8. Inches Recov'd/Driven: This column is self-explanatory.

9. Time: Record the exact time when the sample was collected in military time (for example, 17 15 hours)

10. PID Reading: Record the PID reading in parts per million @pm) units.

11. Analyses (Physical/Chemical): Record the number of containers that will be sent for each type of analysis (physical "Phy" and/or chemical "Chm"). If no sample will be sent for analysis, a zero (0) should be recorded in the appropriate sub-column.

12. Depth in Feet: Enter numerals before or after the preprinted numerals to indicate the depth as multiples of 1 or 10. At the beginning of each day, a new borelog sheet should be used (see item 1 above). The boxes should be used to document soil types and depths.

13. USCS Soil Type: Enter appropriate USCS abbreviations (SW, SP, ML, and so on) based on the soil description in the next column. Complete this column only after the soil types have been described.

14. Soil Description: Record the soil description, noting the following items: soil type, color (with code from the color chart), texture (grain size, roundness, and so on), bedding, odor, consistency (stiffness, plasticity, and so on, for cohesive soils), relative density (loose, dense, and so on, for granular soils), and moisture content (dry, moist, saturated, and so on). The "Field Descriptions for Soil Summary Table" provided in Attachment B can be used to aid in the description formulation process. Record the depth of the water table where it is encountered. The presence of the water table should be indicated by writing down "saturated at __ feet." Soil classified as "sand should be further categorized as well graded (SW) or poorly-graded (SP). It should be remembered that the term "well graded" in geotechnology is the opposite of "well sorted" in geology. Record the sample medium and sample tag number, as necessary.

15. When the borehole is terminated, enter “Borehole terminated at - feet.”

ATTACHMENT A

SAMPLE FIELD BORELOG FORM

FIELD BORELOG Sheet ____ of ____

Location of Borehole	Job No.:	Borehole Designation
	Client:	Surface Elevation:
	Site:	Depth to Water:
	Subsite:	Logged by:
	Drilling Co.:	Drilling Date(s):
	Drilling Personnel/Method:	

Sampler Type	Sample Depth Top	Sample Depth Bot	Blows /6" Sample	Inches Recov'd /Driven	Time	PID Reading	Analysis Phys	Analysis Chm	Depth (Ft)	USCS Soil Type	Soil Description and Notes
									1		
									2		
									3		
									4		
									5		
									6		
									7		
									8		
									9		
									0		
									1		
									2		
									3		
									4		
									5		
									6		
									7		

ATTACHMENT A

FIELD DESCRIPTIONS FOR SOIL SUMMARY TABLE

ATTACHMENT B

FIELD DESCRIPTIONS FOR SOIL SUMMARY TABLE

FIELD DESCRIPTIONS FOR SOIL

1. TEXTURAL TERMS AND PROPORTIONS OF SOIL CONSTITUENTS

Clay	Silty Sand
Silty Clay	Sand
Clayey Silt	Gravelly Sand
Silt	Sandy Gravel
Sandy Silt	Gravel

Where apparent, indicate approximate percentages of each constituent.

Trace (Minor) ~ 0 to 5 percent
Some ~ 5 to 25 percent
Abundant (clayey, silty, sandy, gravelly) ~ 25 to 50 percent

2. PARTICLE SIZE DISTRIBUTION OR RANGE

(used to modify the textural name and describe the second major constituent)

Very Fine Sand	0.01 to 0.07 mm
Find Sand	0.07 to 0.4 mm
Medium Sand	0.4 to 2 mm
Coarse Sand	2 to 4mm
Very Coarse Sand	4 to 6mm
Granule	4 to 6mm
Gravels	6 mm to 7.5 cm
Cobbles	7.5 to 30 cm
Boulders	>30 cm

3. COLOR (see Munsell Soil Color Chart or GSA rock color chart)

Provide name and code in parentheses.
Where mottled, describe all colors present; where weathered or oxidized, modify with these colors as well.

4. SORTING (use to discuss size distribution when coarser grains predominate)

Well Sorted: ~90 percent of particles in I or 2 size classes
Moderately Sorted: ~90 percent of particles in 3 or 4 size classes
Poorly Sorted: Unsystematic range of particle sizes; no size class predominates
Sorting = Spread of range or degree of similarity

5. PLASTICITY

Nonplastic: Soil falls apart at any water content (crumbly)
Slightly Plastic: Soil easily crushed with fingers; a thread can barely be rolled; low dry strength
Plastic: Soil difficult to crush with fingers; easily rolled thread up to the plastic limit, failure after reaching the plastic limit; medium dry strength.
Very Plastic: Soil impossible to crush with fingers (highly deformable); threads require much time to reach plastic limit and can be rerolled several times after reaching the plastic limit
Plastic limit = Boundary between the plastic and semisolid state (an Atterberg limit)

6. MOISTURE

Dry Slightly Moist Moist Wet

7. DENSITY/CONSISTENCY

Density of Granular Soils

Very Loose	Dense
Loose	Very Dense
Moderately Dense	

Consistency of Cohesive Soils

Very Soft	Stiff (firm)
Soft	Very Stiff (firm)
Moderately Stiff (firm)	Hard (tight)

8. SOIL STRUCTURE

Grade/Uniformity

Structureless (homogeneous)	Moderate
Weak	Strong

Form

Bedding (describe bed thickness)	Imbricated
Stratified	Columnar
Laminated	Prismatic
Banded	Blocky
Platy	Granular

Defects in Soil Structure

Slickensides	Burrows
Roots	Fissures
Cementation	Weathering (type and extent)
Salts	Fresh
Caliche	Depth of weathering
Hardpan	Color

9. MINERALOGY/ANGULARITY

(pertinent for coarse-grained constituents, including sand grains)

General Terms	Specific Terms
Arkosic	Feldspar, Quartz
Felsic (light)	K-Feldspar, Quartz, Plagioclase, Feldspar
Mafic (dark)	Augite, Hornblende, Biotite, Pyroxene
Micaceous	Muscovite, Biotite, Phologopite
Plutonic	Granite, Monzonite, Gabbro
Volcanic	Rhyolite, Latite, Basalt
Oxidized	$Fe0_2$, Limonite
Rock Fragments	

Angularity/Shape

Angular	Rounded
Subangular	Flat
Subrounded	Elongated

10. DESCRIPTION OF SECOND MAJOR CONSTITUENT IF APPLICABLE (refer to horizon boundaries)

11. HORIZON BOUNDARIES

General Terms	Specific Terms
Gradational	Abrupt
Sharp	Diffuse
Erosional	Smooth
Depositional	Wavy
	Irregular
	Broken

12. ENVIRONMENT OF DEPOSITION .

General Terms	Specific Terms (Deposits)
Fill Material	Point Bar
Alluvium	Overbank
Colluvium	Channel
Detritus	Turbidity
Lateritic	Alluvial Fan
Landfill Material	Eolian
	Marine/Bay
	Lagoonal
	Deltaic

13. ADDITIONAL INFORMATION

Sample Designations
For soil or groundwater samples collected from borehole, including Hydropunch

USCS Soil Type
(If not provided in field form)

PID Readings (where taken)
Boreholeiheadspaceldirect sample reading

Drilling Information
Drilling ratelprogress

Terminology
Tight Smooth Chattering

Fluid Type/Fluid Loss
Intervals of loss Quantity lost

Changes in Drilling Methods

Explanation of Downtime

Photographic Information
Photo number (!!) and description, date, time, photographer

Groundwater Information
Initial depth to water
Stabilized depth to water

Miscellaneous Information
Borehole to be converted to monitoring well, weather conditions

EXAMPLE DESCRIPTIONS

(1) Silty clay, about equal silt/clay, mottled olive (5 YR 5/3) to yellowish brown (10 YR 5/6), nonplastic (crumbly), dry, dense, with 1- to 2-mm granules and a 2- to 5-cm lens of coarse quartz sand and gravel, gravels are 3 to 4 mm, rounded, crystalline hard siltstone, sharp contact with GC below, probable fill material, Hnu=0.1 (open sample).

(2) Clay or silty clay with abundant gravel (about 50 percent), medium to large pebbles (I to 2.5 cm), well sorted, subrounded, arkosic; claylsilt hard to distinguish, stained dark gray (10 YR 4/1) to gray (10 YR 5/1) with hydrocarbons, slightly plastic, slightly moist, moderately stiff, uniform, sparse mica or sericite, occasional shell fragments, intertidal marine siltslclays; headspace readings 15-25 ppm; photo #29, stained soils in open split spoon, 10/5/90, 1430, D. West; Sample TP-4 (10-11.5) collected.

SOP APPROVAL FORM

TETRA TECH EM INC.

ENVIRONMENTAL STANDARD OPERATING PROCEDURE

FIELD MEASUREMENT OF GROUNDWATER pH, SPECIFIC CONDUCTANCE, AND TEMPERATURE USING THE YSI MODEL 3560

SOP NO. 061

REVISION NO. 1

Last Reviewed: January 2000

Quality Assurance Approved	*February 19, 1993* Date

1.0 BACKGROUND

The YSI Model 3560 water quality monitoring system can be used for determining groundwater pH, specific conductance, and temperature. The system is designed to be used in the field with a pump but can also be used with a bailer. As water is pumped through the system, temperature, temperature-compensated pH, and temperature-compensated specific conductance can be monitored simultaneously. Stable readings of the groundwater running through the sample chamber can be obtained in as little as two minutes. The continuous monitoring of these parameters helps determine when a representative sample of the groundwater has been obtained. The system is designed for simple assembly and disassembly to facilitate frequent calibration and maintenance.

The YSI 3560 consists of a water quality monitor, a temperature probe, a flow-through conductivity cell, a pH electrode assembly, an oxidation-reduction potential electrode assembly, and a sample chamber assembly. The measurement of oxidation-reduction potential is not discussed in this standard operating procedure (SOP).

1.1 PURPOSE

This SOP establishes the requirements and procedures for using the YSI Model 3560 water quality monitoring system for determining groundwater pH, specific conductance, and temperature in the field.

This instrument allows the user to visually monitor three parameters simultaneously by means of three LCD displays. The unit operates on six alkaline “D” cell batteries that will provide a minimum of 1,400 operating hours. An on/off switch controls power to the instrument. A second function switch controls each of the three ranges of specific conductance indicated on the middle display. Temperature is read out constantly in °C on the top display, and temperature-compensated specific conductance, automatically corrected to 25 °C, can be monitored. A third function switch controls the bottom display, which shows temperature-compensated pH in either pH units or millivolts (mV).

1.2 SCOPE

This SOP applies to monitoring temperature, temperature-compensated pH, and temperature-compensated specific conductance simultaneously while using the YSI 3560 water quality monitoring system in the field.

The temperature probe can be used independently as a temperature probe or in conjunction with the specific conductance or pH probe for temperature-compensated readings when attached properly to the water quality monitor. It is usable over a range of -5 °C to 50 °C with an accuracy of ±0.2 °C.

1.3 DEFINITIONS

Flow-Through Conductivity Cell: The flow-through conductivity cell is constructed of polyvinyl chloride. A 3-foot jacketed cable is attached to the cell body. Two electrodes measure specific conductance. The cell response time is 10 seconds for 95 percent reading of specific conductance changes. Accurate measurement can be made with a flow rate up to 1.5 gallons per minute. The conductivity cell constant is K = 5.0 millimhos/cm (mmhos/cm).

ph Electrode Assembly: The pH electrode is a 5.5-inch-long polymer body consisting of a silver/silver chloride reference electrode and a silver working electrode sealed in 4-molar potassium chloride gel. This gel eliminates the need to add filling solution.

Sample Chamber Assembly: The sample chamber assembly is an integral part of the YSI water quality monitoring system. It is designed to be attached to a water pump outlet but can be used as a non-flowing sample chamber. The chamber is designed to provide good mixing of fluid, so residual sample is not a problem. The sample chamber holds approximately 1 liter of sample.

1.4 REFERENCE

YSI, Inc., “YSI Model 3560 Water Quality Monitoring System Instructions, Operator’s Manual.”

1.5 REQUIREMENTS AND RESOURCES

The following are required to measure groundwater pH, specific conductance, and temperature using this SOP:

- YSI Model 3560 water quality measuring system
- YSI 3167, 3168, and 3169 specific conductance calibration solutions
- Buffer solutions of pH 4, 7, and 10 for pH calibration
- Distilled or deionized water
- Rinse bottle
- 50-milliliter (mL) sample cups or beakers
- Sample tubing and connectors (described in Section 2.2.1)
- Waste container to collect purge water
- Logbook or field data sheets
- Ohmmeter for testing the temperature probe (optional)

2.0 PROCEDURES

The procedures outlined in this SOP apply to using the YSI Model 3560 water quality monitoring system to measure groundwater pH, specific conductance, and temperature in the field. Procedures for testing and calibrating the YSI Model 3560 are presented first, followed by procedures for operating the instrument and making field measurements.

2.1 TESTING AND CALIBRATION PROCEDURES

This section outlines procedures for testing and calibrating the YSI Model 3560 water quality monitoring system. The instrument contains no user serviceable adjustments. If testing and calibration measurements are out of tolerance, the instrument must be serviced or repaired.

2.1.1 Calibrating the pH Electrode

The calibration frequency of the pH electrode depends on the electrode, the pH monitor and the characteristics of the water to which the electrode is exposed. Since normal life of a pH electrode is only 3 to 6 months, it is advisable to calibrate the pH system before sampling at each site. The pH electrode should be tested for background noise and appropriately offset on a daily basis.

Before connecting the pH electrode, zero the electronics with the shorting cap attached to the water quality monitor. Turn on the water quality monitor and set the pH function switch to pH. Next, connect the shorting cap to the pH input jack and set the manual temperature compensation knob to 25 °C. Then adjust the CAL control to indicate 7.00 ± 0.01 on the pH-mV display. Disconnect the shorting cap from the pH input and connect it to the mV input jack. The monitor is now zeroed.

Once it has been established that the electrode offset is functioning properly, a two-point calibration should be performed. Use pH buffers of 7.00 and 4.00 or of 7.00 and 10.00, whichever two are closer to the expected sample value. Proceed as follows to make a two-point calibration.

Rinse the pH electrode and temperature probe with pH 7.00 buffer to remove any contaminants. Connect the pH electrode to the pH input jack and the temperature probe to the TEMP input jack. Pour the pH 7.00 buffer into a 50-mL sample cup, then immerse both sensors into the buffer. Allow the sensors to equilibrate in the buffer until a stable reading is obtained. Read the temperature and manually adjust the pH temperature-compensation knob to the same value. Adjust the CAL control knob for 7.00 ± 0.01 pH units on the display and discard the buffer. Rinse the sensors with deionized or distilled water, followed by a rinse of the next desired buffer (pH 4.00 or 10.00). Fill another disposable 50-mL sample cup with the next buffer for calibration and immerse the sensors. Allow the sensors to equilibrate until a stable reading is obtained. If the temperatures of the two buffers differ by more than ±0.1 °C, the temperature should be allowed to stabilize. Adjust the SLOPE control until the display is within 0.01 pH units of the buffer's stated value. Discard the buffer and rinse the sensors with distilled or deionized water. The pH system is now calibrated and ready for use.

2.1.2 Calibrating the pH Electrode with Temperature Compensation

Follow the pH instructions in Section 2.1.1; however, the calibration procedure should be modified as indicated. Set the pH function switch to pH ATC. Connect the temperature probe to the pH ATC input jack. While the temperature probe can be used in either location, the pH ATC function will not work unless the temperature probe is connected to the pH ATC input. It is recommended that a second temperature probe be used for this operation. Manual temperature compensation is not necessary since temperature compensation is performed automatically in this mode.

2.1.3 Calibrating the Specific Conductance Probe

The designed cell constant of the flow-through conductivity cell is K = 5 mmhos/cm. The stainless steel electrodes provide different accuracies in different ranges. The cell constant can be affected by electrode fouling or mechanical shock. Therefore, it is wise to redetermine the cell constant routinely. When testing the calibration of the system, be sure to check the accuracy of the test against system specifications.

To check the cell constant, YSI 3167, 3168, 3169, or similar specific conductance calibration solutions may be used. The YSI calibration solutions are packaged eight to a box in 1-pint unbreakable plastic bottles designed for field use. The solutions are manufactured to nominal values of 1, 10, or 50 mmhos/cm at 25°C, with a ±1 percent accuracy of the stated value. A chart for uncompensated values at temperatures other than 25 °C is included with each box.

Connect the flow-through conductivity cell and temperature probe to the water quality monitor, and remove them from the sample chamber. Set the conductivity function switch to 2 ATC. Rinse the inside and outside of the cell and the probe with about 1/3 of the contents of the calibration solution bottle. Place both sensors into the remaining solution in the bottle, and allow them to come to temperature equilibrium. Make sure that the flow-through conductivity cell body is immersed so that the solution level is at least half way up the knurled portion of the cell. Read the displayed value and determine if the cell/instrument is within specified accuracy. The displayed value is corrected to 25 °C automatically and should be 1.000 ± 0.070 mmhos/cm. If the value is within specification, the measured error can be used to improve the accuracy of the system by providing a correction factor for further readings. This is done as follows:

$$\text{Corrected Sample Value} = \frac{\text{Calibration Value}}{\text{Displayed Value}} \times \text{Sample Value}$$

Calibration Value = 1.000 mmhos/cm

Displayed Value = 0.978 mmhos/cm

Sample Value = 0.634 mmhos/cm

0.648 mmhos/cm = [(1.000 mmhos/cm)/(0.978 mmhos/cm)] x 0.634 mmhos/cm

Discard the calibration solution once the accuracy of the system has been determined. It has been contaminated and should not be reused. If system accuracy is out of specification, see Warranty and Shipping Information for repair instructions.

2.1.4 Testing the Temperature Probe (Optional)

The temperature probe is assembled with a thermistor and may be tested using an ohmmeter. With the sheath of the probe submerged in a 0.0 °C ± 1 °C ice bath, thermistor resistance can be compared to the following values:

Across pins A and B = 94.98 K ± 482 ohms

Across pins B and C = 15.59 K ± 103 ohms

Across pins A and C = 114.6 K ± 585 ohms

Across pins B and D = 0 K ± 1 ohms

If any measurement is out of tolerance, the temperature probe should be repaired or replaced.

2.2 OPERATING PROCEDURES

Operation of the YSI 3560 is discussed below, including hooking up the pump and measuring groundwater temperature, specific conductance (with and without automatic temperature compensation), and pH (with and without automatic temperature compensation).

2.2.1 Hooking up the Pump

The YSI 3560 water quality monitoring system may be connected to the pump outlet at any time during the purging-pumping process as long as the flow rate does not exceed 1.5 gallons per minute. The system is normally connected prior to starting the pump so that constant parameter monitoring may be achieved and the point for logging the representative sample values can be determined. Because of sample chamber construction, it is very important that a 1.5-gallon-per-minute sample flow not be exceeded; otherwise, leakage may occur. Small hose clamps or rubber bands may be used, as appropriate, to tighten seals and avoid leakage that sometimes may occur after properly hooking up the pump.

The outlet from the pump must first be prepared for the sample chamber input. Inlet and outlet lines for the sample chamber assembly are cut to the length desired from the 10-foot-long plastic tubing supplied. Insert a tube-hose stem adapter into each end of the inlet tubing. This section connects the pump outlet to the sample chamber inlet. Insert a third tube-hose stem adapter into one end of the outlet tubing. This goes from the sample chamber to a waste container.

Next, the sample chamber assembly is connected to a 1/2-inch or 3/8-inch outer diameter (OD) pump outlet by using the appropriate straight union connector supplied. For a 1/2-inch-OD pump outlet, use the straight-union connector with two 1/2-inch-ID ports. For a 3/8-inch-OD pump outlet, use the straight-union connector that has one 3/8-inch-ID port and one 1/2-inch-ID port. Hand-tighten the appropriate port of the straight union connector at the pump outlet. Insert one end of the previously constructed sample chamber inlet tubing into the opposite port of the straight-union connector at the pump outlet and hand-tighten it.

Insert the other end of the constructed inlet tubing into an elbow until it stops. Then insert the elbow into the top of the flow-through conductivity cell and push down until it stops. Two internal O-rings in the cell serve as water seals.

The constructed end of the outlet tubing with the inserted tube-hose stem adapter is then pushed into another elbow until it stops. Then the elbow is inserted into the outlet port of the sensor mounting plate of the sample chamber and pushed down until it stops. There is a double O-ring seal here too.

Install the sensors that will be used into the sensor mounting plate in their respective ports. The sensor ports not in use must have plugs (provided with the YSI 3560 system) installed to close off the sample chamber. The input jacks are marked for proper placement of each connector. The temperature, conductivity, pH, automatic temperature-compensation probe inputs, and the recorder output have male connectors. The pH electrode comes with a connector that has a very low water integrity and so its "boot" should be installed over its connector. With the sensors attached to the water quality monitor, place all the cables from the sample chamber into the black cable harness provided with the YSI 3560 system. The harness is slotted for easy cable installation. The system is now ready for operation.

With the system connected to the pump, begin pumping according to the pump manufacturer's instructions. Turn on the water quality monitor. Before recording any values, make sure the sample chamber is full, that all air is voided, and that all of the displayed values are stable.

2.2.2 Measuring pH

To measure pH, connect the pH electrode to the water quality monitor, and set the pH function switch to pH. Install the electrode into its port in the sample chamber assembly. Though the instrument and electrode have been calibrated at one temperature, they can be used at other temperatures as long as the manual temperature knob is reset to the new sample temperature before final pH values are determined. Be sure to reset the dial to the temperature indicated by the top display. Though pH is temperature dependent, it is not customarily corrected to 25 °C, as specific conductance often is; pH changes with temperature at the rate of 0.355 percent/1 °C from the calibration point.

When measuring pH with no electrode connected to the mV input, the shorting cap attached to the water quality monitor should be on the mV input jack.

2.2.3 Measuring Automatically Temperature-Compensated pH

To measure automatically temperature-compensated pH, a temperature probe and the pH electrode must be connected to the water quality monitor. As long as the pH ATC mode is being used, the temperature probe must remain connected to the pH ATC input jack or else the pH display will show an underrange negative value, or an overrange value greater than 14.00; both values are outside of the pH range of 0.00 to 14.00 and cannot be adjusted into the measurable pH range.

Install the electrode into the sample chamber assembly in its appropriate port, and the temperature probe into the pH ATC port. Though the instrument and sensors have been calibrated at one temperature, they can be used at other temperatures, since temperature changes from the calibration point will be automatically corrected to the new value. When measuring pH with no electrode connected to the mV input, the shorting cap attached to the water quality monitor should be on the mV input jack.

2.2.4 Measuring Specific Conductance

To measure specific conductance, connect the flow-through conductivity cell to the water quality measurement. Set the conductivity function switch to 2 and observe the displayed value after the reading is stable. The display reads out in mmhos/cm. If no cell or a dry cell is attached to the water quality monitor, the display will read 000 (±002) with the appropriate decimal point.

If the overrange signal (1.__) is displayed, the specific conductance of the water being tested is greater than 1.999 mmhos/cm. Reset the function switch to 20. If the overrange signal is still displayed, reset to 100. If the overrange signal is still displayed, the specific conductance is greater than 100.0 mmhos/cm and the water quality monitor cannot be used for specific conductance determination.

2.2.5 Measuring Automatically Temperature-Compensated Specific Conductance

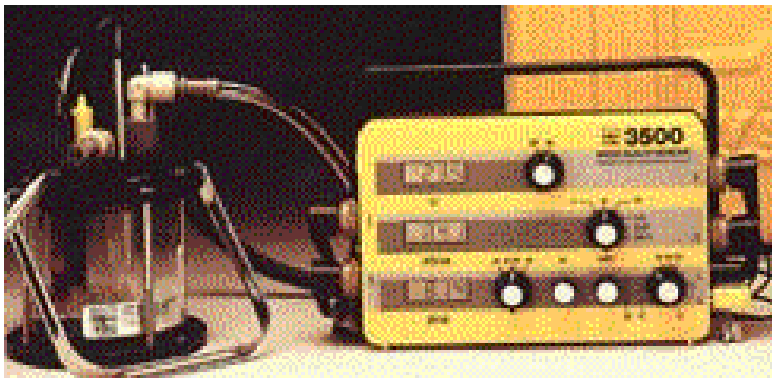
To measure automatically temperature-compensated specific conductance, connect the temperature probe and the flow-through conductivity cell to the water quality monitor, and set the conductivity function switch to the correct automatic temperature-compensated specific conductance range. Readings are automatically compensated by 2 percent/1 °C to 25 °C. The temperature probe must be located in the sample being tested for the automatic compensation to work correctly. If no temperature probe is connected to the monitor, the display will show the overrange signal (1.__).

2.2.6 Measuring Temperature

To measure temperature, connect the temperature probe to the water quality monitor. Temperature is measured in °C and is shown continuously on the top display. With no probe attached, the water quality monitor display will read -34.0 ± 0.2 °C.

FIGURE 1

THE YSI 3560 WATER QUALITY MONITORING SYSTEM



ATTACHMENT C
FIELD FORMS

Field Instrument Calibration Log

Well Development Form

Soil Boring and Well Installation Log

Groundwater Level Measurements Log

Monitoring Well Completion Record

Monitoring Well Sampling Sheet

Daily Site Log

Daily Quality Control Report

Tailgate Safety Meeting Form

Chain-of-Custody Form

Corrective Action Request Form

TETRA TECH EM INC.
FIELD INSTRUMENT CALIBRATION LOG

Project No.: _____

Project Name: _____

Instrument Type	Instrument Serial Number	Calibration Type	Date	By

Tetra Tech EM Inc.

Sheet ___ of ___

WELL DEVELOPMENT DATA SHEET

BORING NO._____ WELL NO._____

Project _____
Project No. _____
Date(s) of Installation _____
Date(s) of Development _____
Personnel/Company _____
_____
Type of Rig Used _____

Casing Diameter/Type _____
Borehole Diameter _____
Screened Interval(s) _____
Total Length of Well Casing _____
Measure Total Depth (TOC) Initial
Final _____
Initial Depth to Water
(TOC)_____ Date _____ Time _____
Stabilized Depth to Water
(TOC)_____ Date _____ Time _____

DEVELOPMENT

TECHNIQUE(S)	EQUIPMENT TYPE/CAPACITY
_____ Jetting (Airlift)	_____
_____ Surge Block	_____
_____ Bailing	_____
_____ Pumping	_____
_____ Other	_____

FLUIDS ADDED

Lost Drilling Fluid:_____ Gallons
Lost Purge Water: _____ Gallons
Water During Installation:_____ Gallons
Total Fluids Added:_____ Gallons
Source of Added Water: _____
Sample Collected of Added Water: Y N
Sample Designation of Added Water:_____

PURGE VOLUME CALCULATION

Casing Volume: _____ Ft. of water
x_____ Gallons/Foot
=_____ Gallons per Single Casing Volume
Sand Pack Volume:_____ Ft. of Saturated Sand Pack
x_____ Gallons/Foot (borehole diameter)
=_____ Gallons (in borehole)
-_____ Gallons of Casing Volume
=_____ X 0.3 (Assuming porosity = 30%)
=_____ Gallons Within Sand Pack
Single Purge Volume:_____ Gallons (Casing Vol. + Sand Pack Vol. + Fluids Added)
Minimum Purge Volume: _____ Gallons (Casing Vol. +
Actual Purge Volume:_____ Gallons (Casing Vol. +
Volume Measured by:_____
Rate of Development _____ Gallons/Minute (Hour, Day)
Pumping Rate/Depth _____ @ _____ Ft. (Below Grd.)
Immiscible Phases Present: Y N Thickness _____

Development Criteria:_____

Total Volume Discharge	Rate of Discharge	Time	Temp	pH	Specific* Conductance	Turbidity (NTU)	D.O., Clarity, Odor, PID Readings, Other:

Development Completed at _____ Gallons Discharged. Date: _____ Time: _____

Personnel: _____

* Specific Conductance readings temperature compensated to 25°C, if not, report temperatures at which reading obtained.

TETRA TECH EM INC.

SOIL BORING AND WELL INSTALLATION AND VISUAL CLASSIFICATION LOG

DO:

Bldg./Site:

Project Name:

Boring Number:	Date Started:
Drilling Method: (*Circle one*) HSA Continuous Core/Direct Push/Hand Auger	Date Completed:
Air Rotary/Mud Rotary/Dual Tube Percussion/Sonic/Vacuum	Logged By:
Outer Diameter of Boring:	Drilling Subcontractor:
Inner Diameter of Well Casing:	Driller:
Depth to Water (ft./bgs.)	Location Sketch:

Time	Depth (ft) bgs	Drive Interval	Recovered Interval	Sample ID	V.B. utility type, dia. / Blow count (per 6 inches)	Description	USCS soil symbol	Well construction	OVM (ppm)

TETRA TECH EM INC.

SOIL BORING AND WELL INSTALLATION AND VISUAL CLASSIFICATION LOG

DO:

Bldg./Site:

Project Name:

Time	Depth (ft) bgs	Drive Interval	Recovered Interval	Sample ID	Blow count (per 6 inches) / V.B. utility type, dia.	Description	USCS soil symbol	Well construction	OVM (ppm)

TETRA TECH EM INC.
GROUNDWATER LEVEL MEASUREMENTS LOG

Type of organic vapor meter used (circle): PID FID

Well Identification Number	Organic Vapor Information		Water Level Information							Depth to Well Bottom from Top of PVC Casing[2] (feet)	Comments
					Depth to Groundwater Information						
	PID/FID Reading (ppm)	Date	Well previously equilibrated? (Yes/No)	If not previously equilibrated, **pressure detected** when cap removed? (NA/Yes/No)	Time	Date	Depth to Groundwater[1] from Pump Platform or Riser, if present (feet)	Thickness of Pump Platform or Riser, if present (feet)	Depth to Groundwater[1] from Top of PVC Casing (feet)		

Notes: 1 Where bladder pump sampling platform or riser is present, depth to water must be corrected to depth from top of PVC casing.
2 Note if access to well bottom is limited by presence of dedicated bladder pump.

Field Staff: _____ **Field Staff Signature:** _____

Page No.: _____ **Date:** _____

TETRA TECH EM INC.

MONITORING WELL COMPLETION RECORD

DRILLING INFORMATION

DRILLING BEGAN:
DATE _____ TIME _____
WELL INSTALLATION BEGAN:
DATE _____ TIME _____
WELL COMPLETION FINISHED:
DATE _____ TIME _____
DRILLING CO. _____
DRILLER _____
LICENSE _____
DRILL RIG _____
DRILLING METHOD:
☐ HOLLOW STEM AUGER
☐ AIR ROTARY
☐ _____
DIAMETER OF AUGERS:
ID _____ OD _____

BENTONITE SEAL

AMOUNT CALCULATED _____
AMOUNT USED _____
☐ PELLETS, SIZE _____
☐ CHIPS, SIZE _____
☐ _____
PRODUCT _____
MFG. BY _____
METHOD INSTALLED
☐ POURED ☐ TREMIE
AMOUNT OF WATER USED _____

FILTER PACK

AMOUNT CALCULATED _____
AMOUNT USED _____
☐ SAND, SIZE _____
☐ FORMATION COLLAPSE:
FROM _____ TO _____
PRODUCT _____
MFG. BY _____
METHOD INSTALLED:
☐ POURED ☐ TREMIE

SURVEY INFORMATION

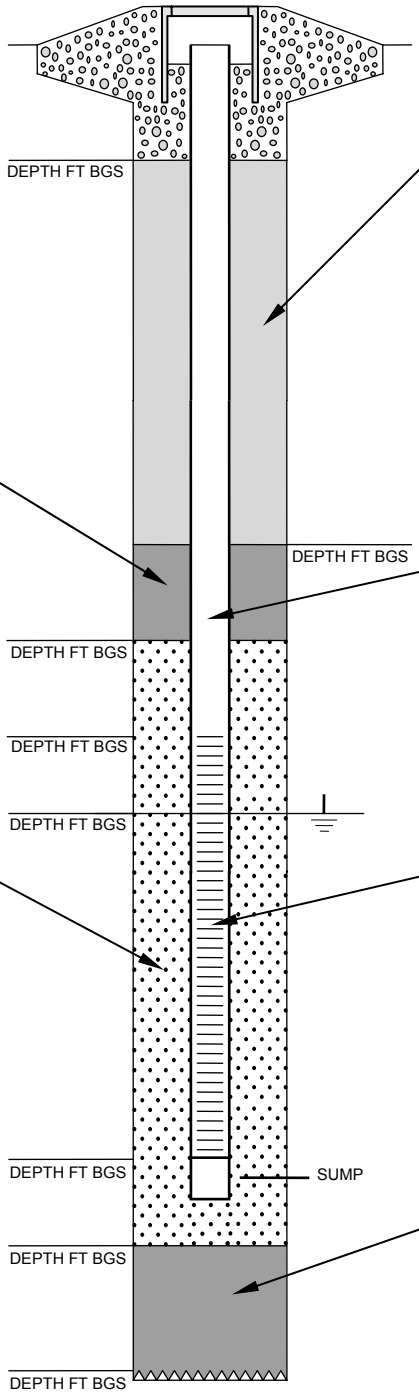
TOC ELEVATION _____
GROUND ELEVATION _____
NORTHING COORD. _____
EASTING COORD. _____
DATE SURVEYED _____
SURVEY CO. _____

CENTRALIZERS USED?

☐ YES ☐ NO
CENTRALIZER DEPTHS: _____

SURFACE COMPLETION

☐ FLUSH MOUNT
☐ ABOVE GROUND W/BUMPER POST
☐ CONCRETE ☐ ASPHALT



MONITORING WELL

MONITORING WELL NO. _____
PROJECT _____
SITE _____
BOREHOLE NO. _____
WELL PERMIT NO. _____
TOC TO BOTTOM OF WELL _____

ANNULAR SEAL

AMOUNT CALCULATED _____
AMOUNT USED _____
☐ GROUT FORMULA
PORTLAND CEMENT _____
BENTONITE _____
WATER _____
☐ PREPARED MIX
PRODUCT _____
MFG. BY _____
METHOD INSTALLED
☐ POURED ☐ TREMIE

CASING

☐ SCHEDULE 40 PVC
☐ _____
PRODUCT _____
MFG BY. _____
CASING DIAMETER (in):
ID _____ OD _____
LENGTH OF CASING _____

WELL SCREEN

☐ SCHEDULE 40 PVC
☐ _____
PRODUCT _____
MFG. BY: _____
CASING DIAMETER (in):
ID _____ OD _____
SLOT SIZE _____
LENGTH OF SCREEN _____

BOREHOLE BACKFILL

AMOUNT CALCULATED _____
AMOUNT USED _____
☐ BENTONITE CHIPS, SIZE _____
☐ BENTONITE PELLETS, SIZE _____
☐ SLURRY _____
☐ FORMATION COLLAPSE
FROM _____ TO _____
PRODUCT _____
MFG. BY _____
METHOD INSTALLED:
☐ POURED ☐ TREMIE

TETRA TECH EM INC.
MONITORING WELL SAMPLING SHEET

Date:_____

Monitoring Well No.:_____ Chain of Custody No.:_____

Personnel:_____

Organic Vapor Concentration TOC:_____ppm Breathing Zone: _____ppm

Depth to Well Bottom: _____ft.

Depth to Water: _____ft.

Water Column:_____ft.

Well Volume: 2-inch well = water column x 0.163 gal/ft
3-inch well = water column x 0.367 gal/ft
4-inch well = water column x 0.652 gal/ft

Well Volume Calculation:_____gal

Time	Vol. Purged (____)	Flow Rate (____)	Water Level (____)	pH	Conduc-tivity (____)	Temp-erature (°C/°F)	Turbidity (NTU)	D. O. (mg/L)	O. R. P. (____)

Begin Purge:_____ Method of Purging_____ Purged Dry?_____

End Purge:_____ Total Volume Purged:_____ How Measured?_____

QA/QC Sample Collected Here? ☐ Duplicate ☐ Matrix Spike ☐ Equip. Blank ☐ No QA/QC Sample

Date and Time of Sample Collection:_____Sample Number (s):_____

Comments:_____

_____

TETRA TECH, INC.

DAILY SITE LOG

Site Name:_____ Date: _____

Name (print)	Company	Time	
		In	Out

Comments:

_____

_____

_____

Tetra Tech EM Inc.

Daily Quality Control Report

Project Name:	**Date:**
Project Number:	**Day:**
Weather:	**Wind:**
Temperature:	**Humidity:**

Personnel on Site

Field Team Leader:

Subcontractors on Site:

Equipment on Site

Work Performed (Including Sampling)

Quality Control Activities

Health and Safety Levels and Activities

Problems Encountered / Corrective Action Taken

Tetra Tech EM Inc.

Daily Quality Control Report

Deviations from Field Work Plan

Additional Notes

Anticipated Activities for Tomorrow

Distribution:	**Submitted By:**
	Signature / Date

Daily Tailgate Safety Meeting Form

Date: _____ Time: _____ Job Number: _____

Client: _____ Site Location: _____

Scope of Work: _____

Safety Topics Presented

Planned Field Activities for the Day: _____

Protective Clothing / Equipment: _____

Chemical Hazards: _____

Physical Hazards: _____

Special Equipment: _____

Decontamination Procedures: _____

Other: _____

Emergency Procedures: _____

Hospital: _____ Phone: _____ Ambulance Phone: _____

Hospital Address and Route: _____

Employee Questions / Comments: _____

Attendees

Name (Printed)	Signature

Meeting Conducted By:

Name (Printed) / Signature	Name (Printed) / Signature
Site Safety Coordinator	Project Field Manager

Tetra Tech EM Inc.
San Francisco Office

135 Main St. Suite 1800
San Francisco. CA 94105
415-543-4880
Fax 415-543-5480

Chain of Custody Record No. _____

Lab PO#:	Lab:
Project name:	TtEMI technical contact:	Field samplers:
Project (CTO) number:	TtEMI project manager:	Field samplers' signatures:

Sample ID	Sample Location (Pt. ID)	Date	Time	Matrix	MS / MSD	40 ml VOA	1 liter Amber	500 ml Poly	Sleeve	Glass Jar				VOA	SVOA	Pest/PCBs	Metals	TPH Purgeables	TPH Extractables										

Preservative Added

No./Container Types

Analysis Required

	Name (print)	Company Name	Date	Time
Relinquished by:				
Received by:				
Relinquished by:				
Received by:				
Relinquished by:				
Received by:				

Turnaround time/remarks:

Fed Ex #:

WHITE-Laboratory Copy YELLOW-Sample Tracker PINK-File Copy

Corrective Action Request Form

Tetra Tech EM Inc.

Project Name: _____ **Date:** _____

Project No.: _____ **Project Manager:** _____

Location: _____

To (Project Manager): _____

From (Audit Team Members): _____

Description of Problem:

_____

_____

_____

_____

Corrective Action Required:

_____

_____

_____

_____

The above corrective action must be completed by (Date): _____

Acknowledgement of Receipt

_____

(Signature and Date)

Corrective Action Request Form

Tetra Tech EM Inc.

Corrective Action Taken:

_____

_____

_____

_____

Project Manager: _____

(Signature and Date)

Audit Team Members:

Corrective Action *is / is not* satisfactory

_____

(Date and Initial)

Remarks: _____

_____

_____

_____

_____

QC Coordinators:

Corrective Action *is / is not* satisfactory

_____

(Date and Initial)

Remarks: _____

_____

_____

_____

_____

cc: **Program QA Manager**

ATTACHMENT D
PROJECT-REQUIRED REPORTING LIMITS

TABLE D-1: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING VALUES FOR METALS METHODS 6010B/7000 (SOIL AND WATER) AND 6020/7000 (WATER), SW-846, MERCURY EPA METHOD 1631, HEXAVALENT CHROMIUM METHOD 7196A, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Soil PRG[3,4] (mg/kg)	Final Soil PRG for Wildlife[3] (mg/kg)	Soil PRRL[a] (mg/kg)	Soil PRRL Below PRG?	Marine Chronic AWQC[b,5,6] (µg/L)	Freshwater Chronic AWQC[b,5,6] (µg/L)	Litigation Area Specific Values[c,7,8] (µg/L)	Water PRRL[a] (µg/L)	Water PRRL Below Most Conservative AWQC ?
Aluminum	50[d]	NA	10	Yes	NA	87[e]	87[e]	1	Yes
Antimony	5[d]	NA	3	Yes	NA	1600	NA	.05	Yes
Arsenic	9.9[d,f]	9.9[f]	0.3	Yes	36	150	36	0.5	Yes
Barium	283[g] 500[d]	283[g]	1	Yes	NA	NA	NA	0.5	NA
Beryllium	10[d]	NA	0.2	NA	NA	5.3	NA	.02	Yes
Cadmium	4[d,g]	4.2[g]	0.2	Yes	8.8	0.64[9,h]	0.64[h]	.05	Yes
Calcium	NA	NA	20	NA	NA	NA	NA	500	NA
Chromium VI	0.4[i] 1[d]	16.1[g]	0.5	Yes	50	11	11	0.2	Yes
Cobalt	20[d]	NA	0.5	NA	NA	NA	NA	.02	NA
Copper	60[i] 100[d]	370[f]	0.5	Yes	3.1	29[h]	3.1	.10	Yes
Iron	NA	NA	3	NA	NA	1000	NA	100	NA
Lead	40.5[g] 50[d]	40.5[g]	0.3	Yes	8.1	11[h]	8.1	.02	Yes
Magnesium	NA	NA	10	NA	NA	NA	NA	500	NA
Manganese	500[d]	NA	0.5	NA	NA	NA	NA	.05	NA
Mercury	0.00051[g] 0.3[d]	0.00051[g]	0.02	Yes	0.94	0.77	0.025[j]	0.025	Yes
Molybdenum	2[d]	4.75[f]	1.0	Yes	NA	NA	NA	.05	NA
Nickel	30[d]	121[g]	1.0	Yes	8.2	168[h]	8.2	0.2	Yes

TABLE D-1: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING VALUES FOR METALS METHODS 6010B/7000 (SOIL AND WATER) AND 6020/7000 (WATER), SW-846, MERCURY EPA METHOD 1631, HEXAVALENT CHROMIUM METHOD 7196A, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Soil PRG[3,4] (mg/kg)	Final Soil PRG for Wildlife[3] (mg/kg)	Soil PRRL [a] (mg/kg)	Soil PRRL Below PRG?	Marine Chronic AWQC[b,5,6] (µg/L)	Freshwater Chronic AWQC[b,5,6] (µg/L)	Litigation Area Specific Values[c,7,8] (µg/L)	Water PRRL[a] (µg/L)	Water PRRL Below Most Conservative AWQC ?
Potassium	NA	NA	25	NA	NA	NA	NA	500	NA
Selenium	0.21[k] 1[d]	0.21[k]	0.25	No[a]	71	4.6[m]	4.6[m]	1	Yes
Silver	2[d]	NA	0.25	Yes	0.19[b]	35[h,b]	0.19[b]	0.02	Yes
Sodium	NA	NA	25	NA	NA	NA	NA	500	NA
Thallium	1[d]	2.1[f]	0.25	Yes	***2130***	40	NA	0.02	Yes
Vanadium	2[d]	55[f]	0.25	Yes	NA	NA	NA	50	NA
Zinc	8.5[g] 50[d]	8.5[g]	1	Yes	81	382[h]	81	0.5	Yes

Notes:

a The listed PRRL reflects the maximum sensitivity of current, routinely used analytical methods. The listed PRRL will be used as the project screening criteria unless reasonable grounds are established for pursuing non-routine methods.

b Because there is no proposed CCC for this chemical, 10 percent of the CMC value was used.

c Lowest total recoverable dissolved concentrations based on either EPA (1998) salt water or fresh water, EPA (1999) salt water or fresh water, or California Toxics Rule (Title 40 Code of Federal Regulations Part 131); these criteria were used during the five year review at the Litigation Area.

d Plants are the endpoint for this value.

e Based on total metals. Criterion valid only for water in the pH range of 6.5 to 9.0. Aluminum may be less toxic at high pH and hardness, but the effects are not well quantified at this time.

f Shrews are the endpoint for this value.

g Woodcocks are the endpoint for this value.

h Criterion is hardness dependent. This value corresponds to a total hardness of 400 mg/L as CaCO3 in the water body.

i Earthworms are the endpoint for this value.

j Bay basin plan criterion for mercury was selected based on the request of the RWQCB.

k Mice are the endpoint for this value.

l These values are the same values used for prey tissue recovery limits.

m Converted from EPA (1999) total metals criterion using conversion factor.

n Criterion in ***bold italics*** represents acute or other rather than chronic AWQC. For these chemicals, chronic AWQC are not available.

TABLE D-1: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING VALUES FOR METALS METHODS 6010B/7000 (SOIL AND WATER) AND 6020/7000 (WATER), SW-846, MERCURY EPA METHOD 1631, HEXAVALENT CHROMIUM METHOD 7196A, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Notes: (Continued)

1 Long, E.R., D.D. MacDonald, S.L. Smith and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. Environmental Management. 19: 81-97.

2 Long, E.R. and L.G. Morgan. 1990. The potential for biological effects of sediment-sorbed contaminants tested in the National Status and Trends Program. Technical Memorandum NOS OMA52. National Oceanic and Atmospheric Administration, Seattle, WA.

3 Efroymson, R.A., G.W. Suter, B.E. Sample, and D.S. Jones. 1997b. "Preliminary Remediation Goals for Ecological Endpoints." August.

4 Efroymson, R.A., M.E. Will, G.W. Suter, A.C. Wooten. 1997. "Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision." November.

5 EPA. 2002. "National Recommended Water Quality Criteria: 2002." EP-822-R-02-047. November.

6 Marshack, J.B. 2000. "A Compilation of Water Quality Goals – August 2000 Edition." RWQCB. August.

7 U.S. Environmental Protection Agency (EPA). 1998. "Quality Criteria for Water." Office of Water. Washington, DC.

8 EPA. 1999. "National Recommended Water Quality Criteria – Correction." EPA 822-Z-99-001. Office of Water. April.

9 EPA. 2000. "Federal Register: Water Quality Standards; Establishment of Numeric Criteria for Priority Toxic Pollutants for the State of California; Rule." 40 CFR Part 131. May 18.

AWQC	Ambient Water Quality Criteria
ER-L	Effects-range low
EPA	U.S. Environmental Protection Agency
µg/L	Micrograms per liter
mg/kg	Milligrams per kilograms
NA	Not available
N/A	Not applicable
PRG	Preliminary Remediation Goals
PRRL	Project-required reporting limit
RWQCB	California Regional Water Quality Control Board

TABLE D-2: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, TPH METHOD 8015B AND 5030B, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Marine Chronic AWQC (µg/L)	Freshwater Chronic AWQC (µg/L)	Water PRRL[a] (µg/L)	Water PRRL Below Most Conservative AWQC?
TPH-diesel	NA	NA	100	NA
TPH-motor oil	NA	NA	100	NA
TPH-gasoline	NA	NA	50	NA

Notes:

a Although there are no criteria for these chemicals, the PRRL listed are judged to be sufficiently low to meet the Data Quality Objectives.

AWQC Ambient Water Quality Criteria

µg/L Micrograms per liter

NA Not available

PRRL Project required reporting limit

TABLE D-3: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, VOCs METHOD 8260B, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Compound	Marine Chronic AWQC (µg/L)	Freshwater Chronic AWQC (µg/L)[a]	Water PRRL (µg/L)[b]	Water PRRL Below Most Conservative AWQC?
1,2,3-Trichloropropane	NA	NA	5	NA
Acetone	NA	NA	5	NA
Benzene	700	1060[a]	0.5	Yes
Bromodichloromethane	6,400	2,200[a]	0.5	Yes
Bromoform	6,400	2,200[a]	0.5	Yes
Bromomethane	6,400	2,200[a]	0.5	Yes
2-Butanone	NA	NA	5	NA
Carbon disulfide	NA	NA	0.5	NA
Carbon tetrachloride	6,400	7,040[a]	0.5	Yes
Chlorobenzene	129	250	0.5	Yes
Chloroethane	NA	NA	0.5	NA
Chloroform	6,400	1,240	0.5	Yes
Chloromethane	6,400	2,200[a]	0.5	Yes
Cis-1,3-Dichloropropene	NA	NA	0.5	NA
Dibromochloromethane	6,400	2,200[a]	0.5	Yes
1,1-Dichloroethane	NA	NA	0.5	NA
1,2-Dichloroethane	22,600[a]	20,000	0.5	Yes
1,1-Dichloroethene	44,800	NA	0.5	NA
cis-1,2-Dichloroethene	44,800	NA	0.5	NA
trans-1,2-Dichloroethene	44,800	NA	0.5	NA
1,2-Dichloropropane	3,040	5,700	0.5	Yes
Ethylbenzene	86[a]	6,400[a]	0.5	Yes
2-Hexanone	NA	NA	5	NA
4-Methyl-2-pentanone	NA	NA	5	NA
Methylene chloride	6400	NA	0.5	NA
Styrene	NA	NA	0.5	NA
1,1,2,2-Tetrachloroethane	1,804[a]	2,400	0.5	NA
Tetrachloroethene	450	NA	0.5	Yes
Toluene	5,000	3,500[a]	0.5	Yes
trans-1,3-Dichloropropene	NA	244	0.5	NA
1,1,1-Trichloroethane	6,240[a]	3,600[a]	0.5	Yes
1,1,2-Trichloroethane	NA	9,400	0.5	NA
Trichloroethene	400	NA	0.5	NA
Vinyl acetate	NA	NA	0.5	NA
Vinyl chloride	NA	NA	0.5	NA
Xylene (total)	NA	NA	1	NA

TABLE D-3: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, VOCs METHOD 8260B, SW-846 (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Notes:

a	Criterion represent 20 percent of the acute AWQC.
b	The PRRL listed reflects the maximum sensitivity of current, routinely used analytical methods. The PRRL listed will be used as the project screening criterion unless reasonable grounds are established for pursuing non-routine methods.
µg/L	Microgram per liter
AWQC	Ambient water quality criteria (Lowest of EPA 2002d or RWQCB 2003)
NA	Not available
PRRL	Project-required reporting limit

TABLE D-4: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, SVOCs METHOD 8270C, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Marine Chronic AWQC[1,2] (µg/L)	Freshwater Chronic AWQC[1,2] (µg/L)	Water PRRL[b] (µg/L)	Water PRRL Below Most Conservative AWQC?
1,4-Dioxane	NA	NA	NA	NA
Acenaphthene	710	1700	10	Yes
Acenaphthylene	60[a]	NA	10	Yes
Anthracene	60[a]	NA	10	Yes
Benzo(a)anthracene	60[a]	NA	10	Yes
Benzo(a)pyrene	60[a]	NA	10	Yes
Benzo(b)fluoranthene	60[a]	NA	10	Yes
Benzo(g,h,i)perylene	60[a]	NA	10	Yes
Benzo(k)fluoranthene	60[a]	NA	10	Yes
Bis(2-chloroethoxy)methane	NA	NA	10	NA
Bis(2-chloroethyl)ether	NA	122	10	NA
Bis(2-chloroisopropyl)ether	NA	122	10	NA
Bis(2-ethylhexyl)phthalate	NA	NA	10	NA
4-Bromophenyl-phenylether	NA	122	10	NA
Butylbenzylphthalate	588.8[a]	3	10	No[b]
Carbazole	NA	NA	10	NA
4-Chloro-3-methylphenol	NA	NA	10	NA
4-Chloroaniline	NA	NA	10	NA
2-Chloronaphthalene	1.5[a]	320[a]	10	No[a,b]
2-Chlorophenol	NA	400[a]	10	Yes
4-Chlorophenyl-phenylether	NA	NA	10	NA
Chrysene	60[a]	NA	10	Yes
Dibenz(a,h)anthracene	60[a]	NA	10	Yes
Dibenzofuran	NA	NA	10	NA
1,2-Dichlorobenzene	129	763	10	Yes
1,3-Dichlorobenzene	129	763	10	Yes
1,4-Dichlorobenzene	129	763	10	Yes
3,3'-Dichlorobenzidine	NA	NA	30	NA
2,4-Dichlorophenol	NA	365	10	NA
Diethylphthalate	588.8[a]	3	10	NA
2,4-Dimethylphenol	NA	424[a]	10	NA
Dimethylphthalate	588.8[a]	3	10	No[b]
Di-n-butylphthalate	588.8[a]	NA	10	Yes

TABLE D-4: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, SVOCS METHOD 8270C, SW-846 (Continued)
Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Marine Chronic AWQC[1,2] (µg/L)	Freshwater Chronic AWQC[1,2] (µg/L)	Water PRRL[b] (µg/L)	Water PRRL Below Most Conservative AWQC?
4,6-Dinitro-2-methylphenol	970[a]	NA	50	Yes
2,4-Dinitrophenol	46	30[a]	50	Yes
2,4-Dinitrotoluene	118[a]	46[a]	10	Yes
2,6-Dinitrotoluene	118[a]	230	10	Yes
Di-n-octylphthalate	588.8[a]	3	10	No[b]
Fluoranthene	16	796[a]	10	Yes
Fluorene	60[a]	NA	10	Yes
Hexachlorobenzene	129	10[a]	10	Yes
Hexachlorobutadiene	6.4[a]	9.3	10	No[b]
Hexachlorocyclopentadiene	1	5.2	10	No[b]
Hexachloroethane	188[a]	540	10	Yes
Indeno(1,2,3-cd)pyrene	60[a]	NA	10	Yes
Isophorone	2,580[a]	117,000	10	Yes
2-Methylnaphthalene	NA	NA	10	NA
2-Methylphenol	NA	NA	10	NA
4-Methylphenol	NA	NA	10	NA
Naphthalene	470[a]	620	10	Yes
2-Nitroaniline	NA	NA	50	NA
4-Nitroaniline	NA	NA	30	NA
3-Nitroaniline	NA	NA	50	NA
Nitrobenzene	1,336[a]	5,400[a]	10	Yes
2-Nitrophenol	970[a]	30[a]	10	Yes
4-Nitrophenol	970[a]	30[a]	10	Yes
n-Nitroso-di-n-propylamine	660,000[a]	1,170[a]	10	Yes
n-Nitrosodimethylamine	NA	NA	10	NA
n-Nitrosodiphenylamine	660,000[a]	1,170[a]	10	Yes
2,2'-Oxybis(1-chloropropane)	NA	NA	10	NA
Pentachlorophenol	7.9	15	50	NA
Phenanthrene	60[a]	NA	10	Yes
Phenol	1,160[a]	2560	10	Yes
Pyrene	60[a]	NA	10	Yes
1,2,4-Trichlorobenzene	129	50	10	NA
2,4,5-Trichlorophenol	NA	NA	50	NA
2,4,6-Trichlorophenol	NA	970	10	NA

TABLE D-4: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, SVOCS METHOD 8270C, SW-846 (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Notes:

a Criterion represent acute rather than chronic AWQC. Chronic AWQC are not available for these chemicals.

b The PRRL listed reflects the maximum sensitivity of current, routinely used analytical methods. The PRRL listed will be used as the project screening criterion unless reasonable grounds are established for pursuing non-routine methods. The analytes with PRRLs that exceed screening criteria are not considered chemicals of concern for the Litigation Area.

1 EPA. 2002. "National Recommended Water Quality Criteria: 2002." EP-822-R-02-047. November.

2 Marshack, J.B. 2000. "A Compilation of Water Quality Goals – August 2000 Edition." RWQCB. August.

AWQC Ambient water quality criteria

µg/L Micrograms per liter

NA Not available

PRRL Project-required reporting limit

TABLE D-5: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, PESTICIDES METHOD 8081A, SW-846 AND HERBICIDES METHOD 8151A, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Marine Chronic AWQC[1] (µg/L)	Freshwater Chronic AWQC[1] (µg/L)	Water PRRL[b] (µg/L)	Water PRRL Below Most Conservative AWQC?
Pesticides				
Alpha-BHC	NA	NA	0.05	NA
Gamma-BHC (Lindane)	0.032[a]	0.95[a]	0.05	Yes
Aldrin	0.26[a]	3.0[a]	0.05	Yes
Chlordane	0.004	0.0043	0.5	No[b]
4,4'-DDD	0.72	NA	0.1	Yes
4,4'-DDE	2.8	NA	0.1	Yes
4,4'-DDT	0.001	0.001	0.1	No[b]
Dieldrin	0.0019	0.056	0.1	No[b]
Endrin	0.0023	0.036	0.1	No[b]
Heptachlor	0.0036	0.0038	0.05	No[b]
Heptachlor epoxide	0.0036	0.0038	0.05	No[b]
Methoxychlor	0.003	0.03	0.5	No[b]
Toxaphene	0.0002	NA	5.0	No[b]
Herbicides				
Dalapon	NA	NA	4.0	NA
Dicamba	NA	NA	0.2	NA
MCPP	NA	NA	100	NA
MCPA	NA	NA	100	NA
Dichloroprop	158	NA	1.0	Yes
2,4-D	NA	NA	1.0	NA
2,4,5-TP (Silvex)	NA	NA	0.1	NA
2,4,5-T	NA	NA	0.1	NA
2,4-DB	NA	NA	1.0	NA
Dinoseb	NA	NA	1.0	NA
Pentachlorophenol	7.9	NA	5.0	Yes
Pichloram	NA	NA	5.0	NA

TABLE D-5: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, PESTICIDES METHOD 8081A, SW-846 AND HERBICIDES METHOD 8151A, SW-846 (Continued)

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Notes:

a	Criterion represent 20 percent of acute AWQC. Chronic AWQC are not available for these chemicals.
b	The PRRL listed reflects the maximum sensitivity of current, routinely used analytical methods. The PRRL listed will be used as the project screening criterion unless reasonable grounds are established for pursuing non-routine methods.
c	The minimum concentration that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix type containing the analyte.
1	EPA. 2002d. "National Recommended Water Quality Criteria: 2002." EP-822-R-02-047. November.
AWQC	Ambient Water Quality Criteria
MDL	Method detection limit
µg/L	Micrograms per liter
NA	Not available
PRRL	Project required reporting limit

TABLE D-6: COMPARISON OF PROJECT-REQUIRED REPORTING LIMITS AND SCREENING CRITERIA, PCB METHOD 8082, SW-846

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analyte	Marine Chronic AWQC[a] (µg/L)	Freshwater Chronic AWQC[a] (µg/L)	Water PRRL (µg/L)	Water PRRL Below Most Conservative AWQC?
Aroclor-1016	0.03	0.014	0.005	Yes
Aroclor-1221	0.03	0.014	0.01	Yes
Aroclor-1232	0.03	0.014	0.005	Yes
Aroclor-1242	0.03	0.014	0.005	Yes
Aroclor-1248	0.03	0.014	0.005	Yes
Aroclor-1254	0.03	0.014	0.005	Yes
Aroclor-1260	0.03	0.014	0.005	Yes

Notes:

a EPA. 2002. "National Recommended Water Quality Criteria: 2002." EP-822-R-02-047. November.
AWQC Ambient Water Quality Criteria
µg/L Micrograms per liter
NA Not available
PRRL Project required reporting limit

ATTACHMENT E
APPROVED NAVY LABORATORIES

TABLE E-1: TETRA TECH EM INC.-APPROVED NAVY LABORATORIES UNDER BASIC ORDERING AGREEMENT

Monitoring Plan for the Litigation Area, Naval Weapons Station Seal Beach Detachment Concord, Concord, California

Analytical Group	
Lab Address:	12189 Pennsylvania Street Thornton, CO 80241
Point of Contact:	Joe Egry / Mary Fealey
Phone:	(800) 873-8707 X103/X135
Fax:	(303) 469-5254
Business Size:	SWO
E-mail	mfealey@analyticagroup.com

Applied Physics and Chemistry Laboratory	
Lab Address:	13760 Magnolia Avenue Chino, CA 91710
Point of Contact:	Dan Dischner / Eric Wendland
Phone:	(909) 590-1828 X203/X104
Fax:	(909) 590-1498
Business Size:	SDB
E-mail	marketing@apclab.com

Columbia Analytical Services	
Lab Address:	5090 Caterpillar Road Redding, CA 96003
Point of Contact:	Karen Sellers / Howard Boorse
Phone:	(530) 244-5262 / (360) 577-7222
Fax:	(530) 244-4109
Business Size:	LB
E-mail	lkennedy@kelso.caslab.com

Curtis and Tompkins, Ltd	
Lab Address:	2323 Fifth Street Berkeley, CA 94710
Point of Contact:	Anna Pajarillo / Mike Pearl
Phone:	(510) 486-0925 X103/ X108
Fax:	(510) 486-0532
Business Size:	SB
E-mail	mikep@ctberk.com

EMAX Laboratories Inc.	
Lab Address:	1835 205th Street Torrance, CA 90501
Point of Contact:	Ye Myint / Jim Carter
Phone:	(310) 618-8889 X121/X105
Fax:	(310) 618-0818
Business Size:	SDB/WO
E-mail	ymyint@emaxlabs.com

Laucks Laboratories	
Lab Address:	940 S. Harney Street Seattle, WA 98108
Point of Contact:	Mike Owens / Kathy Kreps
Phone:	(206) 767-5060
Fax:	(206) 767-5063
Business Size:	SB
E-mail	KathyK@lauckslabs.com

Sequoia Analytical	
Lab Address:	1455 McDowell Blvd. North, Suite D
	Petaluma, CA 94954
Point of Contact:	Angelee Cari
Phone:	(707) 792-7527
Fax:	(707) 792-0342
Business Size:	LB
E-mail	acari@sequoialabs.com

Notes:

DHS	California Department of Health Services
LB	Large business
SB	Small business
SDB	Small disabled business
SWO	Small woman-owned
WO	Woman-owned